UNIVERSITY OF SOUTHERN QUEENSLAND

THE VIABILITY OF WEATHER INDEX INSURANCE IN MANAGING DROUGHT RISK BY AUSTRALIAN WHEAT FARMERS

A dissertation submitted for the award of

DOCTOR OF PHILOSOPHY

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Certification of Dissertation

I certify that the ideas, results, analyses and conclusions reported in this dissertation are entirely my own effort, except where otherwise acknowledged. I also certify that the work is original and has not been previously submitted for any other award, except where due reference is made.

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ABSTRACT

In this study, the viability of weather index insurance in managing drought risk for Australian wheat farmers is considered. The relationship between wheat yield and rainfall index is examined as a prerequisite for the analysis of hedging efficiency of the insurance contracts. Also, the prospects of diversifying a pool of insurance contracts was analysed and opinions were sought from stakeholders on policy issues.

The relationship between wheat yield and Cumulative Standardized Precipitation Index was estimated for 23 shires (counties) in Queensland and 40 in Western Australia over the period 1971 to 2010. The relationship was found to differ across locations but overall, it was sufficiently high to permit the use of the index as a proxy for calculating insurance payouts. It was also found that the hedging efficiency of the insurance varies by locations and was higher in locations with higher rainfall variability.

The major contribution of this study is that when prices were allowed to vary over the period considered, hedging efficiency reduces relative to the constant price assumption. This result suggests that previous studies did not capture the cost of price stabilization or it could be said that the natural hedge between yield and price reduces the willingness of farmers to pay for weather insurance. Although, the efficiency was not sufficiently high to permit the use of the model in this study in that improvements will be required to make it marketable, some important policy recommendations are evident from the results. Also, the loss ratio analysis indicated that risk pooling would reduce the burden to the insurer over the long term. However, it was noted that insurers will be able to diversify moderate drought risks than intense droughts while farmers may be willing to hedge intense drought risks. Policy recommendations made in this study therefore aim at bridging this chasm. Also, there was no significant correlation between hedging efficiency and the measures of the relationship even when the yield-index relationship was disaggregated at the corresponding quantiles to the efficiency levels.

Furthermore, the results from farmers' interview show that; *'it is against the DNA of farmers to pay taxes and they spend one dollar to save 30 cents'*. This attitude of suboptimal choices reduces the tax delivered to the government coffers and farmers who were probably capable of being profitable avoid declaring profits because they were avoiding taxes. It was clear from the interviews that farmers detest welfare approach to risk management but would prefer the market options because it facilitates self-reliance and mutual obligation which the government of Australia aims to promote.

However, demands for such market options like weather index insurance have been known to be low and the hail and fire insurance that has been in the market for a long time is not meeting the needs of the farmers. The poor uptake of weather insurance was traced to systemic risk, basis risk, lack of incentives and low awareness of the option among farmers. Although, there have been attempts to offer the product, the problem of moral hazard it is purported to resolve is the bane of its uptake because farmers are morally hazardous investors who use insurance as a financial option when production outlook is bleak.

It was recommended that the government should give tax incentives on insurance premium in addition to the recent welfare provision for farmers to encourage them to make optimal decisions to become profitable. Doing otherwise could unnecessarily inflate the value of assets used to earn the welfare supports. It was noted that state stamp duties on insurance should be abolished otherwise; insured farmers will be paying the cost of assisting their uninsured counterparts. Should this policy be implemented, it is expected that the rural debt trend recently put at $66 billion will be alleviated as the cost of capital to the rural sector decreases. Finally, the history and future of agro-risk management was documented, the legal and regulatory requirements for the smooth running of this policy recommendation and the necessary theories are also explored and related to the analyses.

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1 CHAPTER ONE: INTRODUCTION

1.1 Background

The global community is concerned about the current increase in the frequency and intensity of weather extremes particularly drought because of its impact on agricultural production and its consequent impact on food supply (IPCC 2007). There are changes in the approach towards managing the risk of drought by farmers. The shift is towards a risk management paradigm rather than a disaster management approach that has prevailed in previous years around the world (Wilhite 2005). Researchers have made frantic efforts to contribute to finding solutions to managing drought risk. However, there is more to be done. The first major area that requires additional research is the price assumptions underlying previous analyses particularly for weather insurance which has been considered a possible solution (Vedenov & Barnett 2004). Secondly, the risk attitude of farmers is yet to be well understood particularly in Australia known to be the land of drought and flooding rains (Patrick 1988).

The case of Australia demands urgent attention because of the extreme exposure of the country to the vagaries of the weather and price fluctuation (Garnaut 2008). The attention is further necessitated by the fact that Australian farmers are among the least supported by governments among the developed countries of the world, next to her neighbouring New Zealand only. Besides, it is a commodity-based economy with wheat being its dominant farm produce (ABARE 2014). In the past three decades the Commonwealth of Australia has focused on giving disaster aids to farmers whenever they experience any excruciating circumstance impinging on their survival (Bardsley, Abey & Davenport 1984; Patrick 1988; Kimura & Antón 2011). The main event so experienced is drought.

Despite the paradigmatic shift to drought as a risk that requires management by farmers, the measures in place are yet to empower farmers to be self-reliant and independent managers of their enterprise (DAFF 2013). Most recently, the principles of mutual obligation and reciprocity have been emphasized which could not be achieved without market-based options to facilitate self-reliance (DAFF 2013). The need for market solutions is necessitated by the extreme variability of price and yield that Australia is historically known to be subject to in comparison to other countries (Kimura & Anton 2011). In addition, the industry is experiencing escalating trend in debt and attrition which if not contained could be detrimental to the economy (Keogh, Tomlinson & Potard 2013).

Besides, the exacerbation of extreme weather events due to climate change has added to this concern and the insurance system is getting over stretched (Parry et al. 2007; Keenan & Cleugh 2011). Although, extreme weather events like drought affect most sectors in the economy at least indirectly, some sectors are more vulnerable than others. The agricultural sector is among those sectors most vulnerable because rainfall deficit has implications on dry land crop yields and livestock grazing (Chantarat et al. 2007; Meuwissen, Van Asseldonk & Huirne 2008; Ghiulnara & Viegas 2010; Kimura & Antón 2011). About 75% of farmers in a survey expressed concern on the impact of drought on the viability of their enterprise (NRAC 2006).

The impact of government laws was also noted to be a concern to participants in the study. Previous efforts to insure against the covariate nature of drought risk have been considered inefficient and have exposed farmers to both financial and social stress (Miranda & Glauber 1997; NRAC 2006; Roy et al. 2013).

Given the importance of crops like wheat, hedging the impact of yield shortfall resulting from rainfall deficit is of paramount importance in order to curtail risk avoidance by farmers which could in turn limit global supply of agricultural products more so because rainfall interacts with a lot of other variables influencing yields (Stoppa & Hess 2003; Breustedt, Bokusheva & Heidelbach 2008; Turvey, Kong & Belltawn 2009). Farmers are therefore concerned not only about price hedging but also yield insurance which is of greater concern to them particularly because covariate yield reduction could be attributed to extraneous weather variables that makes on- farm diversification unproductive (Bardsley, Abey & Davenport 1984; Quiggin 1986; Zeuli & Skees 2005; Chantarat et al. 2008). Although, weather insurance has been in use in the power sector since the mid-1990s, it is yet to be prominent among agricultural risk management tools particularly in Australia with the most exposure to price and yield risk (Quiggin 1986; Geman 1999; NRAC 2006; Kimura & Antón 2011; 2012).

Insurance against the sources of yield variability due to these extraneous variables has become necessary in that assumptions behind previous models that focused on price hedging have been found to be ineffective as much as yield-based multi-peril insurance and government relief packages (Quiggin 1986; Botterill & Wilhite 2005; Kimura & Antón 2011, p. 35). It is therefore logical that farmers are compensated based on the sources of variability leading to low yields. Although, one would intuitively expect that a price hike would result when there is a yield shortfall, experience has shown that price does not sufficiently offset yield risks (Quiggin 1994).

It is also evident that those who are the least hurt by the covariate risk are the ones who actually derive benefits from the event in that when farmers suffer loss of yield during drought, those who did not suffer complete losses are the ones to benefit from price hike. This explains why there is a shift from price stabilization to yield risk management (Newbery & Stiglitz 1979; Quiggin, Karagiannis & Stanton 1994). In the conclusion of Newbery and Stiglitz (1979), price stabilization was considered to possibly have a negative effect while Quiggin (1986) emphasised the shift towards yield risk management. Although, crop insurance currently exists in some parts of the world, the problems of moral hazards, adverse selection, prohibitive cost and systemic risks have led to its failure (Blank, Carter & McDonald 1997; Miranda & Glauber 1997). In an attempt to contain these problems, a Multi-Peril Crop Insurance model based on revenue is developing but may also be challenged by the in-availability of sufficient farm-level data (Quiggin, Karagiannis & Stanton 1993; Mahul & Stutley 2010; OECD 2010).

These inefficiencies could be readily managed using weather index insurance which target specific weather events. Research has shown that insurance against specific weather events such as drought could be a cost effective means of providing risk management strategies when high covariate risk between specific weather events and agricultural productions are imminent (Turvey 2001; Chantarat et al. 2007; Chantarat et al. 2012; Kapphan, Calanca & Holzkaemper 2012). This innovative insurance and risk management mechanisms have been necessitated by the anticipated intensity and frequency of extreme weather events (Stoppa & Hess 2003; Parry et al. 2007; Turvey, Kong & Belltawn 2009; Keenan & Cleugh 2011; Kimura & Antón 2011; Vedenov & Sanchez 2011; Binswanger-Mkhize, Hans 2012). It is opined that since financial markets could be created for anything that varies rainfall insurance (or derivatives) could be used to manage the risk of drought exposure (Duan, Karl Härdle & Gentle 2012).

The basic philosophy behind weather index insurance is that individuals have no control over the states of nature since they are exogenously determined and would therefore contain the inefficiencies resulting from asymmetric information in the traditional indemnity-based insurance (Ahsan, Ali & Kurian 1982). Consequently, moral hazard and adverse selection resulting from asymmetric information are minimized because the information is available in real time and are in public domain.

Besides the problems of moral hazard and adverse selection, it has been noted that ad hoc disaster assistance programs, a form of free insurance, serves as an incentive for farmers to be negligent (Hueth & Furtan 1994). Hence, despite the heavy subsidy from government, the free insurance has been found wanting. Another source of impediment to the indemnity-based insurance as further highlighted by Hueth and Furtan (1994) was that benefits of insurance are not equal across farmer characteristics. This is understandable because the wealth levels, risk exposure and risk aversion of farmers are different. The diversity in farmer characteristics raises the question of equity as noted by Kimura and Antón (2011) who suggested weather index insurance as a means of managing the inequity and inefficiency in government drought risk management in Australia. In addition, weather index insurance facilitates swift compensation and reduces costs. However, these benefits come at some costs; mainly structural and geographic basis risks. On the side of the insurer, the covariate nature of the risk is a major concern in that capacity to bear the risk depends on the extent to which it could be diversified over time and space (Bardsley, Abey & Davenport 1984; Chantarat 2009; Bokusheva 2011). It should however be noted that if a portfolio of weather insurance contracts is added to an existing portfolio of non-weather insurance contracts, the covariance structure of the overall portfolio will reduce.

The case study for this global problem is Australia because it has one of the most variable climates in the world and it is the driest inhabited continent with extreme exposure to price risk and low support for farmers (Hennessy et al 2008). This study therefore examines the viability of weather index based insurance for managing drought risk in Australia. This is achieved by testing some of the necessary conditions stated in the debate between Quiggin and Bardsley (Bardsley, Abey & Davenport 1984; Bardsley 1986; Quiggin 1986) for weather index insurance to be viable in Australia. In particular, the relationship between wheat yield and weather indices was established, the hedging efficiency of weather index insurance was analysed and the diversification prospects of a portfolio of weather insurance contracts was considered. Finally, the challenges and opportunities to the uptake of weather index insurance in Australia are discussed.

1.2 Statement of the problem

Long before climate change issues became a major concern to the global community, the debate on the viability of weather index insurance in the context of Australia remains inconclusive (Bardsley, Abey & Davenport 1984; Bardsley 1986; Quiggin 1986; Quiggin & Chambers 2004) and has been left for too long while other countries, particularly in the developing world, are already deriving benefits from the product (Gurenko 2006). The existence of the insurance in developing countries is the result of lack of safety net for farmers unlike what obtains in the developed countries like Australia. However, both empirical and theoretical studies have shown that weather index insurance could contribute to managing covariate risks in the developed countries as well although the focus has been largely on the developing world (Chantarat et al. 2007; Clarke 2011; Kapphan, Calanca & Holzkaemper 2012).

Besides the exacerbation of extreme weather events, the paradigmatic shift from drought as a disaster to drought as a risk that requires self-reliant management by farmers adds more weight to the need to re-examine the topic with a renewed vigour. This is more so because it has been suggested as a possible means of managing existing inefficiencies in both the market-based and public options to agricultural risk management (Anton & Kimura 2011). The need for swift response becomes more crucial than ever because the trends in years with exceptionally low rainfall will increase and this is expected to occur over a larger spatial expanse of land (Hennessy et al. 2008). The evidences on the frequency and intensity of extreme weather events are further documented in Garnaut (2011) and the IPCC (2007). The case of Australia requires very urgent attention because it is already the most drought-prone inhabited continent and one of the countries where farmers get the least supports (Myers & Kent 2001). At the moment, it is evident that the implications of drought episodes are yet to be clearly articulated in Australia (Dijk et al. 2013). These evidences have shown that future droughts may well break records in new ways but the management may not be better than it was in the past. Dry land wheat yield may be greatly impacted among other sectors of the agricultural industry if changes are not made to current management practices.

Besides being the driest inhabited continent, it is a commodity-based economy in that agriculture contributes significantly to the GDP of the country with wheat being its dominant crop (ABARE 2012). In addition, a significant percentage of Australian primary produce are exported, a situation which further exposes her to price risk and there is no government price stabilization supports because the wheat board has been phased out (Productivity Assistance Commission 2009).

Despite these exposures of Australian agriculture, she remains one of the countries with the least prospect of market-based options because of the extremities of weather events coupled with lack of government supports in terms of infrastructures. The state of risk management in Australian agriculture is evident in the fact that it is one of the least supported countries by government while competitor countries like US are subsidised by as much as 65% of insurance premiums and could still be eligible to obtain government disaster aids (Edwards 2009; Kimura & Antón 2011). More severe risks, because of their covariate nature, could be difficult for insurers to handle. Three classes of weather risks have been posited in literature, namely; risk retention layer, insurance layer and market failure layer (Kimura & Antón 2011). The Bureau of Meteorology (BoM) has a percentile classification of precipitation risk that could be matched with these layers (BoM 2012a). The first layer is diversifiable by the farmer; the market insurance layer could involve the use of insurance mechanisms to manage yield risk while at the market failure layer the risk is uninsurable within a local environment because of its systemic nature and therefore requires risk pooling over a larger geographical space or reinsurance. The second layer is the layer that requires self-reliance while the market failure layer corresponds to exceptional circumstances in Australian Drought Policy which has been benchmarked as a once in 20 to 25 year event. It is reasonable to expect that the market failure layer will be the most expensive to insure and farmers' willingness to insure this level of risk may be reduced by the cost (Liesivaara & Myyrä 2014). Currently, Australia is experiencing drought with accompanying mental health implications for rural area dwellers that do not have a cushion to fall on in the form of cash flow (Fuller & Broadbent 2006; Cuevas 2011; Roy et al. 2013; Thompson 2013). Experience has shown that government's responses to drought have always been slow which would not have been needed if *ex ante* strategies were in place to forestall shortage of cash flows among farmers. Insurance provides an *ex ante* risk management strategy in agriculture. The spatial coverage of the current drought also shows that basis risk would not have been so much of a concern because very large expanse of land in the two states affected, Queensland and New South Wales were affected. Although, the benefits of crop and rainfall insurance are well recognized, there has been a concern on whether or not to subsidize crop and rainfall insurance in Australia (IAC 1986). The equity and efficiency debates surrounding this concern have impeded the prospects of adequate market-based options in the management of drought risk in Australia besides the hail and fire insurance that are not providing adequate coverage for Australian farmers (IAC 1986; Hatt, Heyhoe & Whittle 2012).

This recent trend in Australia is in concordance with the findings of Turvey (2001) that a significant drought could occur once in 10 years in Canada but the frequency and distributions may vary significantly by regions and as a result he concluded that a uniform insurance policy will not be successful on an actuarial basis. Besides the benchmarking of exceptional circumstances at the 5th percentile (once in 20 years or 5% probability of occurrence in 100 years) in Australia, which does not match with the current trends, the ADP introduced some subjectivity in that the declaration of exceptional circumstances is subject to negotiations between those affected, their states and the Commonwealth government (Kimura & Anton 2011). This negotiation has been known to lead to principal-agency problem. There is yet to be enough attention to the market-based alternative to insuring agricultural risk in spite of all the advantages enumerated by Ahsan, Ali and Kurian (1982).

However, it could be expected that with the principles of intergovernmental agreement on NDP Reform which focuses on mutual responsibility and reciprocity, weather insurance may be a serious consideration (DAFF 2013). Another major concern in Australian agriculture that may give preference to market options is the rate of growth in the debt and attrition resulting from inability of farmers to effectively plan their businesses (Thompson 2013).

Similarly, given the inequity, social costs and subjectivity of previous efforts to manage drought risk, recent debates are focusing on event specific insurance as an approach to handling drought risk and should be disentangled from political machinations (Quiggin 1994; Giné et al. 2010; Turvey & Kong 2010). Index Based Risk Transfer Products (IBRTP), particularly weather index based insurance, have gained popularity in countries like Canada, Malawi, India, Mongolia, Kenya, Ethiopia, among others (Gurenko 2006; Gine, Townsend & Vickery 2010) but remains an issue of debate in Australia in spite of evidence that it could help facilitate response to drought in order to achieve the objectives of drought risk management (Bardsley, Abey & Davenport 1984; Bardsley 1986; Quiggin 1986; Zeng 2000; Zeuli & Skees 2005; Meuwissen, Van Asseldonk & Huirne 2008).

The work by Zeuli and Skees (2005) in Australia only illustrated the ideas behind rainfall index insurance as a promising tool for managing drought risk. Likewise, Meuwissen and Molnar (2010) acknowledged that weather index insurance could be an alternative to managing mild and catastrophic weather risks in Australia but did not conduct any empirical study in that respect. Researchers have found that traditional indemnity–based insurance and ex post disaster funding are inefficient in managing drought risk (Quiggin 1994; Chantarat et al. 2008; Turvey & Kong 2010; Hou, Hoag & Mu 2011). The reasons attributed to the inefficiency of the indemnity-based insurance have been largely due to asymmetric information resulting in moral hazards and adverse selection by the insured. Besides, there are political interferences coupled with the debates on equity in governments' attempts to alleviate the socio-economic impacts of drought on farmers' revenue. Furthermore, the ex-post disaster financing is typified by slow response that leaves the affected people helpless for too long (Gurenko 2006; Chantarat et al. 2007).

Kimura and Anton (2011, p.55) recommended the exploration of insurance markets to manage drought risk in Australia. In particular the authors suggested a consideration of *'the feasibility of index-based insurance (because) the systemic nature of yield shocks in Australia, typically associated with a drought, makes it more feasible to introduce insurance that is indexed to rainfall because (of the) high correlation between rainfall in weather stations and farms (low basis risk)'.* This suggestion by Kimura and Anton (2011) is in tandem with Bardsley's (1986) that the viability of rainfall insurance is contingent on the relationship between yield losses and the payout from the insurance contracts and the behaviour of a portfolio of the contracts when aggregated over time and space. Similarly, Quiggin (1994) concluded that; *'there was a consensus that rainfall insurance scheme would not have a major impact in the absence of subsidy at least on administrative costs. On the other hand, if subsidies were to be paid to farmers suffering from adverse climatic conditions, rainfall insurance would be one of the most cost-effective alternatives (p. 123)'.*

In addition, a major proponent of 'no farm subsidy', supports the opinion of Quiggin that rainfall insurance could be a solution if underwritten at a sufficiently low price and emphasizes the role of government in providing the necessary infrastructures to facilitate a market response to drought risk management (Freebairn 1983). Furthermore, he opined that the government will play a facilitating role and advocates for policies that provide incentives for rational private decision making rather than input subsides on the grounds of inefficiency and inequity. The need for government's intervention has been the recurring theme of other similar studies (DAFWA 2009; Hatt, Heyhoe & Whittle 2012). Freebairn further affirmed that input subsidies were blunt instruments that increased the uncertainty facing private decision makers and it did not provide supports to some who were genuinely in need of assistance. He however supports the current shift towards welfare benefits for farmers through the waiver of asset test that has hitherto prevented them. The inequity in the disbursement of government supports is evident during the 2007/2008 drought (Kimura & Antón 2011).

However, on the one hand, the covariate nature of weather risk implies that farmers over a wide space experiencing drought will have their yields correlated with the base weather station(s) and therefore their payout will be triggered because basis risk will be minimised. On the other hand, this high correlation presents a risk to the insurer holding a portfolio of such covariate contracts in that on such occasions, the insurer will incur a very high Loss Ratio. The distribution of the insurer's Loss Ratio is therefore a measure of the diversification prospects of a portfolio of insurance contracts aggregated over time and space. Consequently, the yield-index relationship and the prospects of diversification are of paramount importance in the assessment of the efficiency of weather contracts (Vedenov & Barnett 2004; Chantarat 2009; Sun et al 2014).

Quiggin and Chambers (2004) noted that Australian Drought Policy makes *ex post* provision based on observed losses that penalizes prudent producers who are exposed to yield shocks due largely to the stochastic nature of rainfall. Besides, this provision has been known to be available to about one third of affected individuals and is therefore inequitable and does not facilitate preparedness.

Given the survey of literature, the researcher could assert that sufficient work is yet to be done in the area of empirical analysis of the viability of rainfall index insurance in terms of appropriate methodological framework (Vedenov & Barnett 2004; Hardle & Osipenko 2011; Lee & Oren 2008; Bokusheva 2011). In this study, some research gaps were identified and bridged. In particular, the study considers the relationship between wheat yield losses and weather indices using linear and non-linear approaches across two climatologically diverse states of Australia. The hedging efficiency of weather index insurance was also considered and related to the yield-index relationship. Also, the covariate structure of a portfolio of the contracts across the two states of interest given their climatological diversity was considered. Finally, the qualitative analysis captured some useful suggestions on the challenges and opportunities of weather index insurance for farmers in Australia.

1.3 Objectives of the study

1.3.1 General objectives

The overarching goal of this study is to determine the viability of rainfall index–based insurance for Australian farmers.

1.3.2 Specific objectives

Specifically the study will determine;

- The relationship between rainfall index insurance and wheat yield across the shires of Queensland and Western Australia.
- The hedging efficiency of weather index insurance.
- The dependence structure of rainfall index insurance at different triggers in Queensland and Western Australia.
- The challenges and opportunities associated with the offer of weather index insurance in Australia.

1.3.3 Research questions

- What is the relationship between rainfall index and wheat yield across the shires of Queensland and Western Australia?
- Can weather index insurance help farmers to hedge the exposure of their revenue to drought risk?
- To what extent is covariate risk inherent in rainfall index insurance at different triggers and caps in Queensland and Western Australia?
- What are the challenges and opportunities associated with the offer of weather index insurance?

1.4 Scope of the study

The regions considered in this study were Queensland and Western Australia having the lowest and the highest yields of wheat in Australia respectively. The climates of the two states are also different and are at two ends of the continent. There are other states in the country but these two are used for illustrative purposes and to keep the analysis tractable. The relationship between the pseudo-put-options weather insurance payoff based on different percentile benchmarks (triggers) and wheat yield losses are examined. The weather index of interest is Standardized Precipitation Index (SPI). The SPI considers the standardized value of the precipitation readings. Other indices like the Palmer Drought Severity Index (PDSI) that captures the soil evapotranspiration exist but are not used in this study because of their complexity. The researcher acknowledges that there are other variables influencing yields including soil type, fertilizer, irrigation and farm management skills but they are not considered in this study to keep the study tractable. Similar assumptions have been made by other researchers (Patrick 1988; Turvey 2001; Vedenov & Barnett 2004).

Patrick (1988) in a related study considered the possible demand for crop and rainfall insurance in the Mallee region of Australia and assumed that all variables were constant except rainfall. In the study by Patrick, the other variables relevant to crop growth were temperature, initial soil moisture among others. The researcher acknowledged these variables but considered only rainfall. A major improvement over Patrick's model is that attempt has been made in this study to consider the distribution of rainfall. Turvey (2001) in a similar study in Canada evaluated the efficiency of rainfall insurance in Oxford County in Ontario from the 1st of June to August 31 for corn, soy and hay.

In this study, it was assumed that all other variables were relatively constant within the shires and the only variable analysed was rainfall variability. However, since 63 locations were analysed and sowing dates vary from year to year, an estimate of the expected day of the year when sowing takes place was considered in each of the two states.

The analysis covers only dry land wheat farms and shire-wide data. Wheat is grown on soil with certain characteristics which could vary to some extent but relatively homogeneous within each shire. Wheat is considered in this study because of its importance to the Australian economy (Meuwissen & Molnar 2010). Similar analyses were conducted by Bradsley, Abey and Davenport (1984), Breustedt, Turvey (2001) and Bokusheva and Heidelbach (2008) using shire-wide data as a representation of the farms in the shire.

1.5 Significance of the study

In this study, the evidences on the prospects of weather index insurance in managing drought risk for Australian farmers are examined. In particular, the possibility of adopting rainfall insurance to hedge the production risk among wheat farmers is considered. Previous researchers have considered the debate on the viability of rainfall insurance as inconclusive (Bardsley, Abey & Davenport 1984; Bardsley 1986; Quiggin 1986). The result from the analyses of the research questions will test some of the necessary conditions for the viability of rainfall insurance in Australia as put forward by Bardsley (1986). Two of the conditions are strong relationship between rainfall insurance contracts' payout and yield losses and the decrease in systemic risk as the portfolio of contracts is diversified. Further, the hedging efficiency of the contracts and the context in which the product is expected to operate are analysed.

Furthermore, Nelson, Kokic and Meinke (2007) mentioned that farming excellence depends on successful management of climate risk. As extreme weather events become more frequent and climate science advances, weather risk management would become extremely crucial to businesses because abrupt weather conditions would no longer be regarded as force majeure (Burke 2011). An investigation into the possibility of hedging weather risks, particularly rainfall deficit, on agricultural productions is a worthwhile venture in that it would bridge the policy relevance gap caused by the inefficiencies in the current drought risk management system in Australia (Botterill & Wilhite 2005).

The findings of this study therefore provide the theoretical background for the attainment of the principles of the Intergovernmental Agreement on National Drought Program Reform. Hence, the results will inform a public–private partnership that will add to the portfolio of risk management alternatives available to farmers and create an ex ante disaster funding system to swiftly respond to drought risk and alleviate governments' fiscal burden.

1.6 Research gaps

Literature on the use of weather index insurance as a means of hedging climate related risk is growing, but there has been a focus on temperature related risks in the energy industry without much consideration given to rainfall (or a combination of rainfall and temperature) insurance as a means of hedging shortfalls in agricultural productions (Vedenov & Barnett 2004; Vashishtha 2007; Chantarat 2009; Yang, Brockett & Wen 2009; Yang, Li & Wen 2010; Bokusheva 2011). Therefore, in this thesis, the prospects of managing drought risk with rainfall-based weather options are considered.

Besides the dearth of studies in agro-risk management, researchers have related crop yields to weather indices but concluded that there was need for an in-depth analysis of crop and region specific studies (Turvey 2001; Vedenov & Barnett 2004; Meuwissen et al. 2008). This region-specific analysis of rainfall insurance focusing on wheat was conducted by Bardsley, Abey and Davenport (1984) in Australia without much consideration given to spatial and time-wise diversification of the contracts. In this study, attempt was made to bridge this gap by choosing two states of Australia that were considered sufficiently separated spatially. A similar study has been carried out by some researchers in New South Wales (Bardsley, Abey & Davenport 1984) and Victoria (Patrick 1988) in the far eastern part of Australia. Therefore, Western Australia and Queensland were chosen for demonstrating the effect of risk pooling over the forty-year period ending in 2010. It is also worth noting that the work of Bardsley, Abey and Davenport (1984 p. 11) considered only 48 shires in only one region (New South Wales) from 1945–1969 and they acknowledged that the correlation of the insurer's risk will reduce with spatial expansion of the contracts. This acknowledgement could be ascertained in the work of Woodard and Garcia (2008) that hedging effectiveness is greater at higher levels of spatial aggregation. The work of (Chantarat 2009) also analysed the distribution of Loss Ratios as a measure of diversification over time and space.

The results from this study bridged the relevant gap in literature that emerged from the debate between Bardsley, Abey and Davenport (1984), Bardsley (1986) and Quiggin (1986). Similarly, a 25-year sample was used by Bardsley, Abey and Davenport (1984), which in statistical terms were not sufficiently large. Woodard and Garcia (2008) and Bokusheva (2011) acknowledged the impact of time frame chosen for analysis on the effectiveness of weather contracts while Bardsley et al. (1984, p. 2) alluded to the fact that time smoothens out the probability of loss to the insurer but this idea was not captured in their model.

Similarly, prices were assumed to be constant in previous studies (Turvey 2001; Vedenov & Barnett 2004; Kapphan 2012). The outcomes of the hedging efficiency results based on constant price assumptions were compared with those from variable pricing. This gap deserves attention in that researchers often make the most favourable assumptions in the analysis of the efficiency of weather index insurance (Vedenov & Barnett 2004). Castro and Garcia (2014) concluded that commodity prices have implications for farmers' credit worthiness. Since insurance has impact on farmers' credit worthiness as well (Gurenko 2006), it is logical to expect that commodity prices will affect the willingness of farmers to pay for insurance. The comparative analysis of hedging efficiency based on constant and variable price of wheat will unveil possible differences between previous results and realities. This comparison was necessary because in reality prices are variable and could provide a natural hedge in times of drought whereas researchers had assumed otherwise. The assumption also suggests that the price stabilization was costless.

Also, different regression analysis methods were adopted in the analysis of the yield-index relationship. The use of a regression method (Quantile Regression) that disaggregates the relationship across the continuum was particularly useful in the correlation analysis of hedging efficiency and yield-index relationship.

Finally, the analysis of the challenges and opportunities associated with weather index insurance gives context to the study because the phenomenological research paradigm was adopted. The mix of quantitative and qualitative analyses has been missing in previous related studies globally and in the particular context of Australia (Patrick 1988). In an attempt to bring the quantitative analyses into real life context, farmers were interviewed in order to have their input in the policies that will be recommended in this study.

Consequently, the study adds to the body of literature on the use of weather index insurance in Australia and provides empirical and qualitative information that are urgently needed for adaptation to weather fluctuations to facilitate risk transfer (Quiggin & Chambers 2004; O'Meagher 2005; Garnaut 2008).

1.7 Organization of the thesis

The thesis is organized into eight chapters as follows:

Chapter One – Introduction: The overview of the thesis is presented here. The research objectives, limitation and significance are also presented.

Chapter Two – Literature review: Previous studies and relevant other literature are coherently documented in this chapter with the aim of giving context to the study. Some relevant theories are discussed under six major headings namely; Introduction, challenges to agricultural risk management in Australia, strategies for risk management in Australia, incentives theory, global practices in agricultural risk management and then the summary of the chapter.

Chapter Three – Methodology: In the third chapter, the details of the quantitative and qualitative data collection and analyses are detailed. The data sources are stated and the methodologies adopted are justified.

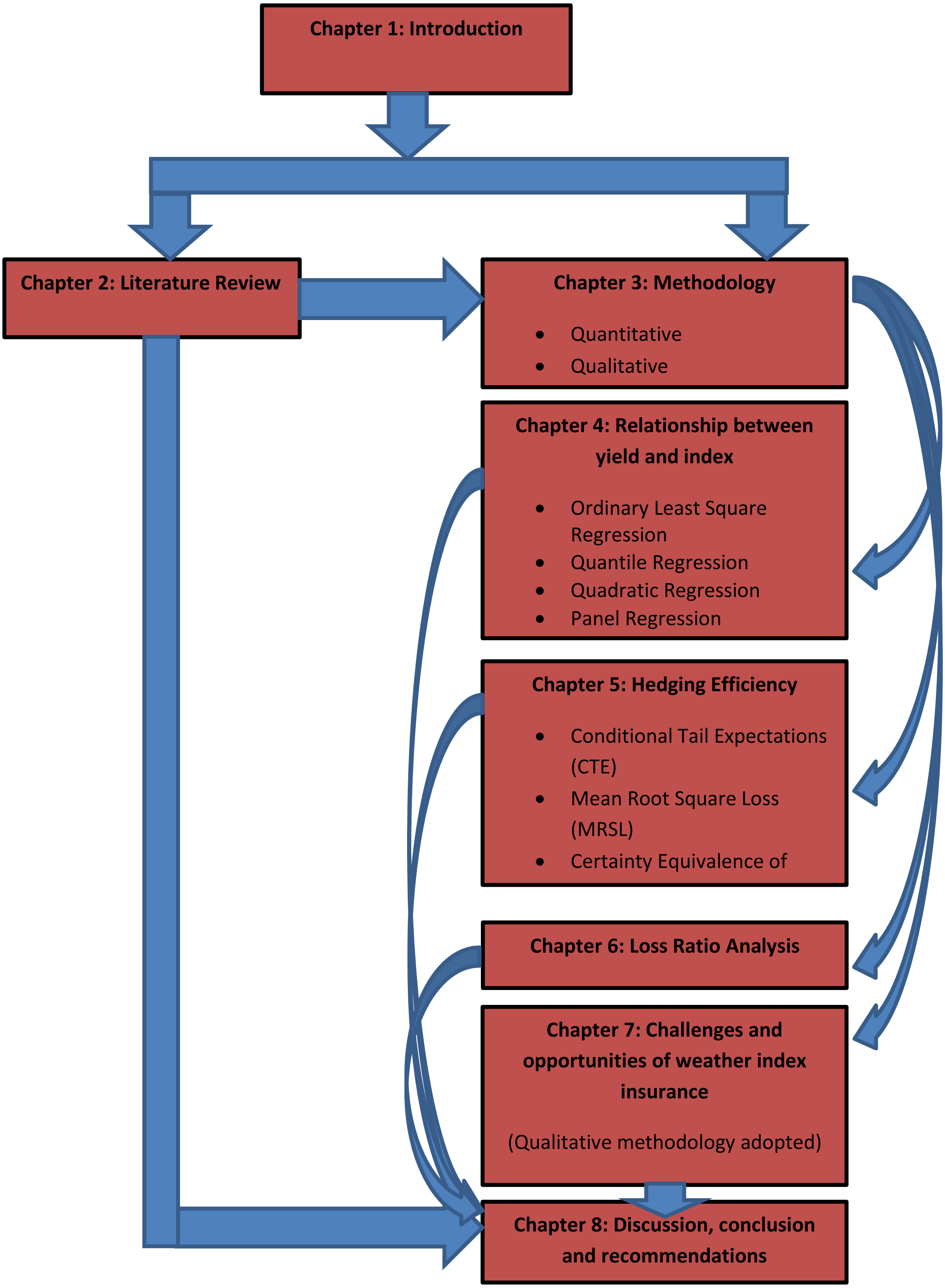
Chapter Four - Descriptive analysis: The descriptive analyses are presented in this section. In addition, the results from the analysis of the relationship between yield and index are presented since the relationship themselves are not the main essence of the study but a prerequisite objective. The chapter ends with a summary.

Chapter Five – Hedging efficiency: The results from the hedging efficiency are articulated in this chapter. Some tables and graphs are presented but most other tables are placed in the appendix so that they do not impede the meanings from the results. The chapter is sub-divided into two broad sections based on the contract design methods. Each section is further divided into three based on the methodology adopted. The chapter concludes with a summary of findings.

Chapter Six – Challenges and opportunities: Two qualitative analyses are presented in this chapter. The first set of analysis is based on documents and newspapers and in the second set of analysis; the opinions of stakeholders were gathered through an interview process.

Chapter Seven - Diversification: In this chapter the loss ratio was adopted in the examination of the spatial and temporal diversification of risks. The summary of the outcomes are presented in this chapter while most of the results are presented in the appendix.

Chapter Eight – Discussion, conclusion and recommendations: The interpretations of the results from the analysis are related to existing context through literature. The chapter ends with some recommendations.


Chapter 1: Introduction
Chapter 2: Literature Review
Chapter 3: Methodology
• Quantitative
• Qualitative
Chapter 4: Relationship between yield and index
• Ordinary Least Square Regression
• Quantile Regression
• Quadratic Regression
• Panel Regression
Chapter 5: Hedging Efficiency
• Conditional Tail Expectations (CTE)
• Mean Root Square Loss (MRSL)
• Certainty Equivalence of
Chapter 6: Loss Ratio Analysis
Chapter 7: Challenges and opportunities of weather index insurance
(Qualitative methodology adopted)
Chapter 8: Discussion, conclusion and recommendations

2 CHAPTER TWO: LITERATURE REVIEW

2.1 Introduction

Agricultural risk management has become an issue of global concern not only because of the impact of drought that has become exacerbated by climate change as discussed in the previous chapter, but also because of the growing world population accompanied by energy demands (Nonhebel 2005). To fulfil some of these demands, global food resources are further depleted in the cause of energy production. Since lack of risk management mechanisms could lead to risk avoidance among potential agricultural investor, particularly because of its low returns (Gray & Lawrence 2001), risk management has become an issue of paramount importance among the rural area dwellers from which the bulk of global food supply emanate.

Most rural area dwellers believe that the struggles of farming communities is not the ineptitude of anyone but the inability of their own organizations (Gray & Lawrence 2001). Similarly, most academic debates on the issue of agricultural risk management have focused on quantitative models that did not sufficiently give a voice to the realities existing among the rural populace (Bardsley, Abey & Davenport 1984; Bardsley 1986; Quiggin, Karagiannis & Stanton 1993; Quiggin 1994; Quiggin & Chambers 2004; Chantarat et al. 2007; Turvey & Kong 2010; Adeyinka et al. 2013). Such quantitative exercises are yet to sufficiently focus on the attitude of farmers as it relates to risk particularly in Australia (Patrick 1988). This focus is a necessary condition for the evaluation of risk management options within the market context in which the risk management tools are expected to function.

Consequently, this review chapter focuses on previous quantitative analysis in relation to agricultural insurance and discusses others that are related to the behaviour of farmers as it relates to risk management. Current issues and theories of relevance to agricultural risk management are also discussed.

The literature reviewed in this chapter is segmented into nine sections. In Section 2.1 (this section), the chapter is introduced. Section 2.2 features the risks that are faced by farmers generally and particularly in the context of wheat production in Australia under the heading weather and climate risk in Australian agriculture. Section 2.3 is titled weather risk management in Australian agriculture. In this section, the means of managing the risks are discussed.

A discussion of the theory of incentives is pertinent to risk management in agriculture because every stakeholder involved in the contract, directly or indirectly, responds to incentives. Particular emphasis is laid on agricultural insurance as it relates to principal agency theory, regulatory economics, moral hazard and adverse selection. In Section 2.4, some relevant economic theories are discussed under the heading incentives theory and insurance. Since furthering the cause of effective agro-risk management is underpinned by technology and relevant data, Section 2.5 was dedicated to the role of technology in agricultural risk management.

Furthermore, in Section 2.6 risk aversion and insurability were discussed. Risk aversion relates to the behaviour of farmers with regards to risk management and the concept of insurability is necessary given the need to examine some clauses that may be essential for insurance to be possible. However, there is rarely any form of insurance that fulfils all the necessary conditions for insurability. Risk aversion and insurability are particularly discussed in the context of index–based insurance and indemnity–based insurance (derivatives).

Until Section 2.6, clear distinctions are not prominent between insurance and derivatives. The purpose of both financial instruments is to hedge the farmers' risks. In the context of weather hedging, their functional and structural similarities are discussed but emphasis is placed on their legal distinction. The need for this distinction is necessitated by the need to institute a regulatory framework required for policy purposes as would be discussed in the concluding chapter of the thesis. Hence, in section 2.7 we cover legal and regulatory treatment of weather derivatives and insurance.

Insurance, in whatever form, has become very prominent in recent debates on agricultural risk management in Australia particularly with regards to farm debt (Keogh, Tomlinson & Potard 2013; Kingwell 2013). Consequently, it was considered necessary to include Section 2.8: debt structure and farm equity in Australian agriculture in this chapter. The concern about farm debt features prominently in the seventh chapter on challenges and opportunities of weather index insurance in Australian agriculture but not in any way captured in the quantitative analysis given the nature of the data in use. Furthermore, some of the stakeholders interviewed compared Australia with other countries of the world particularly US. Hence, the need to examine what obtains in terms of agricultural risk management with a focus on weather insurance in other countries. This comparison is succinctly documented in Section 2.9 – global experience in the use of weather index insurance. Section 2.10 concludes this chapter with a summary and weaves the basic ideas gleaned from the review together in anticipation of the findings of this study.

2.2 Weather and climate risk in Australian agriculture

Agriculture is known to be extremely susceptible to weather risk particularly drought (DAFF 2012; George et al. 2005; Hatt, Heyhoe & Whittle 2012; Keogh, Tomlinson & Potard 2013). Hence, there is a paradigm shift from drought as a disaster to drought as a risk that requires self-reliance on the part of farmers (Kimura & Antón 2011). This shift is further necessitated by the anticipated frequency and intensity of extreme weather events (Hoppe 2007). Several scholarly debates have focused on this risk particularly in the context of climate change (Rosenzweig et al. 2001; Stern 2006; Webb 2006; Parry et al. 2007; Hennessy et al. 2008; Hertel & Rosch 2010; Cuevas 2011; Keogh 2013).

Australian farmers are not exempted from weather risks. The risk interacts with other risks in such a way that affects different segments of the agricultural sector. For instance, Gray and Lawrence (2001) mentioned that, a combination of high interest rate, high input cost, low output price and drought are making things hard for farmers.

Various initiatives have been taken by governments in Australia to facilitate risk management in the agricultural sector leading to reviews of the Australian Drought Policy (ADP) (Kimura & Antón 2011; DAFF 2012; NRAC 2012). Farmers like other entrepreneurs want to maximize their revenue while minimizing their risk but the opportunities to do so has been limited in Australia (Khuu & Weber 2013). Similarly, government's supports for farmers in Australia seem to be low in comparison to other countries where farmers have access to government's subsidized Multi-Peril Crop Insurance (MPCI) (Van der Vegt 2009; Mahul & Stutley 2010).

It has been argued that this relatively insufficient support is the result of the relative size of the Australian rural populace and the voting influence they wield (Van der Vegt 2009). This opinion reflects the reality of political economy that the budget of a state reflects the ability of some stakeholders to defend their interests, and by implication the inability of others to do likewise (Lindahl 1919). The economics of Australian politics itself therefore constitutes a form of risk to Australian farmers. However, there are competing views on the level of state supports for Australian agriculture based on certain other theories and documents analysed in subsequent sections of this review (IAC 1986; Zweifel & Eisen 2012).

Scholars are of the view that market-based options would better facilitate response to agricultural risk management than government palliative efforts that cause farmers to under-price risk culminating in making suboptimal farm management decisions. In contrast, others are of the view that market-based options, like insurance, create opportunities for rent seeking behaviours (Hertzler 2005). In a counter argument, rent-seeking behaviour may not always be detrimental to the economy in that the activities of such rent seekers could enhance the economic wellbeing of the state (Sobel 2005; Zweifel & Eisen 2012).

Since Multiple Peril Crop Insurance (MPCI) has been found to be challenging in other economies, largely due to the information asymmetry resulting in moral hazard and adverse selection, there has been debates on the possibility of managing the asymmetry with index-based risk transfer products including rainfall-based contracts (Quiggin, Karagiannis & Stanton 1993). However, the debate on the prospects of rainfall insurance in Australia remains inconclusive (Bardsley, Abey & Davenport 1984; Bardsley 1986; Quiggin 1986; Quiggin 1994).

Although, MPCI that is based on the revenue of the farmer and rainfall options (weather certificates) have recently featured among the menus of options available to Australian farmers, their continued existence remains an issue of concern given the conclusions that such products may not be viable without some subsidies (Bardsley 1986; IAC 1986; Quiggin 1994). Therefore, previous efforts in managing agricultural risk, current options and future possibilities are relevant analysis for all stakeholders in Australian agriculture.

Australia is prone to changes in temperature and precipitation besides being the driest inhabited continent (Parry et al. 2007; Botterill & Hayes 2012; Keogh, Tomlinson & Potard 2013). These changes have implications for agricultural productions and the overall economic stability of Australia (Webb 2006). In recognition of these fluctuations, farmers are placing more credence on long range weather forecasting (Malcolm 1985; Sivakumar & Motha 2007).

Wilhite (2007) showed the inter-relationships between the four types of drought namely; meteorological, agricultural hydrological and socio-economic and political droughts. She also emphasized that there is no direct relationship between rainfall and infiltration of precipitation into the soil. So, it is not just about the rain but also about the soil type which is beyond the scope of this study. Australian climate has been associated with El Nino Southern Oscillation (ENSO) Index and La Nina events (BoM 2012b). The droughts of 1902, 1972, 1982 and 2002 coincided with ENSO events while the floods of 1973, 1974, 1999 and 2000 coincided with La Nina events. The La Nina events over the period 2010 to 2012 resulted in the record rainfall and floods in Australia. The two events, El Nino and La Nina are both naturally part of the global climate system that result from the interaction between the Pacific Ocean and the atmosphere above it (BoM 2012b). The link between Sea Surface Temperature and its impact on losses were emphasized by (Hoppe 2007) while the impact of the ENSO and oceans could be further gleaned from the work of Botterill and Hayes (2012). The possibility of the 2010/2011 La Nina events were actually noted by meteorological agencies around the world several months earlier based on the interactions among atmospheric variables. More specifically, the Bureau of Meteorology of Australia affirmed the risk of flooding and cyclones by October 2012 and also forecasted a low risk of fire risk given the anticipated wet condition and briefed key government agents ahead of time.

The relationship between rainfall and ENSO forms the basis for predicting seasonal rainfall using Southern Oscillation Index (Stone & Auliciems 1992). Consequently, both ENSO and La Nina are related to the Southern Oscillation Index (SOI) which has a strong relationship with wheat yield in Australia (Rimmington & Nicholls 1993). The movements in these weather indices have been the underlying influence of the temporal and spatial variability of wheat yield in Australia because of their interconnectedness with rainfall variability (Potgieter, Hammer & Butler 2002). The implication of these relationships is that these climatic indicators are in some ways related to agricultural productions in Australia because of their relationship with the Australian climate particularly rainfall (McIntosh, Ash & Smith 2005; Webb 2006).

In an attempt to capture this interconnectedness, Sea Surface Temperature (SST) was related with the gross output of Australian crops. It was noted that more than fifty per cent variance in gross value was explained by Sea Surface Temperature (Hammer, Nicholls & Mitchell 2000). The implication is that as these events influence meteorological characteristics of the Australian climate, they also affect the hydrological characteristics with consequent implications on the agricultural output and eventually the social welfare of the Australian community (Wilhite 2007).

Webb (2006) established that the variations in Australian agricultural output vary from year to year with a consequent loss of as much as 10% of farm production value. The author cited the drought of 2002 which cost 70,000 jobs, 30% reduction in agricultural output and 1.6% reduction in GDP. Drought could have cost implications for the farmer in that pasture production will be low and given that demand is higher than supply, the cost will rise. Paddock cost was $15, 858 per year in non-drought years but jumped to $42, 440 in years of drought in Tocal homestead in (DPI 2013). Other costs may however not follow the same direction but may not make up for the increase to a commensurate extent. This increase in costs of input explains why prices of primary products could rise during droughts (Gray et al. 1995). In addition to the passing through of increased costs of production to the consumers, demands would tend to outweigh supply giving additional incentives to suppliers to increase the prices of their products in the case of crops but the converse is the case for livestock.

Australia faces extreme yield and price shocks than most other countries (Mahul & Stutley 2010). Besides, current projections have shown that; ‘a changing climate may increase the frequency of extreme weather events, including drought’ in Australia

(NRAC 2012, p.2). The emphasis on drought could be further garnered from the analysis presented in Kimura and Anton (2011) that; ‘The key feature of the natural environment that affects farming in Australia is rain during the growing season’. However, pre-seasonal rainfall may compensate for shortfalls in the volume and distribution of growing season rainfall (Johnson 1964). Researchers have focused on the use of growing season rainfall (Patrick 1988; Turvey. 2001; Vedenov & Barnet 2004).

Weather risk affects all parameters of farm income but yield risk is of higher significance than price risk and input risk (Malcolm 1985; Hammer, Woodruff & Robinson 1987; George et al. 2005; Hatt, Heyhoe & Whittle 2012). The variability in prices has been attributed to the focus of the Australian agricultural productions on exports and the fact that there is currently no government price support although there are other options that individual farmers could adopt to hedge their risks (Craik & MacRae 2010; Kimura & Antón 2011; NRAC 2012). Given that the prices received by farmers could be highly variable because of reasons unrelated to domestic demand and supply and the Australian export is largely dependent on commodities particularly wheat, Australia is prone to high variability on commodity prices (Malcolm 1985). The case of Australia is peculiar because as much as 60% of its agricultural productions are exported annually and about 80% for wheat (NRAC 2012, p.11). It is believed that farmers are price takers because they are operating in an atomistic market (; Longworth 1967; Newbery & Stiglitz 1979; Kimura & Antón 2011; Hatt, Heyhoe & Whittle 2012; NRAC 2012). The existence of other mechanisms like forwards to manage price risk has alleviated the risk.

The single-desk approach to wheat marketing has been abolished and price is becoming a concern more than it was before in Australia (Craik & MacRae 2010). It is worth noting that production risk and price risk are negatively correlated (Quiggin, Karagiannis & Stanton 1994). However, should a farmer record no yield, it is the least affected farmers that would benefit from the price increase meaning that hedging production risk may be more important to producers than price risk.

Climatic conditions could also influence commodity prices to some extent. Profitability concern determines farm management decisions rather than gross revenue on which most analyses have been based. Since production costs are usually difficult to estimate in agricultural enterprise particularly for labour in an owner-managed enterprise farm context (Quiggin, Karagiannis & Stanton 1994), most models have been based on gross revenue (Vedenov & Barnett 2004; Kapphan 2012; Khuu & Weber 2013). The inter-relationship between production and the demand and supply of agricultural products links to the impact of weather on input cost which is a part of the profitability equation (Profit = Yield *Price – Input cost) (MunichRe 2011). The net income of the farmer is the most important variable from the farmer’s perspective and is less related to yield than the gross revenue because of the additional consideration of input costs which is largely determined by a farmer’s unique management skills and anticipated output price (Malcolm 1985). In times of drought, variations in the cost of labour and other material inputs could further impact profitability. Therefore, all three parameters in the profitability equation are indirectly linked to the weather.

At a national level, the government as a result of these climatic phenomena spend huge amounts on ex-post disaster aids and grants to farmers. The reasons for these expenditures are largely due to the emotive nature of drought, especially upon livestock and governments will wish to be seen to be doing something obvious in response to the problem. The response to drought is generally political in nature (Gray & Lawrence 2001). Therefore, it is not likely that some form of aids will not be administered even if subsidized MPCI was available (Malcolm 1985). Such supports have been found to be unjustifiable and inequitable (IAC 1986).

The implications of weather extremes make climate forecasting an integral part of agricultural management decisions (Khuu & Weber 2013). Nevertheless, weather forecasting may not be relevant to agricultural management decisions if the lead time to making the decisions is not sufficient (McIntosh, Ash & Smith 2005). The use of these phenomena to make agricultural weather forecasts could only be valuable if useful and readily grasped management response can be based on them (Rimmington & Nicholls 1993; McIntosh, Ash & Smith 2005).

Besides rainfall forecasting, other variables that are worth noting in making decisions include frost, hail and fire risk. Bush fires may not be directly related to weather conditions but bush fire index that is weather-based is associated with the risk of bush fires (Sivakumar & Motha 2007; ABS 2012). The index combines expected wind speed, humidity, temperature and a measure of vegetation dryness on a daily basis to facilitate preparedness. The implication is that these other risks that farmers face are not unrelated to weather and climatic conditions. For example, the years following major floods tend to be followed by heavy bush fires because of the wild growth of forest in the preceding years that serve as fuel for the fire. All these events pose risk to the economy of the state. Similarly, risk may differ by product types and locations. For example, wheat varieties differ in yield under different conditions and wheat generally differ in resistance to weather conditions relative to other grain crops (Fischer & Maurer 1978; Reynolds, Mujeeb-Kazi & Sawkins 2005).

Weather risk affects more than agricultural production because the import of weather risk on production translates into some forms of social tension in the rural communities (Roy et al. 2013). An advantage of appropriate risk management mechanism is that it improves the ability of farmers to plan effectively. Consequently, adequate risk management strategies could be worth more than one could possibly quantify in dollar terms. In the definition of risk as the product of the probability and cost of the consequences of occurrence of severe weather events by Dutton (2002), it is obvious that appropriate estimation of the probability of occurrence of events is crucial to risk management. This management has taken different forms at different levels in different sectors of the Australian economy. Some of the previous and emerging initiatives taken to manage weather risk in Australia are discussed below.

2.3 Weather risk management in Australian agriculture

There are several initiatives towards managing agricultural risks in Australia (DAFWA 2009; Hatt, Heyhoe & Whittle 2012). Since most other forms of agricultural insurance are largely managing the implications of weather exposure, they are considered in this literature. These several initiatives could be classified into three. First are those on-farm initiatives that are taken by the farmers. The second are the market-based mechanisms and lastly government assistance. These three broad categories of risk management in agriculture have been associated with the three layers of risk. The first layer is frequent but has low impact; the third layer has low probability but the highest level of impact while the second layer is in between the two. The major concern to stakeholders in Australian agriculture is the second and third layers of risk. The frequent but low impact risks are well managed by Australian farmers. The major market-based option, hail and fire insurance, that has survived over the years did not sufficiently cover farmers. The third layer with low probability has been more challenging in that previous attempts to manage that level of risk with have defied all policy efforts. These two layers are of particular relevance in this study.

Diversification and other on-farm strategies are means the farmers use to manage the first risk layer. A closely related risk management to diversification is pluriactivity which involves farmers getting involved in other employments off the farm. Pluriactivity however has been challenged on equity grounds because some farmers who depend solely on their farm productions may be entitled to welfare benefits while others who have sought other means of survival are disadvantaged (Gray & Lawrence 2001).

However, drought risk in Australia is very systemic and diversification does not help as much as it could (Kimura & Antón 2011). In order to cope with the impact of weather variability, farmers tend to watch out for the quantity and timing of rainfall and adjust input choices, including cultivars, accordingly. The use of modern cultivars has however been found to cause greater variability and higher spatial correlation of risk (Anderson et al. 2009). The higher variability will lead to increased need for financial risk management tools. The spatial correlation translates into systemic risk for insurers and a reduction in basis risk for farmers thereby increasing their willingness to pay for insurance.

The market-based risk management alternatives could be divided into two namely traditional-indemnity insurance and index-based insurance. Market-based options were limited in Australia until recently because named peril insurance is available in the market while Multi-Peril Crop Insurance has failed after some attempts (Hatt, Heyhoe & Whittle 2012). Although, there are different types of insurance under the traditional insurance options, only a few of them are available in Australia. Examples of traditional insurance include named-peril insurance, multi-peril insurance, crop revenue insurance and mutual funds or farmer pool (Hatt, Heyhoe & Whittle 2012). Named-Peril Insurance protects farmers against perils such as frost, hail and fire. The localized nature of these perils makes the insurance to be viable unlike crop and rainfall insurance that are systemic.

MPCI crop revenue insurance protects against farmers' revenue falling below a specified threshold. This type of insurance according to Mahul and Stutley (2010) only existed in US as at 2009. Currently, there are attempts to provide revenue-based insurance (MunichRe 2011; Cattle 2013; Grieve 2013).

Revenue insurance protects the farmer against both yield and price risks. In the case of Multi-Peril Crop Insurance, yield is protected and the causes of shortfalls are not necessarily examined. Farmer pool is pseudo-insurance in that it functions as insurance but is not legally recognised as such. The pool allows farmers to pool a fraction of their income into a fund every year and they are able to withdraw from this fund whenever an event is triggered.

Payouts from Index–based insurance are based on proxies for yield. Such proxies include weather indices like rainfall and temperature or regional yield that are highly correlated with farm-specific yields. The rationale behind weather derivatives (insurance) is that it will prevent some sources of inefficiencies in crop insurance because it is based on variables that are exogenous to the system. Yield insurance brings together a number of variables used to predict yield through computer models. The history of insurance in Australia indicates that there have been attempts to offer some of these products to no avail. However, there are renewed efforts geared towards offering them (Cattle 2013; CelsiusPro 2013; Newsdesk 2013).

As far back as 1974/1975, Wesfarmers attempted to offer area yield guarantee. The insurance turned out to be poorly patronized because of adverse selection and inadequate yield records which resulted in poor underwriting. Incidentally, the offering that year (1974/75) indicated a payout that was approximately half of the average payouts over the previous fifteen years (Malcolm 1985). Hence, if MPCI was not viable that year, hind-casting suggests that it would not have been in the previous years.

Co-operative Bulk Handling (CBH) in partnership with AON insurance in 1999–2000 season also offered MPCI and downgrading insurance but failed because only 34 farmers took the insurance although 1, 200 quotes were obtained (NRAC 2012). The year 2001–2003 witnessed the partnership between Macquarie Bank AXA and Aquila offering weather derivatives. The product was terminated because of the restructure within Aquila. More recently, CBH/Willis offered an insurance product that helps farmers to cover their cost of production around the year 2010 to 2012. The scheme witnessed poor uptake and was terminated in 2011 to 2012 season. The timing of the contract was considered to be the reason for the lack of demand for the product. The timing concern is in congruence with the previous discussions on the need for appropriate timing of weather information as it relates to agricultural production (McIntosh, Ash & Smith 2005). From 2009 till date, Primacy Underwriting Agency has been offering YieldShield designed specifically to cater to flooding and water deficit for wheat and sorghum. Crop simulation model is adopted and this helps to mitigate the problem of the lack of sufficiently long farm-level yield data. Another recent development in the history of agricultural risk management in Australia is the weather certificate offered by CelsiusPro (A company called WeatherPro merged with a Swiss-based company-CelsiusPro AG to form CelsiusPro Australia).

The company offers Over-The–Counter (OTC) weather derivatives to several industries including agriculture. CelsiusPro, unlike Primacy Underwriting has sufficient demand for its products to make it sustainable. The firm has clients across diverse sectors including agriculture making its portfolio less risky. The product covers flooding, drought, frost and heat (CelsiusPro 2013). A specifically interesting product offered to the agricultural sector is the Full Season Weather Certificate (FSWC). CelsiusPro's offering is similar to the idea of a rainfall bet insurance suggested in (IAC 1986). The FSWC captures the biology, timing and distribution of rainfall. Since accumulation of seasonal rainfall may not benefit the farmer as noted in (Malcolm 1985), the inclusion of the timing and distribution of rainfall would tend to add value to the product and increase client-base specifically in the agricultural sector. It was noted in the commission's report that there is only at best a moderate correlation (0.68) between yields and seasonally (May to October) accumulated rainfall in drier regions and less than that in the wetter regions. It was suggested that a simulation model could be more profitable since it will capture the timing and distribution of rainfall more than a regression model. The simulation procedure probably explains the relative success of YieldShield till date (Hatt, Heyhoe & Whittle 2012) although its uptake is still very low.

In 2013, Latevo has moved into the agricultural insurance market by providing Multi-Peril Crop Revenue Insurance to farmers (Newsdesk 2013). This insurance is attempting to take off at the time of this review. It was surprising to note that a firm would attempt to offer MPCI despite the failure of previous efforts. The revenue insurance could be attractive to farmers in that it attempts to capture the covariance in the yield and price of the farmer meaning that there may be years of low yield when the contract will not be triggered because of the natural price hedge. Reasonably high negative correlations were observed between yield and price for some Australian commodities particularly wheat (IAC 1986; Mahul & Stutley 2010). The other side of the coin is that price may also lead to a trigger. However, Latevo seems to suggest that the conclusion in Malcolm (1985) and IAC (1986) that MPCI is highly unlikely to eventuate is due to the assumption of the use of shire-level data rather than the farmers' individual yield on which its products are based. In contrast to the benefits expected from risk disaggregation in the pricing of insurance contracts, Quiggin, Karagiannis and Stanton (1994) were of the view that individual farm level yield series will be too short to make any meaningful pricing possible.

Hence, should Latevo survive in business, its advantage will be that it has included a price hedge in its offering. Intuition suggests that farmers who were able to take hail and fire insurance and simultaneously sell forward would not find it too difficult to pay for this comprehensive offering by Latevo. The offerings by Latevo and CelsiusPro are attempting to contain some of the challenges highlighted in the Industries Assistance Commission Report of 1986 (IAC 1986). Despite the disincentives highlighted in IAC (1986) and Malcolm (1985), offering the products suggests that the circumstances surrounding crop and rainfall insurance might have been altered within that period of time (DAFWA 2009). A major alteration is the reviews of the Australian Drought Policy that emphasize self-reliance on the part of farmers and with the most recent changes to policy, the market may emerge (DAFF 2013).

The World Bank has noted that Australia is not offering any form of intervention in bearing a part of the insurance premium paid by farmers (Mahul & Stutley 2010). From the government's view point, countries that have their insurance premium subsidized still have disaster aids paid to their farmers (IAC 1986; Edwards 2009). Malcolm (1985) concluded that assistance to farmers is ineffective and may become a permanent assistance to an industry that is not viable. To lend credence to this conclusion is the report by the World Bank which suggests that premium subsidies are not necessarily always prerequisite for farmers' uptake of insurance.

However, subsidy was considered as a prerequisite for the existence of rainfall insurance in the debate between Bardsley and Quiggin (Bardsley, Abey & Davenport 1984; Bardsley 1986; Quiggin 1986; Mahul & Stutley 2010). Recent developments seem to suggest that even without government subsidies, insurers are optimistic about the prospects of insurance despite previous failed attempts. This optimism could stem from the changes to farmers' attitude to risk due to anticipated increment in extreme weather events and the emerging policy focus and the fact that some innovations have been introduced into the design of the product (DAFF 2013).

Since taxpayers' money will be spent to subsidize the insurance, some equity questions could arise. In the case of wheat, insurance subsidy will suggest that every tax payer consumes wheat product to an equal extent. Suppose Mr. A does not consume flour products and Miss B on the other extreme lives solely on them, then, A will be subsidizing B's consumption. If insurance is not subsidized and farmers have to pay for themselves, the implication is that the insurance will be passed through to the consumers and the extent to which individuals consume the product will be the extent of the insurance paid in the form of cost passed through to the consumer. Should the subsidy cut across all crops, then this form of inequity may be minimized. This analysis seems to concur with the ideas expressed in Lindahl (1919) in that one party is bearing part of the cost of the other. Hence, each party attempts to shift the equilibrium to its own advantage.

Another perspective is that Australia's competitiveness could reduce in the international market since competitors are heavily subsidized (Edwards 2009). The subsidy may then be worth it since future production would be contingent on profitability and farmers remit taxes based on profits. However, Malcolm (1985) and IAC (1986) concluded that subsidizing crop or rainfall insurance will not in any way create a net benefit to Australians. On the contrary, Tiffin and Irz (2006) concluded that such subsidies would drive growth in other sectors of the economy for a country like Australia with highly competitive agriculture. Other researchers seemed to debunk the worth of subsidies (Chris, 2009; Edwards 2009; Goldschlag, 2009).

Similarly, it has been noted that subsidy would provide incentives to shift production towards crops that are subsidized because of the alterations it makes to farmers' expected utility in comparison to other ventures (Just, Calvin & Quiggin 1999). Some studies have affirmed that individuals may respond to the mere presence of incentives although the extent of the incentives may also be important and it has different outcomes for different sub-groups (Gneezy, Meier & Rey-Biel 2011). One could therefore concur with Bowles (1998) that preferences are shaped by policies and institutional arrangements and the analysis of the implications of new policies could be challenging because of their endogeneity. The expected utility analysis is seconded by psychologists who have warned that explicit incentives may be counterproductive (Gneezy, Meier & Rey-Biel 2011; Bowles & Polania-Reyes 2012). In the case of agriculture in Australia, one may argue that there is no insurance subsidy, but efforts to bail farmers out of crisis amount to a form of subsidy (Edwards 2009). The issue therefore is not whether or not there should be subsidies but what is the best combination of options that could maximize the net benefit of Australian agriculture to the state.

There is a body of literature confirming the counter-productivity of explicit incentives or at best their marginal benefits in public policy (Frey & Jegen 2001; Bar-Gill & Fershtman 2005; Sobel 2005). It is not surprising therefore that the Australian government is emphasizing self-reliance in the form of market-based options like insurance. However, there is room for implicit incentives in the form of tax rebates in the current policy framework rather than the explicit payouts to farmers and the government has always been opposed to insurance subsidies (IAC 1986; DAFF 2013).

The study by Patrick (1988) affirmed the theoretical possibilities of using insurance to spread agricultural risks. Ahsan, Ali and Kurian (1982) reiterated the conclusion in Bardsley, Abey and Davenport (1984) that insurance would not make a major contribution to risk management in the Australian wheat industry. Patrick (1988) showed that area rainfall insurance was more elastic than crop insurance and the participation rate is relatively low for both products but more so for rainfall insurance. Besides the problem of basis risk, participants seem to be concerned about fraud in the form of tampering with the weather readings. It seems that the non-preference for rainfall insurance is partly behavioural. The low demand for insurance was noted to be consistent with those of other countries where as much as 50% subsidies may be required to enrol a sufficiently large number of farmers (Gardner & Kramer 1986). In a related study, it was concluded that only 18% of Australian farmers would enrol in a Multi-Peril Crop Insurance scheme at a viable premium (Ernst & Young 2000). Also, it was clearly observed by Patrick that there were differences in farm level risk in the Mallee area considered for the study and the recognition of this difference was well recognised by the farmers. The lack of participation in Patrick's models of insurance was found to be consistent with maximization of expected utility. Some of the factors impacting on participation were attributed to absolute size of risks, availability of alternative strategies, capacity to bear risks, personal characteristics, risk attitudes and government supports for droughts. The research by Patrick concluded that a modified response to drought would change producers' risk management practices and further suggests that unsubsidized insurance may provide efficiency gains. It should be noted that this Multi-Peril Crop Insurance was based on yield only. Besides the efforts of the insurance providers, the government of Australia has also taken initiatives to facilitate agro-risk management.

2.4 Government intervention in agro-risk management in Australia

Steps taken by the government to insure Australian farmers include; price stabilization, tax averaging, income equalization deposits, rural adjustment finance and emergency disaster relief (Craik & MacRae 2010; Mahul & Stutley 2010; Kimura & Antón 2011). In Australia, disaster aids are given to farmers in different forms but these have impeded the development of market alternatives (Kimura & Antón 2011). Some of the justifications offered for the provision of government intervention include systemic risk, information asymmetries, limited access to reinsurance, agricultural market infrastructure, low risk awareness, lack of insurance culture, regulatory impediments and market failure (Mahul & Stutley 2010).

The fiscal implications of government intervention has shown that the costs of such intervention may be unsustainable in the long-term and the Jeffersonian (Peterson 2009) supports of agricultural insurance subsidy and aids were found to be a form of wealth transfer from tax payers to rent seekers and asset-rich farmers (Mahul & Stutley 2010). Edwards (2009) highlighted eight types of subsidies and brilliantly debunked Jeffersonianism on a six-count charge in the particular context of US which is of global relevance.

A closely related argument against disaster approach to agricultural risk management as noted in Edwards (2009) is that financial implications of disaster aids are often open ended and therefore very difficult to budget. Furthermore, such subsidies distort the price of insurance thereby sending wrong signals to farmers about their risk exposure. Adaptation to extreme weather events will be delayed if risks are mis-estimated. With subsidized insurance, risk is quantified but a part of the risk would have been explicitly paid for by government.

Two types of insurance subsidies are identifiable in Mahul and Stutley (2010) namely: market-enhancing subsidies and social insurance premium subsides. In the former, the government provides the necessary infrastructure that could facilitate participation. In the later, the intervention takes the form of welfare benefits (Mahul & Stutley 2010). Recent policy changes in Australia is another version of the old and they both follow the social insurance types as would be further discussed in subsequent sections of this chapter.

The paradigm shift from drought as a risk and not a disaster has led to the separation of drought risk from the National Disaster Relief and Recovery Arrangements (NDRRA). The NDRRA covers bushfires, earthquakes, floods, storms, storm surges, cyclones, landslides, tsunamis, meteorite strikes and tornadoes (Kimura & Antón 2011; OECD 2011). The NDRRA is normally paid whenever a state or territory within the commonwealth of Australia spends above $240,000 on a disaster. It is a form of partnership that later excluded drought because of its slow onset and relative certainty of its periodic occurrence. The essence of the NDP is enhancing self-reliance on the part of farmers and maintaining long-term viability of producers. The NDP led to the formulation of Exceptional Circumstance declaration which consists of a specialized form of relief packages for farmers experiencing drought. Whenever there is an Exceptional Circumstance (EC) declared in a region, three forms of government supports were available to those within the affected areas.

The first is Exceptional Circumstance Relief Payment (ECRP), second, Exceptional Circumstance Interest Rate Subsidy (ECIRS) and the third is the Exceptional Circumstance Exit Package (ECEP). For any region to be qualified for any of these packages the EC must be as rare as a 20 to 25-year event with an accompanying down turn in farm income. The ECRP was designed to cover the daily expenses of the affected farmers. The ECIRS supports the debt of farmers in that they are able to obtain as much as 50% off the interests on their loans in the first year and 80% in following years. This benefit has been criticized as an incentive for farmers to increase their debts. ECEP affords farmers some financial supports should they decide to leave the farming business. However, the EC has been considered as a much maligned policy and is suffering from the Principal-Agent problem that has led to inefficiency and inequity (Kimura & Antón 2011; NFF 2011). This malignity of welfare support for farmers was considered as penny pinching and a degrading approach to agro-risk management (Gray & Lawrence 2001, p. 82). The inefficiency and inequity arguments were affirmed by Quiggin (1996) who opined that the concept of efficiency supplemented by equity dominates policy debates in Australia.

Prior to the redefinition of drought as a risk requiring self-reliance in the early 1990s (DPRTF 1990), farmers were having drought relief on equity grounds and media depictions of drought as a disaster particularly for livestock, helped farmers in achieving this goal (Simmons 1993; West & Smith 1996). However, changes arose because some analysts were of the view that the supports distort the cost of farming operations leading to over-cropping and over-grazing (mining the land) thereby exacerbating long term financial and environmental problems. The special drought assistance of 1994 by Prime Minsiter Keating was considered as punctuation in the exercise of the shift towards drought as a risk that was emphasized in the report of the Drought Policy Review Task Force (DPRTF 1990; Gow 1997; Gray & Lawrence 2001). Recent activities of governments are yet to send a clear cut message to all and sundry on the philosophy of drought management vis a vis. disaster or risk (Cawood 2014).

Quiggin (1996) further explained the vertical and horizontal equity as relative desirability of different distributional outcomes and process judgement respectively. He concluded that policies targeting efficiency should not redistribute wealth inequitably. It seems evident that Australian farmers deserve more supports but the form the support should take to avoid inequity and inefficiency is the problem (Gray & Lawrence 2001). In an attempt to improve efficiency without jeopardizing equity, there has been a move towards controlling the agency problem in drought risk management. (Agency problem is further discussed in the next section).

The attempt to achieve the delicate balance between equity and efficiency explains why some stakeholders are of the view that drought policy should be overhauled. Such overhauling is expected to be a difficult political process, hard for farmers and challenging in terms of establishing the appropriate institutional settings. These difficulties explained why drought policy has never been seriously attempted in Australia but all stakeholders agree that the time is rife to seriously attempt reshaping drought policy in Australia (NFF 2011).

Furthermore, government measures, if not carefully implemented, may impede the market for crop and rainfall insurance in two ways. First, such measures may shift risks from growers and influence their risk management decisions with a consequent reduction in demand for insurance. Secondly, government regulation of the insurance industry may influence the supply of insurance (IAC 1986).

The opinion is that for any insurance model to operate there must be some forms of incentives as it has been in other countries as would be seen in a later quotation below. Although, there is currently no incentive for Australian farmers to take up insurance in the form of subsidies, the recent policy change makes a tacit provision for this possibility. It is expected that taxation concessions that support risk management by farmers including Farm Management Deposit are allowable in managing agro-risk in Australia (DAFF 2013). Tax concession may therefore be considered if it is found appropriate and since the policy allows for reciprocal obligation, mutual responsibility and behavioural changes that could lead towards a market-based risk management practices.

Should a subsidy regime, direct or indirect, be given to farmers, it will somewhat be in contrast to the peg that has earlier been put in the ground in the reports of the Industries Assistance Commission (IAC 1986). The commission concluded that insurance will not be directly or indirectly subsidized in Australia:

The commission found no compelling evidence to justify the subsidization of crop or rainfall insurance schemes. No impediments were found which would prevent the offering of crop and rainfall insurance, if it were commercially viable. Nor was there found to be any potential benefit to the community which would warrant government assistance to the provision of crop and rainfall insurance (IAC 1986, p. ix).

This report concludes that the case for government intervening in the insurance industry either directly or indirectly to encourage provision of crop or rainfall insurance is on balance a weak case (Malcolm 1985, p.1). The report of the Industries Assistance Commission of 1986 also concluded that the net welfare benefit of a subsidized insurance scheme in Australia is not favourable to the economy because the cost will exceed the benefits. However, Malcolm (1985) issued some caveats on their conclusion as follows:

While this is a firm rejection it cannot be absolutely categorical as the analysis is based on some assumptions and estimates about which there is some (little) doubt. This doubt could be seen by some as justifying the establishment of a pilot scheme to explore all possibilities. If this pilot scheme were a fully commercial venture or entailed token government involvement it could be useful in clarifying issues and removing doubts (Malcolm 1985, p. 21).

Consideration of these options highlighted many practical problems associated with intervention. There is a wide variety of crops, types of insurance schemes and measures available for any government choosing to intervene. It is difficult to specify a basis on which to choose between the various alternatives. A large number of different insurance schemes would be required if it were considered desirable to insure most of the risks faced in Australian agriculture (IAC 1986, p. ix).

Furthermore, new ideas are evolving in the management of farmers' risk exposure. In the Multi-Peril Crop Insurance Task Force Report (DAFWA 2003), four suggestions were made for managing agricultural risk in Australia. These four new proposals were; Mutual Fund or Farmer Pool (discussed earlier), Trowbridge Proposal, Farm Management Deposit Guarantee Scheme and Higher Education Contribution Scheme (HECS) proposal.

The Trowbridge proposal was made as a contingent loan that is paid back should an event be triggered. The farmer would be allowed to pay back the loan when yields are above average otherwise no repayments are made that year. The philosophy behind this proposal is that farmers would not want to accrue debt and therefore there will be no moral hazard. In essence, this proposal considers the interest on the loan as the premium paid in excess of the actuarially fair price if the time value of money is not factored in. With this model, mispricing risk could be traded for credit risk.

Farm Management Deposit Guarantee Scheme is similar to the Farm Management Deposit Scheme. This proposal insures the farmers' operating cost. Under this scheme, the farmer deposits a fixed amount for a fixed period of time. The deposited amount is tax free and the farmer withdraws this amount whenever a weather event triggers it. Unlike the Farm Management Deposit Scheme, it could be withdrawn at any time after the contract is signed but the contracted amount will be paid annually.

The HECS proposal is drawn in parallel to the Australian Higher Education Contribution Scheme (HECS) model which allows domestic students to school on the bill of government and pays back their fees when they earn up to a certain threshold wage (Chapman 1997). This model was introduced in Australia for the first time in the global experience in higher education funding in 1989. The payment is automatically withdrawn through the tax system. The equity debate surrounding state financing of education led to the HECS model. The debate centred on the fact that if graduates are turned over on the bill of tax payers, these graduates will on average in their lifetimes earn more than the tax payers and therefore free education was reviewed in Australia. The parallelism drawn between graduate and farmers is that if government kept bailing farmers out with the EC programmes, it will amount to tax payers offering free insurance to asset-rich farmers. This same argument remains valid under current policy in that it permits welfare benefits to farmers. Botterill and Chapman who sponsored the HECS model were of the view that with income contingent loans, farmers' tendency to default is minimized while tax payers also benefit. The model has been tested by the sponsors and it was observed to cater to the problems of moral hazard (Cawood 2014).

Recently, the direction for response to drought has received a new turn (DAFF 2012, 2013). The government is of the view that declaration of EC is subjective and has adopted a policy that does not require any line on the map. The new policy which was agreed to by the states and territories governments on the 13th of May 2013 will commence on the 1st of July 2014. It will support farmers as other members of the Australian community are supported through the Department of Human Services (Centre Link), the main-stream government agency that disburses welfare supports to Australians. However, since farmers will not normally qualify for the main stream welfare packages given the nature of their assets even in times of hardship, the asset-test will be waived under the current policy.

The new policy aims at improving the capacity of primary producers to manage business risk while at the same time offering them some supports in times of hardship irrespective of the causes. Although, drought is still recognised as a major source of hardship, the focus is on mutual responsibility that enhances the willingness of farmers to build resilience to climatic variability. Whenever in–drought support would be delivered, the government expects that such supports must deliver a net public benefit and not put the government in a position of 'lender of last resort'. At the moment, the specific guidelines are yet to be set for the implementation of the new policy. Currently, three forms of supports are available until the Farm Household Allowance commences in 2014. These supports are Transitional Farm Family Payment which will be phased out by the 30th of June 2014. Farm Management Deposits is available but will be enhanced beyond the current transition phase. The Rural Financial Counselling Service will also be available into the future to help farmers in their decision making.

Since the government is more interested in a mutual approach to assisting primary producers (Malcolm 1985; IAC 1986; DAFF 2012, 2013) it is possible that agricultural insurance products will flourish. The anticipated increase in extreme weather event would possibly increase the demand for these new products (Garnaut 2008) coupled with the removal of the Exceptional Circumstances clause and recent innovations in products offered.

This section of the literature review has documented previous, current and anticipated agro-risk management initiatives in Australia with a focus on government response. An analysis of the Australian risk management landscape may not be complete without some exploration of the regulatory theories surrounding the market. Such theories are considered under the broad theme of incentives theory. Regulatory Economics and Principal-Agency theory are of particular interest as discussed in the next section.

2.5 Incentives theory and insurance

The theory of incentives is pertinent to the discussion of insurance. In talking about incentives, principal agency theory and regulatory economics readily come to mind. Three competing theories of regulation and principal agency theory are therefore discussed in this section.

Zweifel and Eisen (2012) analysed the three competing theories of regulations in the context of insurance. The theories are; public interest theory, capture theory and market for regulation theory. The basis for regulation in public theory is acting in public interest to prevent market failure. Anderson et al. (2006) opined that government response in the absence of such failure or externalities would reduce the welfare of the citizens implying that response to prevent market failure by the government could actually improve welfare. The opinion of Van der Vegt (2009) may be gleaned from the weakness of the public interest theory in that the adherents of the theory assumes that politicians are saints who solely act in public interest (Quiggin 1996).

Pragmatism has it that theories and models are assessed based on the extent to which their outcomes meet the required objectives. James Dewey, a major proponent in the pragmatic school of thoughts has it that;

'To the extent that a theory functions or 'works' practically in this way, it makes sense to keep it – though we must always allow for possibility that it will eventually have to be replaced by some theory that works even better.' (McDermid 2014).

The attempt to find the alternative dimension of thoughts has led to a serious debate on weather-index insurance and a revenue-based MPCI since the current available options are not adequately utilized by Australian grain growers and the EC has been considered as a 'much-maligned' policy that does not enhance farmers' capacity to independently manage their risks (Meuwissen & Molnar 2010; NFF 2011; Wilsmore n.d.).

The three competing theories on regulatory framework above could shed more light on the conflicting perceptions on drought risk management in Australia. According to Meier (1991, p. 700) regulatory policy results from the interaction of political institutions within an environment that influences the abilities of competing institutions and/or actors to use their political resources effectively. Gray and Lawrence (2001) were of the view that decisions are made in the context of power relations (p. 42) and reiterates that regional Australia is disadvantaged in the current politico-economic framework and it is therefore reasonable to say that farmers' chance of altering this trajectory of disadvantage is slim. The authors traced the farmers' plight to three elements, the first and most unique to Australia is; 'the attempt to recreate institutions of European agriculture and North American federalism within a colonial economic system in spatial locations which lacked the social, political and economic resources of an industrial base. The second was exploitative farming practices and lastly the vulnerability of family farmers. Given their vulnerability, they are exposed to political processes beyond the control of current institutions.

The provision of EC could be seen as an act of government in public interest due to concerns about market failure. Another obvious criticism of this theory is the difficulty in defining the basis of acting – market failure. Other criticisms of the theory as noted in Zweifel and Eisen (2012, p. 323) have to do with lack of explanation of the choice of instruments and lack of incentive to act as hypothesized. The lack of incentive criticism of the public interest theory and the preceding market failure makes it difficult to determine what policy is actually in the interest of the public and hence the third criticism. The pioneering work on the economic theory of regulation by Stigler presumes that policy makers maximize their self-interest and could influence the outcome of regulatory processes (Stigler 1971). They therefore lack the incentive to act in public interest as purported under public welfare theory (Peltzman, Levine & Noll 1989). Quiggin in explaining Mills theory of methodological individualism and utilitarianism affirmed the self-interest maximization of policy makers as a corollary to the fact that individuals are the best judges of their own interest (Quiggin 1996; Udehn 2002).

Capture theory refers to the regulation that results from the attempts by the owners of certain industries to maximize their risk-adjusted returns (Zweifel & Eisen 2012). Capture theory is based on the idea that conflicts will always arise in the distribution of the wealth of the state but the resolution of the conflict is only possible if all stakeholders have equal political weight. Since this equality is far from reality, one party will tend to capture the attention of institutions and actors to its own benefit as would be reflected in the budget that shows the disequilibrium in public finance (Lindahl 1919). The theory therefore suggests that since the equality of counterparties to a contract is a mirage, there may never really be an objective solution to social problems. In essence, a real equilibrium may never exist. Whatever agreement the counterparties accept would then be at best the second best option exerted by the party with the dominant influence. A true equilibrium may never exist but the best point could be objectively determined through research. The capture theory is a reflection of entrenched self-interest of a group of powerful individual owners of industries who are capable of overriding policies by influencing those who are supposed to act in public interest. Since the individual consumer may not be having sufficient interest at stake and if so, they are so dispersed that they could hardly be coordinated to exert sufficient interest, these powerful stakeholders have a free rein as they capture policy makers.

The final theory, the market regulation theory attributed to Peltzman, is a mix of the preceding theories but it focuses on a cost-benefit analysis of the issues at stake with preference for the option that creates an electoral advantage to the incumbent (Niskanen 1971; Peltzman, Levine & Noll 1989; Zweifel & Eisen 2012). While the capture theory emphasizes benefits to a niche of stakeholders, the market for regulation theory emphasizes the benefits to the government. A regulation that follows either capture or market regulation theory would always deliver some benefits to the public and determining whether or not a policy is truly in public interest may be a difficult task. Perhaps, the keys to determining the theory path of a regulation is examining its origin, timing, the power formation of stakeholders and the weights of the benefits accruing to the stakeholders.

It is therefore not surprising that there are indications from literature that the Australian policy follows the market regulation theory (Gray & Lawrence 2001; Van der Vegt 2009) but analysis of government documents suggest a public regulatory economics (Malcolm 1985, IAC 1986). Although, the policy direction in Australia focuses on delivering net welfare benefit to the state on an equitable basis it seems that sufficient analysis of what constitutes a net benefit is yet to be adequately researched holistically (IAC 1986; DAFF 2013). Given the discussions above, it is a challenging task to place Australia in one regulatory paradigm or the other.

Quiggin (1996) affirmed the need for rigorous analysis of welfare impacts of reforms and attributed the failure of previous policy reforms to lack of rigorous theoretically consistent economic analysis. An empirical investigation of competing set of alternatives could aid policy formulation. The idea of competing set of alternatives is well articulated in Arrow's impossibility theorem and rational choice theory. In Arrow's impossibility theorem derived from his 1951 thesis and published in his social choice and individual values, it shows that certain conditions need to be imposed in making social choices (Ravindran 2005). First is the condition of unrestricted domain (U) in that all possible combinations of individual preferences must be considered as noted in Quiggin's (1996) welfare theoretic assumptions. Next is Pareto's principle (P), Independence of irrelevant alternatives (I) and finally non-dictatorship (D).

Arrow concluded that there is no collective action that can satisfy all these conditions (U, P, I and D). The difficulty in making collective choices therefore explains why methods of combining individual preferences into a collective social preference could be very difficult and seemingly inconsistent (Ravindran 2005). Arrow's discussion of an almost decisive and a decisive individual reaffirms/reiterates the stance of political economists on policy issues (Fishburn 1970; Van Til 1978; Kelly 1988; Geanakoplos 1996; Grofman 2003). In the context of agro-insurance in Australia, the literature suggests that whatever course of action will be taken in terms of policy direction will require some political economics and care would need to be taken to ensure that the incentives do not distort productivity. Similarly, since the individual preferences differ in terms of agricultural insurance given diversity of exposure and asset combinations, a range of options would have to be provided in such a way that does not impose any preference on individual farmers.

In a related effort, Anderson et al. (2006) highlighted some methodologies for assessing the impact of government policies. The authors further noted that non-agricultural policies have flow on effects on agriculture while agricultural policies also affect the overall economy in some ways. This flow-on effect was noted in (OECD 2011, p. 12).

An efficient and effective policy approach to risk management in agriculture will therefore pay attention to the interactions and trade-offs among different risks, strategies and policies. For instance, an appropriate agro-risk management policy may foster a constructive demographic restructure of Australia in that the population of the country is dense at the coasts. The interactions to be considered are multiple, and include the following considerations: the prices of inputs and outputs can sometimes move in the same direction and thereby reduce their combined impact on net returns; production risks can partially offset price risk; farmers routinely adjust their production activities and financial decisions as part of a normal risk management strategy; government payments, as well as production and price-linked policies, affect the farmer's risk exposure and influence the risk management strategy chosen. These interactions are significant and strongly suggest that the approach to risk management needs to be holistic and not be limited to a single source of risk, nor a single strategy or single policy instrument.

Evaluating policies will therefore have to capture both direct and indirect impact of agricultural policies on the whole economy. Arriving at a solution would therefore require that the mix of options be evaluated empirically both at the sectoral and economy-wide levels. The evaluation is necessary because of the flow-on effects of sector-level policies. Anecdotal evidences will not be sufficient.

Another theory that is relevant in the analysis of the rationale for change in Australian Drought Policy is the Principal Agency Theory. The principal-agency theory is a model of the theory of incentives (Berle & Means 1932; Laffont & Martimort 2009) that analyses the behaviour of the agent given that he aims to serve a different purpose from that of his principal. An agency relationship is said to exist between parties when a party, the agent, is designated to act on behalf of the other, the principal (Ross 1973). It could be said that much of the problems of moral hazard and financial intermediaries in monetary models are examples of agency theory (Arrow 1971; Marschak & Radner 1972; Ross 1973; Laffont 1995). Palfrey in Laffont (1995), recognised agency relationship under his implementation in Bayesian equilibrium in addition to optimal regulation and taxation.

Applying the principal-agency theory in the context of EC, the state is the agent and the Commonwealth of Australia is the principal. The trend in the commonwealth expenditure on EC is prevalent in Australia as Quiggin noted that 'microeconomic reform at the state level in Australia frequently involves the shifting of costs back to the federal government' (Quiggin 1996, p. 36). Part of the problems associated with the EC arose from the fact that the principal cannot efficiently monitor the agent. Moffitt and Bordone (2012) highlighted three differences between an agent and his principal. First is the difference in preferences followed by the difference in the incentives and finally information. The need for adequate information was also emphasized in OECD (2011) along with training and education. Palfrey is of the view that social welfare plans are contingent on information collected from individuals. These individuals may misrepresent their information or conceal them depending on their expectation of the use of the information collected by the planner. Secondly, the expectation of the deception of others may cause individuals to conceal or misrepresent information and finally, the nature of the information required. Given the deception decision of the individuals, the EC may be inadvertently declared more than necessary. The expectation by an agent that other agents are declaring EC may have kept the EC flowing in an unending cycle even when it is not necessary.

Kimura and Antón (2011) in their analysis unveiled the fact that the arrangement for the declaration of EC gives the agent the incentives to declare EC. The incentive arises because the state/territory government who makes the case for EC gets all the credits whereas the bulk of the cost implication rests on the Commonwealth government. Since the needed information for decision making is decentralized, the principal is at a disadvantage. This incentive model partly explains the increase in the declaration of EC in Australia.

Similarly, should individual farmers expect to be assisted by governments in times of natural disasters, they are bound to under value the costs of their decisions (Varangis, Skees & Barnett 2003, p. 9). Consequently, the farmers will socialize their losses while privatizing profits. Such government aids tend to foster sub-optimal choices as farmers act to trigger their expectation of government supports which becomes a part of their production decisions.

Besides the EC supports, Farm Management Deposit (FMD) assists farmers to smoothen the variability in their income over the years through the taxation system (Kimura & Antón 2011; OECD 2011). The FMD is a variant of the Income Equalization Deposit (IED). Inspite of these and other initiatives of the Australian governments, Australia remains the least protected country, besides New Zealand, among the developed countries of the world in terms of agricultural risk management.

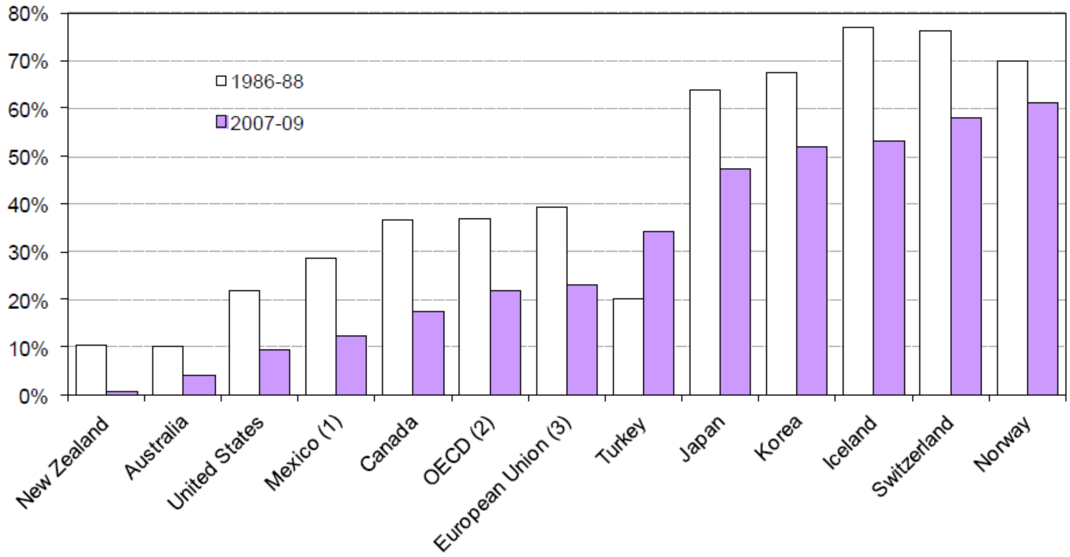


Figure 2-1: Producer support estimate by country as percentage of gross farm receipts.

[Source: OECD (2010, p. 18)].

Farm income stabilization has been the focus of governments in recent years. This form of supports have drawbacks in that they could be counter-productive, can interfere with normal risk management decisions, displace market responses and blur the boundaries between risk layers (OECD 2011). These drawbacks have led to the decision that whatever form of support that will be given to Australian farmers will focus on behavioural changes and reciprocal obligations (DAFF 2013). These changes are not possible without the interaction of structural factors and dispositions of stakeholders to act (Shucksmith 1993). To advance from this current state into the future, Australia will require appropriate technological investment since most decisions that will be required by governments and other stakeholders in Australian agriculture will be underpinned by relevant data.

2.6 The role of technology in agricultural risk management

The role of adequate information in making optimal public policy cannot be dispensed with (Hurwicz 1972). It has been noted that Australia's investment into agricultural system is relatively low (Potard & Keogh 2013). There are however contentions on this issue (Mullen & Cox 1995). It has also been noted that less than 15% of the budgets of global National Meteorological Services (NMS) are recovered from non-government sources. The poor investment notwithstanding, the benefit-cost ratio of 10:1 is immense (WMO 2004). The low investment coupled with poor cost recovery will be a major challenge to contend with in the future if steps are not taken in that the offering of agricultural insurance in whatever form may be hampered.

The cost recovery of NMSs is therefore an issue of concern as governments may have limited budgetary allocations for NMSs. Well-designed cost recovery arrangements that are accountable, transparent and responsive could be an incentive for improved efficiency of NMSs as noted in (Gunasekera 2004, p. 79). The nature of data that would be required for efficient insurance design in the future would definitely require additional meteorological infrastructure and precision which may be beyond the scope of government's budgetary allocation. Cost sharing may be a means of a guaranteed continued support for such services given their economic importance to users.

Recent trend suggests that there will be a consistently growing relationship between the public and private sector in the provision and demand for meteorological services with the private sector taking advantage of the profitability prospects in the relationship (White 2001). Similarly, Pielke and Carbone (2002) were of the view that 'weather research is unlikely to more effectively meet society's needs - or receive greater resources – if the community proceeds in balkanized fashion; integration is an imperative'. The authors in describing this imperative drew a parallel with the symphony orchestra that requires co-ordination. The focus of weather and climate forecasting is therefore on providing information for decision making in a well-organized manner for all stakeholders.

A general decline in government expenditure on science has been noted by Alston, Pardey and Roseboom (1998). More specifically, the authors noted a reduced support for agriculture-related research funding which has coincided with concerns about global food security. They further affirmed that agriculture particularly has a diminishing influence on government policy. Meteorological services are not excluded. Wilks and Wolfe (1998) have attested to the economic value of weather forecasting in agriculture. In their model, optimal use of weather forecasts added as much as \$1000 per hectare per year for lettuce farmers. The results from this model is in congruence with the argument by George et al. (2005) that weather and climate information in an educational forum could facilitate improvements in farm business management.

Dutton (2002) noted that new information will be required to manage profit volatility in weather sensitive industries including agriculture. The author further affirmed that effective farm management decisions will depend on how atmospheric observations, statistics and financial models are integrated. The importance of information system in the design of weather derivatives is further attested to by Varangis, Skees and Barnett (2003) who opined that reliable and verifiable weather measurements are critical to the provision of weather hedges. Nevertheless, they recognized that data could be missing even in the most developed countries. It is therefore not unusual to use the best data available to price weather insurance as it has been done in this thesis. (Data issues are further elaborated in Chapter 3 – Methodology). In addition, they recognized the concern of clients on the possibility of mispricing weather derivatives as a result of the exposure of a location to long-term climate change thereby making historical records less predictive of the future. The effect of future variance in the frequency and intensity of extreme events that is not captured in the historic data may pose a major problem for pricing weather hedges. This explains the use of Monte Carlo simulation in the pricing of weather derivatives (Chantarat 2009).

There are other uses of meteorological services that may further justify this perception. Consequently, there has been argument as to who pays for the services and technologies needed for agro-insurance because of the debates on whether or not they should be treated as public goods (Gunasekera 2004). Some technologies that have been adopted in the provision of agricultural insurance include the satellite, early warning computer models, Doppler Radar Technology and Geographic Information System (Wenner & Arias 2003). This technology is needed in Australia as noted in a recent negotiation by some insurers. These insurers, Global agri-corporate, demanding for some infrastructures like the Doppler Radar Technology in order to get more detailed information on weather before they commence offering their products (Opray 2013).

The lack of adequate data of sufficient resolution is a concern for insuring against adverse weather in agriculture. This data inadequacy leads to concerns about insurability which is discussed along with risk aversion in the next section.

2.7 Risk aversion and insurability

For a risk to be insurable, it must be accidental, determinable and measurable, independent and non-catastrophic but these four conditions are hardly fully satisfied in any line of insurance (Wagner 2007). Weather index insurance is not an exception and the insurance market exists because individuals are risk averse (Wagner 2007). Since the insurer does not bear the risk of the insured without some compensation, the insured would have to pay a premium in excess of anticipated payout since farmers like other investors are risk averse and would therefore be willing to forgo some utility in exchange for relative certainty. The willingness to pay for certainty is a function of risk aversion (Zweifel & Eisen 2012).

Different types of agricultural financial products exist and they could be broadly classified into two namely; traditional indemnity-based insurance and the index-based insurance. The major difference between the two is that the traditional indemnity-based insurance requires proof of individual yield losses whereas index-based insurance pays out on the basis of a proxy for losses. Since the farmer is more aware of his production options than the insurer, there is asymmetric information.

The problem of asymmetric information leads to two inter-related issues that could lead to market failure – moral hazard and adverse selection (Quiggin, Karagiannis & Stanton 1994; Mahul & Stutley 2010; Zweifel & Eisen 2012). The challenges posed by asymmetric information and diversity in demands across locations are also evident in the insurance market in general including automobile, health and housing insurance (Rowel 2011; Liu & Chen 2002). However, researchers as documented in Eisenhauer (2004), differ on the issue of adverse selection across insurance markets in different countries of the world. In particular, Eisenhauer (2004) concluded that results on the willingness to pay for insurance could be ambiguous because of the complex interplay between risk, risk aversion, income and substitution effect. The income may refer to the initial wealth and the existing portfolio of assets of a potential insurance client. These variables account for the mixed results obtained in the analysis of the empirical relevance of adverse selection. Hence, the preferences of farmers interact with these and other variables and it is equally possible that the analysis of their willingness to pay for insurance could be misleading. In the case of weather insurance, the major preference for weather index insurance stems from the fact that losses are not verified and it could therefore contain the challenges associated with asymmetric information. The analyses of the pros and cons of these products are best considered in the context of the concepts of insurability.

The first clause for insurability, accidental clause, requires that the loss experienced by the farmer is not the result of actions that were afore-thought to trigger or aggravate the loss. In the case of weather insurance, accidentalness is not an issue because the insured has no influence over the weather. It should however be noted that weather insurance could create an incentive for both counterparties to the insurance contracts to manipulate weather readings if it is not well secured but we assume the weather stations are well secured (Malcolm 1985; IAC 1986; Mahul & Stutley 2010). The problem of moral hazard in indemnity-based insurance results from the endogeneity of the investment risk whereas investment risk is exogenous to the payout trigger in index-based insurance particularly for weather derivatives (insurance). Hence, it was concluded that the impact of moral hazard is a function of the extent to which the risk could be objectively observed (Belhajy, Bourlesy & Deroian 2011). Moral hazard exists because of the behaviour of the insured in terms of risk taking and effort to prevent excess losses.

This hazard could be ex ante or ex post in that a farmer could deliberately insure with the aim of making production options that will trigger the contract and may also decide not to salvage the crop if the salvage cost outweighs the benefits (Zweifel & Eisen 2012). This hazard is facilitated by the risk perceptions of the farmer and the chances of allocating resources, including those paid as premium, in such a way as to maximize their expected utility (Quiggin, Karagiannis & Stanton 1994). Hence, agents tend to under-invest unless the risk allocation maximizes the total sum of their utilities (Chambers 1989; Belhajy, Bourlesy & Deroian 2011).

Scholars have opined that weather insurance solves the issue of moral hazard but often neglect the paradox that the product is probably suffering from poor uptake because of the same problem it is purported to resolve. Not all losses would have required indemnification if insurance does not exist at all. In essence, the existence of insurance actually triggers some losses that would not have been experienced. Several indemnifications could have been salvaged if the insured was not insured. This explains why insured farmers were found to have lower yield than their uninsured counterparts (Quiggin, Karagiannis & Stanton 1994; Just, Calvin & Quiggin 1999). This explanation buttresses the perception of moral hazard as hidden action (Arrow 1971). Therefore, the poor performance of yield-based MPCI is inherent in the design of the product. Index-Based Risk Transfer Products (IBRTP) tends to cater to this problem in that it does not allow moral hazard. This means that it gives no room to farmers to use it as one of the input to their optimal decisions in a way that allows them to shift other inputs to the disadvantage of the insurer. Although, IBRTP if purchased could be considered as a financial input, it is an inflexible constraint to the farmer. This inflexibility is the bane of the poor uptake of the product.

Monitoring and exposure of the insured to part of the risk are two sets of mechanisms developed to contain moral hazard but these do not work perfectly well (Wagner 2007). Deductibles are also among the possible options available to the insurer to expose the insured to a part of the risk. It was however found that an optimal deductible is not necessarily a high deductible as lower deductibles may result in appropriate actions than otherwise (Chambers 1989). In the case of multiple peril crop insurance, Quiggin, Karagiannis and Stanton (1993) have found that even a deductible of 35% will not make the insurance feasible because the payouts from such a scheme may not cover the variable costs of the farmer. A preventive mechanism for moral hazard is to offer multi-year insurance contract (Chambers 1989). This will prevent inter-temporal adverse selection that results from the ability of the insured to forecast weather events close to the season.

In essence, a typical farmer is a morally hazardous risk averter and considers insurance as a financial option that could be exercised when production decisions are being made. Should production outlook be unfavourable, the holder of the Option exercises the right by cutting back on input after considering that the cost-benefit analysis of additional input may be unprofitable. Since this Option is not valuable in the case of weather insurance, the willingness of farmers to pay for it could diminish. This behaviour of farmers explains why weather derivatives could be used to complement other forms of insurance that farmers take for a more complete hedging of weather risks (Khan, Rennie & Charlebois 2013).

Determinability and measurability of risk is another ground on which both types of insurance could be compared. Applying this concept in the case of weather insurance, it is easier to measure and determine the proxy on which index-based insurance are paid out but the extent to which the measurements align with losses could be difficult to assess because of basis risk and the complexity of interactions between the proxy and yield (Vedenov & Barnett 2004). In contrast, it may be difficult but possible to measure and determine actual losses for indemnity-based insurance, but it could be very costly. The measurability and determinability clause of insurability is therefore a challenge for both types insurance. Independence of risk as a requirement for insurance does not hold for both types of insurance because of the interconnectedness between meteorological drought and agricultural droughts. The occurrence of the risk is cumulative and because many locations are affected at once it is also systemic. Besides independence of risk, both insurance could be of catastrophic magnitude.

The argument by Wagner (2007) that some erstwhile uninsurable risks have become insurable suggests that inspite of the current insurability challenges to weather index-insurance; it could become a profitable venture in the future. However, basis risk reduces the cost benefit anticipated from its adoption because it would have to be localized (Vedenov & Barnett 2004; Turvey & Mclaurin 2012). Basis risk could be geographic or structural. Geographic basis risk results from the gap between the station where the weather readings are made and the farm land with insured crops. Structural basis risk refers to creating weather index insurance that is not suited for the particular crop or location.

There is an increase interest in weather insurance because yield-based MPCI is unviable across the world, even when premiums are subsidised (IAC 1986; Kimura & Antón 2011), because farmers who are more likely to exercise their options would be the ones to pay the premium to do so through the purchase of insurance. This behaviour of farmers could be gleaned from the conclusion by Quiggin, Karagiannis and Stanton (1993) that farmers' production and insurance decisions are responsive to economic incentives, and that these incentives work in a way which undermines the viability of MPCI. Coble et al. (1996) revealed that market expectations in terms of returns and return to insurance significantly affect the demand for insurance.

The moral hazard therefore leads to adverse selection in insurance (Ahsan, Ali & Kurian 1982; Just, Calvin & Quiggin 1999). However, the case of revenue insurance may be different because farmers are ‘price-takers’ on world markets and have limited opportunities to influence prices. This price taking is particularly so for Australian farmers whose commodity price taken largely depends on the production and consumption in other countries (Chisholm 1992).

Since the trade of insurance is supposed to divide among a great many that loss which could ruin an individual (Adams Smith in Zweifel & Eisen 2012, p.v), adverse selection makes this impossible. Attempts to curtail adverse selection through compulsory insurance could cause cross-subsidization of high risk farmers by low risk farmers which could be socially sub-optimal because it does not lead to a Pareto-optimal state. Pricing in such a way to discriminate farmers by their risk profile may therefore be essential.

If the analysis of Randall (1983) is applied in the context of agricultural insurance, one can say that a price high enough to cover the cost of providing insurance would exclude some farmers. The exclusion further increases the cost of participants in the insurance pool. These excluded farmers incidentally would be the ones who need it the most because they may not be able to achieve the same diversification and economy of scale that the included farmers could. The exclusion leads to the production of an inefficient quantity of the product. On the other hand, there could be a public provision of an efficient quantity of the product *‘but financing procedures permitting this outcome would necessarily violate the pricing conditions for Pareto-efficiency’* (Randall 1983, p. 135).

In the absence of competitive equilibrium and pareto-efficiency, non-market options to resource allocations are often adopted in the form of government expenditure programmes, credit, price stabilization programmes, taxes, and subsidies (Arrow 1969; Stiglitz 1987). This absence has been the justification for government’s interventionary role in agricultural insurance (Stiglitz 1987; Cary 1993; Besley 1994; Alston, Pardey & Roseboom 1998; Bohman et al. 1999).

The absence of competitive equilibrium is obvious in Quiggin (1996) who is of the view that although most economists favour market processes but intervention may be justified for the following reasons; natural monopoly, externalities, market power, adjustment costs, coordination failure and income distributional issues. Attempt to resolve these inefficient quantity and pricing leads to the provision of efficient quantity at a discriminatory price as suggested by Samuelson and Lindahl in consonance with the view of Randall (1983) (Lindahl 1919; Samuelson 1954).

This attempt was also noted in the work of Arrow (1969, p. 2); “Given the existence of Pareto inefficiency in a free market equilibrium, there is a pressure in the market to overcome it by some sort of departure from the free market; i.e., some form of collective action. This need not be undertaken by the Government”. Although, Arrow suggests that there could be collective action without the government, it should be noted that the government would, at least, have some indirect roles to play in providing the necessary technological and regulatory infrastructures for the operations of the market. Although, these scholars did not necessarily focus on the market in the context of insurance, their theoretical abstractions and models are relevant to the context of agricultural insurance in Australia today.

Lindahl's model suggests a different price (Lindahl-price) for each individual and the exclusion of non-payers and individuals who are not paying for their own risk profile in the insurance pool irrespective of whether or not the insurance is provided by the government (public) or private sector. This model is logical because individuals behave in a strategic manner and would make choices that will maximize their self-interest given their unique combination of parameters and available options (Walker 1981). The differences in the utility of individuals in an heterogeneous society was also affirmed in the work of Majone (1993, p. 168); *"...regional redistribution tends to be inefficient because of the difficulty of targeting for redistribution communities containing a mix of rich and poor people. If our concern is with inequalities among individuals, redistribution should be aimed at individuals, not regions".*

In a similar welfare theoretic framework, Quiggin (1996) emphasized consequentialism, individualism and the domain of concern. Consequentialism emphasizes outcomes at the expense of the means by which the outcomes are achieved. Individualism suggests that individuals rather than the communities or nations are the appropriate objects of concern and that each individual is the best judge of their own welfare (Quiggin 1996, p. 37). Individualism explains the difficulty in realizing a consensus on drought policy even among farmers and their representative groups as noted by Gray and Lawrence (2001). In explaining the domain of concern, Quiggin assumed that only members of a prescribed set of individuals are the objects of a policy. The individuals within this domain are in the best position to judge their own welfare irrespective of the methods adopted. Therefore, these individuals will tend to be diverse in their utility or response to different policies or available options to aid their welfare leading to disparity in the valuation of these options. Quiggin's individualism therefore suggests that differences in individual characteristic will lead to farmers taking different prices for the same products.

The individual pricing affirmed by Majone (1993) underlies the pricing mechanisms of recent insurance products as adopted by CelsiusPro and Latevo offering weather derivatives and revenue insurance respectively (CelsiusPro 2013; Grieve 2013). Available information from these budding insurers is however insufficient for analysis. Section 2.3 has some details on these products. However, it is evident that revenue insurance captures the covariance in the price and yield relationship which available information suggests is yet to be impounded into the pricing of weather derivatives. An analysis of the effect of this covariance is a significant gap in previous studies. Nevertheless, both products have their limitations and advantages in terms of structural, functional and legal requisitions for them to be effective hedging mechanisms. Similarly, there efforts aimed at improving pricing of insurance contracts. The theories behind the improvements discussed along with the principles of insurability and risk aversion are further emphasized below.

2.8 Implications of pricing models for agro-insurance

Previous models of agricultural insurance have not adopted the efficient actuarial assessment of farmers' risk using the Lindahl-price. That is, individualism has not been appropriately catered to in previous modelling of insurance. For example, the EC benefits came at no cost to the farmers and previous Multi-Peril Crop Insurance did not sufficiently discriminate between farms. The nonexistence of certain risk markets in Australia may point to the fact that they are inefficient. The absence of these markets, as noted by Arrow (1969), are indicative of market failure which is caused by the inability of service providers to exclude certain individuals and lack of necessary information to permit appropriate transactions. The two causes are actually not mutually exclusive in that lack of information leads to inability to exclude. Should the market be able to provide adequate information, then exclusion will be possible and at least the society moves closer to the pareto-optimal equilibrium. The current state of agro-insurance in Australia is not unusual in a free market economy because the chaos of conflicting interests will eventually lead to 'the best of all possible worlds' (Borch 1967).

Apart from spatial adverse selection, inter-temporal adverse selection is possible with weather derivatives (insurance). If farmers are able to predict the weather, adverse selection could still be possible with weather index insurance in that farmers would only insure in years when they are at risk thereby limiting the prospects of diversification. The work of Coble et al. (1996) however concluded that their analysis did not support temporal adverse selection for Kansas wheat growers with an estimate of -0.65 price elasticity of insurance demand.

Also, some locations could be at risk of droughts than the others (IAC 1986). The implication is that farmers who are farming in locations at risk of drought will take drought insurance thereby creating a risky portfolio of insurance contracts (APRA 2012). A development in Australian agriculture is to shift from more susceptible areas to drought to areas that are less affected (Gray & Lawrence 2001). This shift is a method of risk management and may have implications for risk diversification. The adverse selection resulting from this geographical diversity could be aggravated if the pricing of the contracts does not reflect the relative susceptibility of these locations to drought. In the context of Australia, yield risk is widespread but to a variable extent across locations.

As an example, it has been found that yield risk is related to income in the drier zones (Malcolm 1985). More specifically, the correlation between yield and income was lower in wetter regions and higher in drier regions but the relationship may not necessarily translate to demand for weather hedging because farmers are more interested in the timing and distribution of the rainfall (IAC 1986). It should be expected that if insurance is voluntary, those from wetter regions will tend not to participate thereby loading the scheme with higher risk clients. The findings of Chantarat (2009) reflected the disparity in the hedging efficiency of index insurance across locations while that of Kapphan (2012) reflected disparity efficiency among different indices. It is worth noting at this juncture that the yield-index relationship is highly variable and when the relationship is strong in a location it does not necessarily lead to high hedging efficiency (Vedenov & Barnett 2004; Turvey & Mclaurin 2012; Adeyinka et al. 2013).

Hence, if location A is at higher risk than B, then the pricing should reflect this relative risk. Most analyses of the prospects of weather insurance focus on a relatively small expanse of farm lands thereby limiting their generalizability (Turvey & Mclaurin 2012). A consideration of weather insurance on the basis of only such locations could overstate the usefulness of weather insurance because the results may not be generalizable and such analysis does not consider the offering in a portfolio of other assets and do generally make the most favourable assumptions (Turvey & Baker 1990; Vedenov & Barnett 2004; Turvey & Mclaurin 2012).

The appropriate measure of risk of an asset's riskiness is its contribution to the riskiness of the investor's existing portfolio rather than its isolated riskiness (Doherty & Schlesinger 1983). Turvey and Baker (1990) noted that evaluating farmers' use of hedging instruments without a consideration of their capital structures, participation in government programs, transaction costs, whole farm diversification, timing of cash flows, basis risk and the dependence structure between yield and anticipated price of outputs could be misleading. The implication is that the loss ratio analysis or semi-variance measures for a particular product may be the same when measured in isolation but will differ when considered in a portfolio of other existing products or production possibilities for different insurers and farmers.

However, such data resolution that could permit such analysis is not available, hence a caveat for users of the analyses presented in this and other similar studies (Chantarat 2009; Turvey & Baker 1990; Binswanger-Mkhize, 2012). The offering of CelsiusPro would be an example in view because it caters to the needs of other sectors beside agriculture and modelling based on agriculture alone underestimates the effect of diversification. This implies that, the diversification modelled could actually be improved in reality since the insurer would underwrite other contracts that could aid its prospects in the market.

This prospect of diversification is a major advantage of weather insurance over revenue-based insurance. The modelling of such risk exposure may not sufficiently capture the risk except when measured by the hedge provider. On the side of the insured, the initial wealth levels of individuals would go a long way in rationally determining the optimal insurance to take in terms of type and quantity. A farmer with one unit acreage in a wet region and the same unit acreage in a dry region may have hedged the risk of drought with the output from the wet region whereas a farmer producing on one unit acreage only on the dry land may not have the same hedge and has a lower wealth level all other things being equal. Insurance will be worth less to the richer diversified farmer than the other given the production options available to them while a more diversified insurer will possibly find a new line of products like weather insurance as a means of reducing their portfolio risk even if it does not have any direct net monetary benefit. That is, an insurer may simply offer the product at a break-even cost but uses the proceeds to enhance its liquidity. Therefore, the utility of insurance to the counterparties to an insurance contract are best analysed by the parties themselves. As the existing portfolio changes, the initial optimal insurance changes. This change underscores the discussion on the aversion of farmers to risk with regards to wealth levels.

Studies on the efficiency of weather index insurance tend to assume that farmers exhibit Constant Relative Risk Aversion (CRRA), that is risk aversion is the same across wealth continuum (Chantarat 2009; Kapphan 2012). Zweifel (2012) in the analysis of wealth levels on risk perception and management has shown that the CRRA conceals differences across wealth levels. At lower wealth levels, individuals exhibit Increasing Relative Risk Aversion (IRRA) whereas at the higher wealth levels they exhibit Decreasing Relative Risk Aversion (DRRA). Zweifel (2012) affirmed that wealthier farmers in the lower wealth echelon would spend a larger chunk of their resources to protect their wealth (IRRA) while the richer farmers at the higher wealth level devoted a lower proportion of their assets to protecting them (DRRA). The diverse nature of risk aversion explains why Carter (1996, p. 194) posited that identical risk exposure stimulates different behaviours which depends on the endowments of farmers.

Rosenzweig and Binswanger (1992) in a related study revealed that;

"... average wealth losses for wealthier farmers are smaller than for less wealthy farmers in rainfall-variable environments and differentials in rates of profit per unit of productive wealth by wealth class shrinks as rainfall variability increases".

This wealth variance between the wealthier and the less wealthy farmers could impinge on risk aversion and willingness of farmers to pay for weather insurance. Differences in the performance of Index Based Livestock Insurance (IBLI) at different wealth thresholds were similarly observed by Chantarat (2009). It was noted in the study that IBLI is not well suited for the poorest but is appropriate for farmers around the critical herd threshold with larger herd sizes. It was noted in the report that willingness to pay among the poorest pastoralists responds to premium loading meaning that the cost of the insurance is the bane of the uptake among the poorest for whom it is most beneficial to. The lack of suitability may therefore emerge from the cost-benefit analysis of the insurance to poor farmers. The initial wealth and cost of insurance may therefore interact with the risk aversion of the insured in a way that may be prohibitive to the uptake of the product.

It however seems that should wealth demographics be captured in the analysis of weather insurance, those who need the insurance the most will be discriminated in that it will become cheaper for the rich farmers who need it the least and more expensive for the poor who need it the most. Consequently, targeted subsidization of the insurance was suggested based on initial wealth as proxied by herd size. Another main finding of Chantarat (2009) was that district-level aggregation of contract is characterised by low demand for a commercially viable contract.

A major issue to note is that, the value of insurance could increase because of the ability of the farmer to acquire credit at a cheaper price. This prospect is ignored also by Chantarat (2009, p. 167) and she affirmed the inverse relationship between risk preference and wealth; "In our model, IBLI is not well suited for the poorest who already slowly collapse towards destitution over time, as the premium payment tends to further speed up such herd de-cumulation during good seasons" p.167.

Other important findings from Chantarat (2009) are that there are spatial differences in the performance of IBLI, in essence, contracts are more efficient in some locations than the others. Also, household specific factors were found to determine the overall performance of IBLI. Such household specific factors are not within the reach of the researcher in this thesis. In the work of Chantarat (2009) 10% strike contract with the highest coverage of covariate risk out-performs others for each household and location, and is there chosen for the optimal contract. This conclusion affirms the need to benchmark drought at different levels for analysis and a possible interaction between efficiency and such benchmarks as will be noted in the 5th chapter of this thesis. The 10% strike contract translates into a once in ten-year contract.

Disaggregation and appropriate risk benchmarking may be required to make the contract more viable. Further “willingness to pay among the most vulnerable pastoralists is very sensitive to premium loadings and lower than commercially viable rates, on average, despite its potentially high dynamic value” (Chantarat 2009 p. 168). This quote suggests that the insurance is beneficial to these farmers but not affordable. Inequity may arise if subsidy is targeted in such a way that benefits the poorer farmers. The district-level aggregated demand is shown to be high price elastic with evidence of potentially low demand for commercially viable contract meaning that disaggregated contracts may be more viable. Since the existing weather product offered by CelsiusPro attends to this disaggregation, the reality may be more favourable than what has been modelled in this study. By implication, all other things being equal the current reality with weather hedging for Australian farmers may be more favourable in efficiency terms than modelled here because CelsiusPro disaggregates farmers by their specific farms. Further, flood is captured in the offering by CelsiusPro. This product therefore remains a useful innovative tool if well managed.

Scholars have attested to the possible usefulness of weather derivatives (insurance) for agricultural endeavours (Chantarat et al. 2012; Kapphan, Calanca & Holzkaemper 2012) but some are currently issuing caveats in order not to overstate its usefulness (Vedenov & Barnett 2004; Binswanger-Mkhize, 2012; Turvey & Mclaurin 2012). In essence, weather insurance/derivative for agricultural uses may not be worthless but could be worth less than the hype.

Reduction of basis risk, increasing awareness level of farmers and other suggestions for improvement therefore cannot improve the chances of these poor farmers except that their credit worth may increase because of insurance. They would therefore be in need of some forms of welfare supports in times of extreme weather events or associated perils. Binswanger (2012) therefore argues for improvement of safety nets for farmers rather than a focus on weather-based insurance. However, Moreteau (2008) affirmed the need for individual and collective action because ad hoc and ex post solutions are not efficient in managing risk because of the distortions they create. Nevertheless, the principle of the second best by Lipsey and Lancaster (1956) suggests that removal of one distortion does not necessarily lead to gains in efficiency.

In this section, the idea behind current developments in insurance pricing was discussed. The implications of the natural hedge which also affects the price farmers may be willing to pay for insurance is the focus of the next section of this review. The discussion on this natural hedge is pertinent to the pricing of insurance contract because it is an important part of insurance pricing that has been largely ignored in the analysis of hedging efficiency of insurance contracts.

2.9 The effect of commodity prices on hedging efficiency

Another limitation in the analysis of weather index insurance is the assumption that price is constant over the period under considerations (Chantarat 2009; Kapphan 2012; Pelka & Musshoff 2013). The assumption implicitly suggests that the cost of price stabilization is free. This assumption also ignores the covariance structure between farm output and price. This relationship favours broadacre farmers but not the livestock farmers as noted in Section 2.2 above.

Given the implications of this assumption, one could conclude that the utility of weather index insurance would in reality be less than anticipated because of the inverse relationship between yield and commodity prices. Consequently, there will be a reduction in the willingness of farmers to pay stemming from the fact that in reality, the cost of price stabilization will reduce the Certainty Equivalence of Revenue (CER) of the farmers because of the expectations of a price increase in times of shortfalls in productions. This analysis suggests that an insurance model that captures price variability will probably be preferred by farmers. Therefore, a revenue insurance will possibly deliver better value to both counterparties to the contract in that price may compensate for yield shortfall and the probability distributions of the revenue changes in such a way that creates mutual value for the counterparties. However, should the pricing of weather insurance recognize the price variance, its uptake may be enhanced.

The nature of price-yield relationship serves to be a natural hedge for grain farmers but aggravates the losses of livestock farmers in that the yield-price relationship is inverse but the cost of fodder rises as prices taken by livestock farmers drops (ABS 2012). The study by Finger (2012), focused on revenue insurance, affirmed that price-yield relationship is of paramount importance in the design of insurance contracts as it affects demands. In addition the author noted that larger farms will tend to have a stronger natural hedge than smaller farms and the heterogeneity of the relationship among farms and crop types affect policy measures targeted at assisting farmers in managing their risks. However, models capturing the effect of farm sizes on hedging are yet to be considered according to the author. The author cited Coble et al (2007) for the case of the USA where price-yield correlation for maize is on average -0.064 at farm level and -0.381 at aggregate level. A major gap in the analysis of agricultural insurance particularly yield-based MPCI and weather insurance is this price-yield relationship which is covered in this work through a comparison of constant and variable pricing of wheat after adjusting for inflation.

In the results from the study by Finger (2012), it was found that the fair insurance premium estimated for maize when the relationship was left out was 192.18 CHF ha^{-1} y^{-1} but when the relationship was considered it reduced to 134.54 CHF ha^{-1} y^{-1} because of the correlation between price and yield at an aggregate level. When the resolution of the relationship increased to farm level, the premium was 154.67 CHF ha^{-1} y^{-1}. This shows that the effect of the natural hedge could also be overestimated if aggregate data is used. Furthermore, it was noted that a unit increase in acreage resulted in an inverse relationship by as much as -0.08 for barley. This result suggests another paradox that subsistent, small-scale, household farmers who would possibly need the natural hedge the most do not have it whereas those who could afford to pay insurance premium are the least prone to risk.

The effect of farm size on risk management and technology adoption are well recognized in literature (Feder 1980; Just & Zilberman 1983). Just and Zilberman noted that there are no consistent patterns in the relationship between land size and technology adoption and that production under new and traditional technologies is risky and the existing portfolio of the farmer goes a long way in determining the decision to insure. Pricing insurance effectively is therefore a difficult task in that there is a limit to the information available to the insurer on which to price the contracts and different individuals will have different levels of risk aversion. However, larger farms are swifter at adopting new technology because of the costs associated with the initial fixed investment. Labour charges and market identification and hence the relationship between farm size and technology adoption but the farmers must be able to expect relative advantage with the adoption (Rogers 2004; Pannell et al. 2008; Feder & Umali 1993).

It has been noted that the effect of such adoption could be an additional source of variability which could actually impact on the demand for insurance by these larger companies particularly in a country like Australia where labour charges are known to be high (Feder 1980; Anderson et al. 2009). Feder (1980, p. 265) further asserted that an increase in the scale of production (farm size) will increase the expected value of yield while also increasing its variability. The initial endowment of wealth may however temper this riskiness effect if they are unrelated to agricultural risk. Hence, it is not just about the nominal value of wealth that the farmers hold but its relationship with the agricultural asset held.

The decision to insure therefore depends on whether the positive effects of large farm size outweigh the negatives. Also, the decision may differ from farm to farm depending on the initial endowment of wealth and diversification prospects available to the farmer as noted by researchers who affirmed that the decision to hedge may be influenced by pre-existing assets held by the farmer (Deane & Malcolm 2006; Lence 1996). Hence, the decision to insure depends on a holistic analysis of the farm assets and their productivity. A uniform assumption about the risk aversion of farmers may therefore be a major limitation of analysis of the impact of insurance on farmers' revenue as different farmers will have different optimums given their diversity of productive assets and risk exposures.

Since more land acreage generally translates to more wealth, this paradox lends credence to the Decreasing Relative Risk Aversion (DRRA) particularly in the context of an agricultural investor in that it explains why farmers in the higher wealth echelon may have additional incentives not to insure their wealth. The assumption of a DRRA is however beyond the scope of this study. Since farm level data are rarely available for sufficiently long period of time, Finger (2012) suggests a simple adjustment procedure which could lead to improved insurance design. The researcher is however of the view that this adjustment may lead to cheaper insurance for wealthier farmers, who already have economy of scale and diversification possibilities in their favour, thereby giving room for the large multinational farms to acquire more household farms. Nevertheless, Finger (2012) shows that the willingness of insurers to deliver agricultural insurance products may be greatly enhanced if the price-yield relationship and farm acreage are factored into the pricing model. It has been shown that this relationship is very prominent in Australian agriculture particularly at the aggregate level but the trend may be different in other countries (Kimura & Antón 2011). The diversity and extent of this relationship and the unique response of producers explains why one cap may not fit all when it comes to agro-insurance (Vedenov & Barnett 2004; Turvey & Mclaurin 2012).

Other scholars have emphasized the role of risk aversion on the willingness to pay for derivatives to hedge farm revenues in Australia (Simons & Rambaldi 1997; Simmons 2002). Simmons (2002) in particular noted that hedging price is low among Australian broad acre farmers and concluded that under the assumption of an efficient commodity futures market, farmers would tend to speculate rather than hedge. To this effect, government policies should discourage the propensity to speculate rather than hedge. Since derivatives do not require insurable interests, insurance could be supported rather than derivatives. This is necessary to deter farmers from becoming gamblers and gamblers from becoming farmers. The behaviour of farmers as it relates to this possibility is considered in Chapter 7.

The figure below shows that the findings of Finger (2012) are also true in the case of Australia but previous models are yet to capture this natural hedge (Vedenov & Barnett 2004; Chantarat et al. 2012; Kapphan 2012; Kapphan, Calanca & Holzkaemper 2012). Consequently, the willingness to pay may be higher in reality if farm level data are used in the analysis.

Since farm level data are not available, shire-wide data were used in this study. The difficulties in acquiring farm-level data over a sufficient period of time have been attested to in previous similar studies (Quiggin, Karagiannis & Stanton 1993; Kimura & Le Thi 2011). Kimura and Le Thi (2011) affirmed that data analysis based on aggregated data could under-estimate farm-level production risk.

Similarly, the inverse relationship between yield and commodity prices for wheat and other broad acre crops has been well documented (Kimura & Le Thi 2001; Kimura & Anton 2011). However, it is evident that while the relationship between yield and price is negative for broad acre farming the converse is the case for livestock production (Kimura & Anton 2011). Therefore, the impacts of the relationships on insurance may differ, but some similarities and differences are expected. Given the nature of these relationships, Australian farmers tend to diversify between crop production and livestock production (Kimura & Anton 2011; Kimura & Le Thi 2011). However, in addition to the diversification prospects that livestock production offers, there are other incentives for Australian farmers to practice mixed production (USEPA 2013; Keogh & Potard 2014).

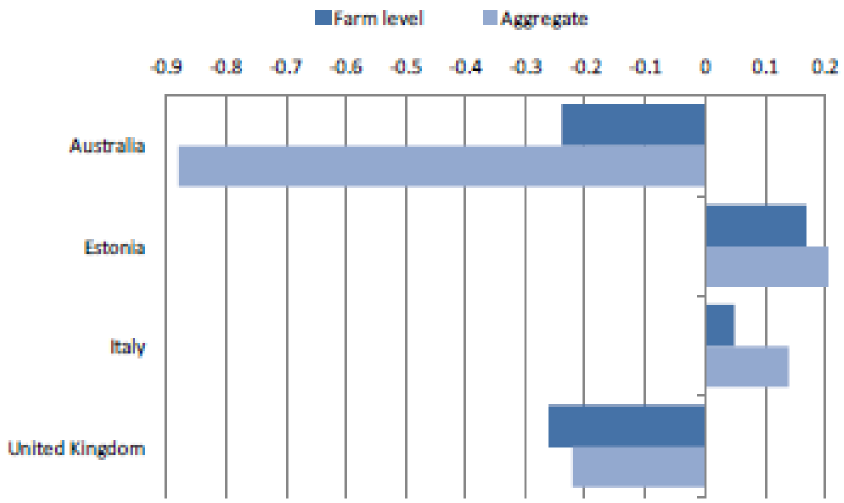


Figure 2-2: Correlation of wheat price and yield: Australia and other countries

[Source: Kimura and Antón (2011, p. 13)].

Table 2.1: Correlation of per hectare revenue

	Wheat	Barley	Oilseeds	Crop production	Livestock production
Wheat	1	0.28	0.15	0.86	-0.05
Barley		1	0.37	0.67	-0.01
Oilseeds			1	0.61	-0.02
Crop production				1	-0.05
Livestock production					1

(Source: Kimura and Anton 2011, p. 18)

These challenges notwithstanding, agricultural insurance can help farmers invest in more profitable but sometimes riskier activities to the benefit of the state (Mahul & Stutley 2010). Beside the objective benefit of insurance in terms of payouts in the occurrence of fortuitous events, the subjective confidence derived from its existence deserves a consideration (Kimball 1960). This subjective confidence is in contrast to the idea that some losses in the presence of insurance may not have been experienced should there be no product to hedge the risk. That is, production factors would not have been shifted in favour of ventures that have no means of insurance coverage or at least the extent could have been minimized. A full consideration of what constitutes net benefit of insurance should weigh-in these subjective benefits.

It is also worth noting that while this literature has focused on weather index insurance, it does not attempt to suggest that it is a substitute for crop insurance (Skees 2008). Similarly, the focus of weather index – based insurance has been in low income countries because they do not seem to have a sufficient safety net like the western countries. However, there are lessons for more developed countries in managing extreme drought risk as suggested by Skees (2008) from these developing countries.

Since the insurance market operates like the capital market in that it enhances the production capacity of farmers, it is better than non-market alternatives to managing farmers' risk exposures (Quiggin & Chambers 2004; Mahul & Stutley 2010; Zweifel & Eisen 2012). A concern may be that shareholders of insurance companies will demand a return which makes it a more expensive option but this additional cost may be compared with the benefit of lower cost of capital and the attainment of the tenets of mutual obligation, self-reliance and reciprocity intended by the government of Australia.

In an attempt to combine collective actions with individual responsibility, governments in Australia have formed different teams that have looked into the future directions for managing agricultural risks in Australia as would have been noted in the literature reviewed so far. However, whatever policy direction will be taken will require additional legal and regulatory framework to govern the operations of the necessary institutions to facilitate response.

2.10 Legal and regulatory treatment of weather derivatives and insurance

Stern and Dawkins (2005) have affirmed the need for an appropriate legal structure to facilitate the offering of weather hedges. More so, given that an insurance company is financed by its policy holders unlike an average firm that is financed by its shareholders, it requires more stringent legal and regulatory conditions (Zweifel & Eisen 2012) which has huge implications for its solvency (Quirin & Waters 1975). Insurers are concerned about the challenges of changes in legal norms governing their conducts. These legal norms are crucial to Australian state governments because insurance taxes are a growing source of revenue for Australian state governments. The revenue from insurance taxes grew from $2 billion in 1998-1999 to $4.3 billion in 2007-2008 making a 112% increase in comparison to 46% from other state taxes over the same period of time (CoA 2010). The taxes may hike the cost of weather hedges as weather insurance than derivatives more so that insurance taxes in Australia particularly New South Wales and Victoria are among the highest in the world.

The Commonwealth report concluded that insurance taxes are regressive. The passing through of taxes from the insurers to the farmers could explain the relatively low investment of farmers in insurance (IAC 1986). The effect of this is that low-income earners tend to be uninsured even when they are the ones who need it the most. Also, insurance may return farmers who could have been unprofitable to profitability and on the basis of income earned may not be eligible for assistance. The tendency to be short changed in the scramble for government assistance will be an incentive for farmers not to insure particularly because they are levied to contribute to government coffers through insurance. Consequently, the burden of under-insurance rests on the government. Recommendation 79 in the report that insurance taxes should be abolished would further make weather hedging in the form of insurance more affordable to Australian farmers. On the other hand, trading in options delivers tax benefits (Broughan & Noble 2009). This may have implications for the form that weather hedging will take in Australia because weather insurance and derivatives may be structurally and functionally equivalent; they are legally distinct from one another.

Weather hedges could be sold as derivatives or insurance and they have certain similarities and differences (Raspe 2002; Skees & Collier 2012). In terms of similarities, weather insurance and derivatives require the forfeiture of a premium to be entitled to receive payouts should a contingent event occur. There are regulatory, tax and accounting standard differences between the two products as noted by (Raspe 2002). The insurance market is highly regulated while derivatives are excluded from too much regulatory scrutiny as long as it conforms to certain conditions (Raspe 2002). This regulatory and tax advantages may be an incentive for weather hedges to remain as derivatives.

In Kelly and Ball (1991), insurance contract was defined in the context of Australia and it was noted that three essential requirements are needed for a contract to be an insurance contract. The first is premium and benefit, the second being uncertainty of the event and finally an interest besides that created by the insurance contract itself. The premium paid obligates the insurer to confer value on the insured should the fortuitous event occur as noted in Raspe (2002). Kelly and Ball (1991) argued that these three requirements are also present in other contracts like warranties and acknowledged the difficulties involved in defining insurance contract. Kimball-Stanley (2008) identified two basic theories in articulating the difference between insurance contracts and other contracts; they are legal interest test and the factual expectancy test. Kelly and Ball (1991) recommended an approach that focuses on the intention of the parties as being helpful. In particular, the intention of the assured who has more information peculiar to the risk, to transfer possible losses to the insurer confers on him (the assured) a duty of care in the form of disclosure of necessary information. The duty of care by both parties in the risk assessment remains a major distinguishing factor between insurance and other contracts.

Unfortunately, research suggests that this duty of care is hardly adhered to. Translating this definition into the context of weather hedging, it could be said that since meteorological information is publicly available, there is no private information to disclose by the assured and both parties have limited opportunities to engage in malpractices. It seems that the function of weather index insurance may not be different from weather derivatives but they require a well-articulated legal distinction to prevent abuse of the classification and regulatory frameworks guiding derivatives and insurance. Some authors (Chantarat 2009; Kapphan 2012) in their reports interchangeably used insurance and derivatives because of the functional convergence between the two products.

The possible mismatch in the payout and yield loss suggests that weather index insurance may not completely satisfy the conditions of insurance like the traditional indemnity-based insurance. Hence, in defining what constitutes insurance, there is need to differentiate between indemnity-based insurance and index-based insurance. Vortex (2012) effectively summarized the differences between weather derivatives and insurance on the grounds of accounting treatment, liquidity, flexibility and regulatory control. Among the regulatory standards in place in other countries is that employees of meteorological stations used in the weather hedge trades are not allowed to take any position in the weather market (Stern & Dawkins 2005). Other areas that demand legal specification are; quality control of weather data, changes in the characteristics of the observation sites and the security of the collected data.

Also insurance or derivatives may be purchased as a speculative instrument rather than a hedging instrument particularly if there is subsidy attached to risk management (Pannell et al. 2008). Consequently, more gamblers may actually turn to farmers in that the government will bear the downside risk of their behaviour. Similarly, it may also be possible to turn some farmers into gamblers. A way of preventing this is to ensure that such subsidies are only paid on hedges taken with insurable interest. Hence, the weather hedge may retain its structural and functional form but may metamorphose into insurance for the purpose of enhancing policy implementation.

The current state of the insurance market also requires a consideration of other laws. For example, one may anticipate that if an insurer successfully offers a form of insurance, there will be other investors who will be interested in becoming new entrants. This leads to consideration of patent rights and anti-competition laws. There are concerns that access to farmers' data could lead to a breach of Section 47 of Consumer and Competition Act 2010 as it relates to marketing of farm produce (MPCIC 2014). The concerns are related to the offering of revenue insurance that requires some forms of information that may need to be regulated to avoid exclusive dealings or third line forcing. Should these legal and regulatory issues be appropriately resolved, it should be expected that insurance will be a long-term strategy to curtailing unhealthy growth in farm debt.

2.11 Debt structure and farm equity in Australian agriculture

Corporate debt comes at a price that is dependent on the rate of return on the risk free debt, agreements on the debt and the probability of default of the borrower (Martin, Barnett & Coble 2001; Bhojraj & Sengupta 2003). The firm's specific determinant of cost of debt is the default risk (Bhojraj & Sengupta 2003). This risk is related to the lender's credit risk and so has implications for the entire financial system within the financial jurisdiction. The extent to which a borrower is likely to default may not only determine whether or not he will get the required loan but may impinge on the rate at which the loan is advanced (Morgan & Ashcraft 2003).

Since endogenous current and future liquidity has implications in trade (Diamond & Verrecchia 1991), the lender penalizes the borrower on the basis of the borrower's expected liquidity. It is therefore logical to think that insurance could increase the expected liquidity of the farm business thereby leading to a lower cost of capital. Given the increasing decline in land value against which borrowing is made, it is expected that farmers' cost of capital will have to increase since higher risk investment require higher returns (KielholzÃ 2000). Insufficient insurance coverage for the farm business in Australia could have served to increase the cost of capital with its attendant debt burden in the agricultural industry. This insufficiency is an example of the impact of the larger economy on agriculture as noted in Kenney et al. (1989).

At the moment, Australia is going through an increasing trend in debt in the agricultural sector (Barr 2004; Keogh, Tomlinson & Potard 2013). The causes and trend in the debt hike could be attested to in the review of the Rural Financial Counselling Service Committee:

There are predictions that changing resource access, together with declining commodity prices will place many producers in a ‘double squeeze’. Reforms and changing regulations may impact on the structure of both industries and regions. In some industries, expansion by large companies with greater capacity to respond to change is affecting the viability of smaller enterprises that cannot compete. The loss of farm families and enterprises from a region affects the viability of associated businesses, and ultimately the presence of adequate support infrastructure for continuing enterprises (NRAC 2006, p. 31).

Although, there is a consensus on the debt trend, there are differences in the opinion on whether or not the escalation of debt constitutes a crisis (Neales 2013). Debt in rural Australia has been evident since the mid-1980s as finance institutions were competing to lend funds (Lawrence 1999). Lawrence further ascribed the current debt trend in Australian agriculture to the deregulation of the banking industry as competition made lenders to advice farmers to increase their property size with a consequent farmer indebtedness to the banks (Lawrence 1987, 1999). The blame game between the financial institutions and the rural sector is also evident (Mooney 1988). The attempt to capture the lion share of the market led to sub-optimal lending to farmers beyond the levels they can service. Beside the fact that the terms and conditions of loans favour the lenders, the interaction between interest rates, commodity prices and input costs have not favoured farmers (Gray & Lawrence 2001).

This web of interrelationship has led to a strong decline in farm profitability for approximately 80% of broad acre farmers in Australia (Robertson 1997). The increment in the debt to value ratio has led to attrition from the sector (Gleeson & Topp 1997; Barr 2004). Barr (2004) has shown that there is a decline in new entrants into the agricultural industry, particularly among young people, because of their inability to cope with debt and the demand for land in peri-urban areas is making agricultural activity less promising. Furthermore, it has been shown that fewer farmers are encouraging their children to pursue a career in farming and this decline in farm succession through inheritance is expected to be steeper despite the desire for intergenerational transfer that has kept the system going for ages (Stayner 1997).

While the government has alleviated the pains of farmers through several other programmes targeting drought, the debt trend is yet to be given sufficient attention. Currently, there are discussions on establishing a rural development bank to buy back the debts but short-term solutions cannot be sufficiently contain the long-term pattern (Neales 2013).

In a recent study, it has been concluded that this trend does not constitute a risk to Australia (Keogh, Tomlinson & Potard 2013). Although the authors acknowledged an increase in rural debt, it was thought that in comparison to mining sector it is a modest growth. They argued that analysis of the debt trend is a function of the basis of the analysis because farms in Australia are now larger but farm businesses have declined in number particularly in the cropping and dairy sectors. They did not make any direct forecast but it may be safe to err on the side of caution (Garnaut 2008) as it may be difficult to identify the point at which the current trend would be regarded as a crisis.

The failure of analysts to identify the correct timing of occurrence of major events of mammoth weights was well documented in (Peltzman, Levine & Noll 1989, p. 3). There were increases in the sizes of Australian farms in order to achieve efficiency through economy of scale. It could also be said that this increase also help to achieve the form of hedge that was noted in Coble et al (2007) where price-yield correlation increases the inverse relationship between yield and price with a consequent increase in a natural hedge for farmer. Given the increase in Australian farm size over time, the analysis by Keogh, Tomlinson and Potard (2013) was conducted on per unit hectare basis rather than per farm business that could be misleading over time. It was further concluded that the current trend in rural debt is not in itself detrimental to the economy rather the converse is true given that financially healthy and growing businesses normally use debt to expand their operations. Rees (2012) is of the view that the current trend constitutes a crisis emanating from policy failure. He buttressed his points using Say's (Skinner 1967; Kaldor 1975) and Engel's laws (Laitner 2000; Murata 2008) and traced the root cause of the trend to the deregulation in 1983-84.

There is little doubt that following deregulation in 1983-1984 the banks, in pursuit of market share in the face of heightened competition, made loans based on security levels offered by existing equity but without sufficient regard to the capacity of clients to repay. The aftermath of the deregulation was the pursuit of market share fuelled by competition leading to insufficient regard to the capacity of the lender to pay back. Consequently, loans were made based on the equity levels of the farming operations.

Furthermore, the rate of attrition has escalated because of the debt. The attrition has been largely the result of small farmers selling up to larger scale farmers and only a miniscule of younger farmers are taking over family farms. Over the past 30 years, 40% of Australian farmers, about 294 farmers a month, have left their properties. There was an attrition of 19,700 farmers, a fall of 11% over the five years ending in 2011. Evidence suggests that events such as major droughts have a big impact on the farming workforce. For example, there was a decline of 15% in the number of farmers during the 2002-03 drought (ABS 2013b).

It could be noted that as rural debt increased, the net value of farm debt increased albeit, the rate of growth in debt is generally higher than the rate of growth in farm value leading to an increase in debt-to-value ratio. The disparity is however somehow closing up in recent years as shown in Figure 4 below.

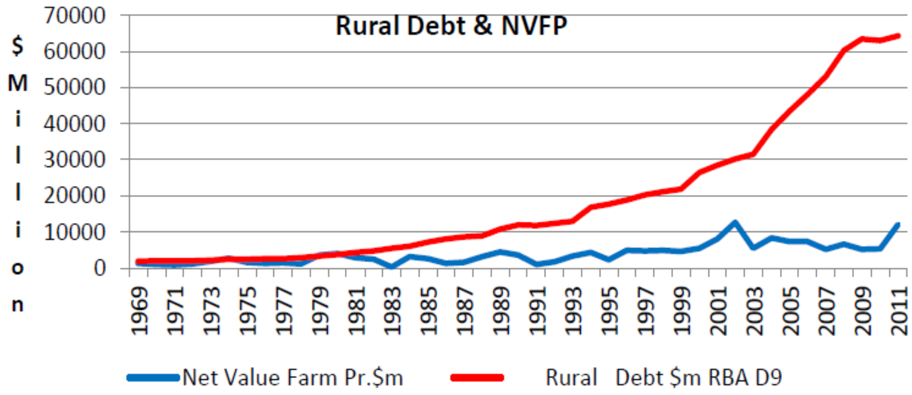


Figure 2-3: Rural debt and net farm value

[Source: Rees (2012, p. 1)].

Looking at this growth from a critical dimension from productivsm/post-productivism perspective, it may be reasonable to exercise some caution as more production is not necessarily good. In this context, more debt is not necessarily good (Schumacher 1973; Schumacher 2009).

The literature has considered two sides of the same coin or two different perspectives. One side is the school of thought that views debt increment as healthy while the other believes that it could be an indicator of a looming crisis. One common denominator between the two schools is that Australian farms are attempting to make efficiency gains through economy of scale but those in favour of the debt rise seem to ignore the cause of the rise which is rooted in lending practices.

Unlimited growth takes a system to an unsustainable point. While leverage may be useful in improving the operations of the firm (a farm in this case), there is an associated risk of insolvency that has to be considered (Scott 1976; Bradley, Jarrell & Kim 1984). An examination of financial theory on debt financing may suggest a prima facie acceptance of the Modigliani and Miller's propositions given the propensity to accept a new theory as being superior. Other scholars have accepted the phlogiston by upholding the status quo of the capital structure relevance theory (Ross 1988). In essence, debt financing is not an absolute truth or a universal truth in that it depends on the circumstances surrounding the individual firm. Debt financing therefore brings Quiggin's individualism to mind. It may be correct to say that financial truths, unlike mathematical truths, should not be considered from the absolutist's perspective (Ernest 1992, 2002; Andrews & Hatch 1999). Ignoring relativity or not contextualizing financial truths could cause a crisis!

2.12 Parallelism between Australia's rural debt and the global financial crisis

Australia is not the only country where farmers at the lower rung of the revenue ladder are priced out of the market in their bid to gain efficiency through massive land acquisition (Raup 1978; Gray & Lawrence 2001). The tendency to debt finance land acquisition may be faulty if the land value is on a consistent steep decline.

The Global Financial Crisis (GFC) is a recent case in mind of the failure of a system that is built on assumptions that were considered absolute and therefore infallible.

Such assumptions tend to be taken as absolute under a deregulated environment coupled with competition for market share by overly aggressive lenders as the case was after the deregulations of the mid 1980s in Australia (Vanclay 2003; Shiller 2008; Rees 2012). According to Shiller (2008, p.4) in respect of the global financial crisis;

> *It is time to recognise what has been happening and to take fundamental steps to restructure the institutional foundations of the housing and financial economy. This means taking both short-run step to alleviate the crisis and making longer-term changes that will inhibit the development of bubbles, stabilize the housing and larger financial markets, and provide greater financial security to households and businesses, all the while allowing new ideas to drive innovation.*

Some cues could be taken from the quotes above. First, the case of the global financial crisis was gradual. Secondly, policies should focus on both short-term and long-term steps to alleviate such crisis and finally, these policies should not stifle innovations. A further analysis of the trend in the global financial crisis and the current debt trend in Australia suggests that lending to prospective home owners was based on the assumption that property value will be above the amount owed to the bank. The assumption was found to be fallible when the value of homes declined making the debt-to-value ratio to soar. The erosion of farm equity in Australia against which loans were issued may be an indication of a pending crisis.

It seems evident that the ability to obtain loans on the basis of farm equity abruptly increased land value; therefore the current decline in land value indicates the fallacy of this assumption. The GFC clearly indicated that a financing system based upon debt-equity ratios carries the potential to become a systemic weakness in any globalised reliant financial system (Rees 2012, p. 4).

Agricultural lending practices in Australia have been based on this fallacy. Perhaps, if the loans to farm owners were granted against some cash flows in the form of sufficient insurance cover, the financial structure of Australian farms could have been different and the trend moderated. The moderation could have arisen out of the reduction in the cost of capital to farmers. The aggressive competition for market share by lenders could cause them to have overlooked the necessity of bridging this lacuna in agricultural finance in Australia.

Nevertheless, the type of insurance required for a comprehensive coverage of Australian farmers could be very expensive. This high cost is the result of the susceptibility of the country to drought and its systemic nature though there have been efforts to offer such products to no avail (Hatt, Heyhoe & Whittle 2012; NRAC 2012). On the other hand, the systemic risk limits the prospects of basis risk (Kimura & Anton 2011). The recent debt rise could be an indication that it is high time such products emerged in the market as an alternative to some government interventionist programme and/or a complementary investment to other programmes. Government's investment in times of drought could be better spent on providing the infrastructure required for innovative insurance.

The insurance option would have to be valued both objectively and subjectively in order to fully comprehend its full worth in the scheme of things (Kimball 1960). This valuation is because the mere existence of insurance on its own creates a subjective confidence beside its actual payout in times of fortuitous events. One would expect that this subjective confidence is worth the investment because it could facilitate increased production and alleviate attrition rather than 'mining the farm' to stay afloat because of increasing debt due to increasing input cost and decreasing profitability (Gray et al. 1995, p. 60). The provision of this option will however require that the existing institutional structures be responsive to community needs if rural Australia will remain economically productive, socially viable and ecologically sustainable (Gray & Lawrence 2001).

There are concerns on the outcome of a spate of default in the industry (Cawood 2014; Leyonhhjelm 2014). While some are of the view that the recent equity slide could lead to takeover of Australian farms by multinational farms and the consequences may be detrimental to the economy, others are of the view that such takeovers would enhance efficiency in the sector (Brehm 2005). The argument by those who believe in a corporate future for Australian farms stems from the fact that they expect an economy of scale due to size and the capacity of such firms to employ latest technology (Wittmaack 2006). In essence, if all farmers default, their farms will be taken at a price by someone else or a group of individuals ready to make the assets more productive (Cawood 2014; Leyonhhjelm 2014). Should such individuals be capable of integrating such farms into a large corporate farm, technology should aid productivity. Leyonhhjelm (2014) was particularly of the view that there will be no changes to prices or shortages in contrast to the view expressed in RRDF (2013) that a wholesale sell down could have a negative impact on Australians. Rural bank backed by the government was suggested by the RRDF to prevent this sell down. The opinions of farmers have shown that very few of them (0.0245%, n = 245) perceive the impact of restructuring Australian agriculture to be positive (Gray & Lawrence 2001, p. 80). This survey outcome resulted from the debate on the two major farm structures in Australia that is worth discussing in the context of this study.

2.13 Corporate versus family farm structures

There are different structures of farming operations but family and corporate farming systems are prevalent. The corporate structure has been associated with economy of scale. It has been shown that the economy of scale may only be valid in the case of livestock farming and not broad acre cropping which is prevalent in Australia (Allen and Lueck 1998 in Wittmack 2006). Therefore Australian farmers may not be able to take advantage of economy of scale because its agriculture is largely based on cropping. The editorial comments of the winter edition of the Farm Policy Journal clearly reveal some objective opinions on the issue of corporate versus family farms (Keogh 2012). The corporate farms lack the flexibility and resilience of the family farms while the family farms are limited by capital and skills (Gray & Lawrence 2001). The editor in pulling together the analysis in the journal however concluded that there cannot be a winner between the two schools of thoughts because there are more than two models of farming and the contest between corporate and family farms may be unrealistic. The unrealistic nature of the contest is further necessitated by the fact that the socioeconomic, industry and market contexts have a lot to do with the analysis. Hence, the conclusions from one analysis cannot be generalized to the other. The case of New Zealand which is often used as a case of corporatization of the agricultural sector is relatively different in a market context.

Nevertheless, some researchers have concluded that there are ample evidences that family farms are more productive than corporate farms (Chayanov & Chaianov 1986; Finkelshtain & Chalfant 1991; Barrett 1996) and the contention on whether or not corporates are a blessing or a curse in the 'get big or get out' system (Gray & Lawrence 2001, p. 8). Chayanov (1966) affirmed that auto-plunder of labour by family farms could make smaller farms more profitable than one could normally model. His notion of differential optimums suggests that different sectors of agriculture in different regions of Australia irrespective of the stage of technological development have differential optimal enterprise size.

Any point below or above this optimum would lead to a reduction in utility of productive assets. The analysis by Wilkinson, Barr and Hollier (2012) confirmed the need for policies to focus on improving the productivity of family farms in addition to improving regional social wellbeing. It could also be noted that there are different farm structures. The literature so far has established that rural life possesses some characteristics that could give the peasant non-capitalist farmer an edge in a capitalist economy.

This edge is partly because of the intrinsic advantages in terms of labour. The labour cost structure of family farms has been noted to be cheaper relative to that of the corporates largely due to some forms of principal agent problem in labour supervision (Eswaran & Kotwal 1986; Frisvold 1994). Similarly, family farmers have a direct stake in what they do and have the highest incentives to invest beyond the time they are working on the site besides being multi-taskers. Attempt to specialize in crop production may be eroded by labour costs because of a higher opportunity cost of capital incurred by corporate farmers (Barrett 1996). Consequently, Australians are yet to appreciate that they are getting more for less in terms of the labour of farmers.

Similarly, if corporate farms were to account for the cost of their externalities, corporate farming may not be beneficial (Brehm 2005; Wittmaack 2006). Vanclay (2003) affirmed that structural adjustments impacts on rural area dwellers and deregulation is promoted by globalization the logic of which ignores the social and environmental effect of such policies. This deregulation, he noted further has been called 'global misfortune' by Gray and Lawrence (2001). The misfortune stems from the politico-economic framework that hurts the disadvantaged rural Australia. Vanclay (2003) reiterated further that valuation of the end- state of a policy may depend on the value system of the analysts, should such ends be beneficial, the way the changes are implemented is important in order to alleviate the inevitable pains associated with change. Australian farmers attested to the fact that changes brought about by deregulation affected them and wondered what governments were there for if everything is to be deregulated (Gray & Lawrence 2001).

Other concerns about corporate farming are well enumerated by Wittmaack (2006). For example, corporate farms have been associated with higher rates of unemployment and poverty (Lyson & Welsh 2005). The disappearance of the traditional Australian culture is another concern as rural Australia is the nucleus of the Australian life (Gray & Lawrence 2001; Wittmaack 2006). Wittmaack further noted that the concentration of power of corporate farms may have a negative implication for the markets in the long-run as they could easily form cartels to control prices. This power relations is evident in Gray and Lawrence (2001) in that farmers reckoned the governments are out to help the big persons and not the little ones (p. 86) and that ‘corporate-owned farms have more power because they are buying and selling a lot more’.

This concentration is often ignored by those who advocate for a corporate model in that the efficiency they anticipate could result from economy of scale may actually go to the farms not the whole community. Hence, family farms may be worth keeping at least to reduce the extent of the concentration of market power. Such concentration could lead to collusion among the powerful producers. At the moment in Australia, because of the absence of such collusion, the government has not been captured to the side of the industry a situation that will become increasingly impossible with power concentration as it is in the US.

Although, the analysis of Wittmaack focuses on the US, the major lesson for Australian policy formulation is that government subsidies if it would be needed to stimulate agricultural production in Australia should not be for ‘corporate welfarism’ that allows the largest grain farmers to hoard the largest subsidies in order to avoid over acquisition of productive assets which may lead to a more systemic inefficiency. In this regard, the conclusion by Barrett (1996) that; ‘modest land redistribution to take advantage of the stress-induced diligence of land peasants, might be the most effective extra-technological means by which to stimulate agricultural productivity’. He affirmed that this land redistribution is what has led to the productivity of East Asian countries (p.211). Barrett noted further that the key to agricultural efficiency is not just about redistributing land to enhance economy of scale rather making necessary technologies available across the whole continuum of farm sizes.

Policy may therefore focus on facilitating land acquisition by farmers up to the optimal level that maximizes their diligence rather than an inefficient acquisition by corporates that may not be able to optimize their labour costs. Therefore, promoting bigger family farms may be more profitable in the long-run rather than mega corporate farms whose labour cost structure could make them less productive but powerful to the detriment of the state. This power could become more inhibitive to the economic growth of Australia should the farms comprise of largely foreign owned corporate farms (Gray & Lawrence 2001).

The attempt to forestall foreign control underlies the decline of the sale of GrainCorps to Archer Daniels Midland (ADM) of the US and the phasing out of the wheat board (Gray & Lawrence 2001; Feast & Packham 2013). The power that monopolies or cartels of corporate farms could wield may be strong enough to inhibit growth and lead to an eventual capture of the government.

Wittmaack (2006) noted that corporate farming has been relatively delayed in the grain sector because family farmers are compensated monetarily in times of yield short fall through increase in price unlike their livestock counterparts who are disadvantaged at both cost and price ends. Perhaps, this double-edged disadvantage explains the focus of the government on support for livestock farmers in addition to the sympathy that animals generate in the media unlike crops (Keogh & Potard 2014). Allen and Lueck (1998) are of the view that corporate farms may be less interested in the grain sector also because of the higher susceptibility to nature given its exposure to natural cycles than livestock farming. Attempt to gain efficiency of scale could be an incentive for agricultural asset owners to shift production resources towards livestock. The authors therefore advocated for market differentiation when debating the impact of corporate farming on agriculture. The analysis by Llewellyn and Umberger (2012) suggests a hybrid of family farm that could help Australian agricultural sector to manage the inefficiencies associated with a typical family farm model and avoid the challenges of a corporate farm. Similarly, Byerlee, Lissita and Savanti (2012) highlighted the cases of Argentina and Ukraine and forms of corporate farming that has led to an increase in their grain export. They tacitly convey the fact that corporate farming is more suitable in intensive livestock farming and horticulture than broad acre farming.

One way to enhance availability of technology across the farm size continuum is to make credit available in an efficient manner. This credit availability will tend to enhance productivity without overstretching the equity value of the farms. The availability of appropriate insurance mechanism could facilitate the provision of this credit by ensuring that farmers pay sufficiently low cost on their capital. Premium on tax incentives will allow farmers to take decisions that do not necessarily redistribute land but affords them to take advantage of available technologies across the range of endowments of wealth. In the context of Australia, the theoretical models on which an increase in land space for agriculture is based may be faulty in line with the post productivist's ideals in that more is not always better.

The economy of scale may therefore be eroded. In the context of cropping adoption of technology by corporate farms translates into using genetically modified varieties which are known to increase net yield but comes with an increase in yield variability. Risk management in the form of insurance is therefore a necessity for both corporates and family farms.

Besides, there are concerns about nature giving way to technology, although, Aristotle suggests that technology is incapable of changing natural things since 'human technology imitates natural teleology' (Schummer 2001). Recent concerns have shown that although technology may imitate natural effects markets are creating niches for both natural and technological products particularly because of sustainability and health concerns (Wittmaack 2006). The industrialization that permits the use of inputs by 20% of farmers who are producing 80% of Australian agricultural output has become a major concern (Gray & Lawrence 2001, p. 146). In an attempt to compete and service debts, farmers are beginning to place short – term objectives over long-term sustainability with immense implications for the environment (Cameron & Elix 1991; Vanclay & Lawrence 1994; Marsden, Murdoch & Morgan 1999).

Since productivity is stress-induced, social welfare support is not a sufficient condition that leads to efficiency. One way of productively stressing farmers is to induce them to chase premium subsidies in the form of tax incentives on insurance (not derivatives). The self-induced stress will reduce the cost of capital to acquire additional land for cultivation. This increment in productivity diminishes as the farmer increases the land farmed to the extent that his opportunity cost of labour becomes high with increased wealth. The welfare benefit could therefore serve to be an equitable means of promoting productivity if there are tax incentives on insurance premium. How this works is that, the welfare provision through the waiver of asset test provides a cushion for the farmer whose opportunity cost of farming is low in comparison to others. Now, the availability of tax incentive on insurance subsidies draws the farmer towards profitability albeit to a marginal extent and could be cushioned when there is a loss due to over hedging.

On the other hand, Freshwater (2004) was of the view that farmers tend to capitalize farm subsidies into the amount they are prepared to pay for farmlands. Consequently, increment in farm subsidies does not necessarily improve farm profitability in the long–term. Perhaps, the analysis of Freshwater explains why subsidies could be perverse (Myers & Kent 2001). However, the subsidy itself may not be the cause of the problem of low farm profitability but the manner in which it is dispensed. It is evident that the old dispensations of farm subsidies in the form of Exceptional Circumstances in Australia were not only inefficient but inequitable and the current policy changes do not seem to be promising either. The lack of promise stems from the fact that more farmers will claim welfare benefits and therefore less farmers will pay taxes.

In 2007/2008, 23% of farmers were paid $ 1 billion, if all farmers affected were to be paid, then, $ 4.35 billion would have been paid (Kimura & Anton 2011). It means that, if welfare benefits were delivered in that year, all the affected farmers would have claimed. However, in anticipation of such benefits, taxes delivered from the agricultural sector will also reduce since farmers will have incentives to be profitless. The implication of waiving asset test for farmers could be worse than that of EC in that if farmers were expected to hold on to their lands because they have impounded the EC payments into their expected future cash flows, then the same argument is valid under current policy. Also, in a probabilistic sense, the chance of getting such payment is higher under the current policy and they will therefore impound this into their Net Present Value (NPV) thereby further increasing what they will demand to give up their assets. The current policy may also be criticised on the grounds of inequity in that if farmers are given welfare supports, why should other self-employed members of the Australian society not be given the same support.

The changes so far to policy have not made any difference in terms of conceptualizing drought. Alternatively, there could be a mix of policies that will make farmers to choose to be profitable even though their downside risk is catered to. Instituting subsidies on insurance premium concurrently with welfare benefits for unprofitable farmers may be worth considering.

Based on the reports of the Industries Assistance Commission (IAC 1986; Malcolm 1985), the prospects of subsidized agro-insurance is bleak because the commission concluded that; *"the case for government intervening in the insurance industry either directly or indirectly to encourage provision of crop or rainfall insurance is on balance a weak case (Malcolm 1985, p.1)".* The main reason on which the reports stood was that the costs of subsidizing insurance outweigh the benefits.

However, some contributors to the report suggested that insurance may be able to fulfil the objectives of drought policy in a way that reduces economic distortions and creates community net benefits (IAC 1986, p. 48). In a related development Kimura and Anton (2011) were of the view that the government should; consider the feasibility of index-based insurance. The systemic nature of yield shocks in Australia, typically associated with a drought, makes it more feasible to introduce insurance that is indexed to rainfall because high correlation between rainfall in weather stations and farms (low basis risk). Development of index-based insurance is expected to cost much less than traditional crop yield insurance, which requires individual loss assessment. This instrument can be available for grazing industries. However index insurance requires information from an appropriate number of trustable weather stations. A feasibility study should explore the costs and benefits of developing such insurance products (Kimura & Anton, 2011 p.55). Similarly, Quiggin (1994) is of the view that; *the debate (on the viability of weather insurance) did not reach a settled conclusion; there was a consensus that a rainfall insurance scheme would not have a major impact in the absence of some subsidy at least on administrative costs. On the other hand, if subsidies were to be paid to farmers suffering from adverse climatic conditions, rainfall insurance would be one of the most cost-effective alternatives (p. 123).*

One would expect that the provision of welfare benefits in the form of asset test waiver would be more detrimental to Australian agricultural productivity in that if one billion dollars were spent on 30% of affected farmers in 2007/2008 season, then, with welfare instituted, $3.3 billion would have been spent on the same event. Hence, the provision of welfare packages for farmers may sound equitable but is actually inefficient. Quiggin (1996) rightly noted that efficiency should be given priority over equity more so that it could be better defined than equity. Given that other events will be covered under the current policy, then it would be expected that government's coffers will be stressed.

Should such an amount be spent on insurance subsidies, farmers would actually deliver more taxes because they could only get the incentives if they are profitable, they will produce more, further adding to government taxes and tax payers who are often protected by the no-subsidy policy will pay less for more food. Also, the rate of growth in debt in Australian agriculture will be tempered as farmers borrow at a lower cost and are therefore able to produce more for less. Given the recent changes in the agricultural sector as it relates to debt and attrition, the cost-benefit analysis of the insurance options requires an urgent review. These changes are themselves not unrelated to the state of the weather as drought has been more consistent and prolonged than before.

The benefits associated with corporate and family farm models have been highlighted in this section. It has been noted that net welfare benefit has been more anecdotal than objectively proven with empirical evidences in Australia and the benefits of insurance to the agricultural sector transcends beyond the industry. There is therefore the need to clarify doubts. The experiences of other countries with respect to agricultural insurance particularly in the context of weather insurance are therefore discussed below as they may be a good place to commence the clarification of the doubts and inform direction for future research.

2.14 Global experience in the use of weather index insurance

The earliest ideas of index insurance have been based on rainfall as proposed by Chakravati (1920) in India (Mishra 1995; Skees 2008). The weather index insurance mechanism has been successfully used in some countries while it is been pilot tested in others and further researches are being undertaken in this area (Gurenko 2006; Sharma & Vashishtha 2007). The study by (Skees, Barnett & Murphy 2008) focused on the use of IBRTP including weather derivatives in Low Income Countries (LICs). They reiterated that governments in most LICs cannot afford to subsidise the risk transfer markets as is done in most developing countries. The researchers noted the success of index–based rainfall insurance in India and attributed it to World Bank supports. The prospects of the product in India have been attested to by (Sharma & Vashishtha 2007). In Malawi, index – based insurance has been tied to the lending and seed sales processes and has been considered a success because it improves their credit worth (Gurenko 2006).

The case of Mongolia was emphasized by (Skees 2008; Skees, Barnett & Murphy 2008) as a model for LICs. The Mongolian case is a typical example of how index insurance could be used to hedge livestock losses. The drought and harsh winter in the early 2000s in Mongolia led to losses of about a third of the country's cattle. The disaster was financed through a loan agreement with the World Bank to finance a tranche of index–based livestock insurance. In Honduras, the use of weather index insurance has been found to be effective among smallholder farmers (Nieto et al. 2012). Nieto et al. (2012) identified rainfall patterns associated with yield loss and separated the season into dekads (10) and assigned weights representing sensitivity of crop yield to rainfall deficit during each period. This method has been trialled in Ethiopia, Malawi and India and was found to be effective. The methodology adopted in the design of the contracts in this study followed this design. Lack of such insurance mechanism, according to the authors, was found to promote avoidance strategy to risk management which in turn inhibits investments that would otherwise have driven development and income for households.

The study by Meuwissen, Van Asseldonk and Huirne (2008) focused on European agriculture. In the study, it was noted that perception of risk by scientists and farmers are not necessarily in congruence and that a theoretically promising risk management instrument may not necessarily work well for farmers. This divergence in risk perception could partly explain the friction in the uptake of weather index insurance by farmers. The study concluded that risk perception varies considerably across EU member states as would be expected to vary among member states in the commonwealth of Australia.

Another important conclusion of the study was that risk management solutions need to be 'tailor – made' to cater to the diversity in risk perception and exposure among the EU states. This customization is expected to lead to price discrimination as noted in earlier discussions under risk aversion and insurability (Section 2. 6). Palinkas and Szekely (2008) also noted that crops are relatively more at risk than livestock and emphasized that irrigation was perceived as an effective way of reducing yield risk among Spanish and Polish farmers. They concluded that there is need for a policy framework that could be customised to the specific needs of individual member states in the Union within the universal policy framework guiding it. The implication of this for Australia is that a national framework that caters to regional diversity may be designed. Also, in Spain, Italy and France, eligibility for receipt and size of ad hoc aid is contingent on the purchase of agricultural insurance. In Netherlands, a public – private insurance has been launched to compensate for excessive rainfall while the UK is making effort to implement cost – sharing between the government and the industry in a bid to fight livestock diseases outbreaks.

Generally, the case of EU has revealed that unless insurance are subsidised coverage will be limited and may not fully cover losses. It was further noted that farmers' selection of hedging instruments are based on incentives and experience (Garrido & Bielza 2008). The findings of Garrido and Bielza (2008) are not surprising since the mere presence of incentives is sufficient to influence decisions irrespective of size of the benefits (Sobel 2005). Garrido and Bielza (2008) further noted that reduction in subsidies would likely be followed by lower rates of use of instrument because of the general rule that instruments with higher coverage and risk reduction potential come with lower subsidy efficiencies (p.93). This reduction implies the need for a well-designed contract so that the subsidy level that would be required for uptake will be lower.

Although, studies have been carried out across the world on insuring agricultural risk, the case of Australia deserves a unique consideration given its susceptibility to drought and the miniscule assistance Australian farmers are given by the government relative to other countries. The need for research in agro-risk management is urgently needed for the purpose of enhancing productivity. This study attempts to capture issues of pertinent importance in agro-risk management particularly by considering the impact of price variability on hedging efficiency and capturing the relationship between this efficiency and yield-index relationship more appropriately. It also considerers the prospects of diversifying a portfolio of weather insurance contracts within Australia and considered the analysis of the opinions of stakeholders in formulating policy response.

2.15 Summary

This chapter examined literature in regards to the state of agricultural risk management globally an in the particular context of Australia along with a discussion of relevant theories. It commenced with a discussion of the risks that farmer face and their management. It was established that weather risk is the risk with the most implication for farmers particularly rainfall. The past, present and anticipated future of agro-risk management were traced.

Some critical issues that are of significance like the impact of varying prices over the period of analysis were emphasized. The implication of the assumption of a constant price in the analysis of insurance contracts was unravelled. The literature reviewed tacitly suggests the assumption of a variable price in the analysis of the impact of insurance contracts. In the case of broad acre crops, the relationship is inverse and the extent of this relationship has implications on the willingness to pay for the contract. This relationship remains a major missing concept in previous studies. Some theories behind this pricing model were also discussed. The variation of the relationship across locations also has implications for insurance design. Similarly, this relationship varies with farm size which is a measure of wealth. Since farm size is a form of reflection of the initial wealth of the insured and farm size already provides a natural hedge, consequently, an insurance paradox ensues because wealthier farmers who need insurance the least can afford it while poorer farmers who need it the most cannot.

This paradox is the bye product of risk aversion which was discussed along with the concept of insurability. The review of the concept has it that no line of insurance satisfies all the conditions of insurability but markets exist for them and weather insurance is not excluded. The argument presented in this review is that the interaction between yield and price variability may have impeded the uptake of weather insurance since the insured does not have any means of triggering output unlike the case of yield-based insurance. Hence, the low uptake of weather insurance results from its purported capacity to solve the problems of moral hazard. Emphasis was laid on the limitation of previous analysis with respect to factors that may impinge on the insured's willingness to pay and the providers' willingness to insure particularly with regards to the unique interaction of each party's existing portfolio and its impact on response to risk.

The role of technology and data were discussed. It was evident from literature that Australia has to invest more into the necessary infrastructure for efficient pricing of insurance contracts that is valuable to farmers. The current state of debt was also considered in the review given the recent association that is being made between debt and risk management in Australia. There is a debate on whether the debt level in Australia has reached a crisis point. It is however obvious that the rate of debt is not catching up with the level of productivity in Australian agriculture and insurance could be a means of achieving a productive growth in debt rather than an unending spiral of government supports. The researcher therefore prompted questions from the participants in this study using the information gathered from the reviewed literature.

This review therefore sets the stage for the quantitative and qualitative analyses that follow in this thesis. In addition, it is of immense value in the concluding chapter where the analyses are related to the review for the purpose of policy recommendations. The analyses sections followed the order of the hypotheses and proposition (see Chapter 1) from Chapter 4 to Chapter 7 and concluded with Chapter 8. However, the next chapter (Chapter 3) documents the methodological framework on data collection and procedures that underlie these analyses.

3 CHAPTER THREE: METHODOLOGY

3.1 Introduction

This chapter is divided into seven sections. The first section (this section) introduces the chapter. Next to the introduction is a brief discussion on the justification of the research paradigm adopted (Section 3.2) followed by a section on drought indices (Section 3.3). A brief overview of the study area and crop is discussed in Section 3.4. In Section 3.5, the data used in the quantitative analyses are explained. Similarly, the design of the weather index used and methods of analyses are enumerated in the section according to the research questions. In Section 3.6, the qualitative part of the study is explained while the final section (3.7) summarizes the chapter.

3.2 Justification of mixed-method research paradigm

Research methodology has been an issue of interest to researchers since classical times (Johnson, Onwuegbuzie & Turner 2007). It has been argued that insistence on quantitative analysis of facts based on rigid models is misguided (Kamarck 2002; Lawson 2003; Downward & Mearman 2006). From the researcher's point of view, a purely quantitative approach to analysing issues of policy interest does not accommodate a dialectical dissection of possible policy options by stakeholders. Hence, the need for triangulation of quantitative truths with qualitative realities in finance and allied epistemological niches.

The integration of a dialectical component to research actually adds to the objectivity in contrast to the thoughts that qualitative studies only reflect the value of the researcher. Although, scholars are of the view that quantitative analysis is value free, Olsen (2004) has argued that quantitative researchers are not excluded from the domain of the phenomenon of interest in their study. A researcher could therefore ascribe meanings to quantitative findings based on his/her own values. It is also worth noting that some scholars interested in the hermeneutics of quantitative models have reiterated that model mis-specification could lead to in-appropriate conclusions (Brenner 1977). To avoid the problem of quantitative model mis-specification, within method triangulation has been suggested (Kamarck 2002).

In the context of this study, different quantitative models were adopted in the analysis of the same objectives. Since the current state of agricultural risk management is complex and involves diverse range of stakeholders, a posteriori justification that involves the use of multi-paradigm analysis is required to find the way forward. Consequently, in this study, the mixed method, a combination of both quantitative and qualitative paradigms, was adopted (Creswell 2009).

3.3 Drought indices

Drought is difficult to define and to measure (Keyantash & Dracup 2002; Amor, Carrasco & Ibáñez 2009; Iglesias et al. 2009). It could be said to be the result of a prolonged abnormal period of deficiency in precipitation over a spatial boundary (Heddinghaus & Sabol 1991). Hence it was rightly called an insidious temporary aberration, the most complex of all natural hazards for which planning and preparedness has been challenging (Iglesias et al. 2009). However, all droughts have precipitation deficiency at its nucleus and the diversity of the effects on various disciplines affected makes it a difficult phenomenon compared to other forms of natural event (NOAA 2013).

The difficulty makes the choice of an appropriate index among several available options a daunting task, but a careful study of the nature of the indices and the objectives of this study facilitated the choice of an appropriate index. There are different types of drought and drought indices (Vangelis, Spiliotis & Tsakiris 2010). Droughts could be classified into meteorological, hydrological and agricultural droughts. Numerous drought indices exist (Heim 2002) but some are in more common usage than the others depending on the nature of the drought. Some common types of drought indices are: Palmer Drought Index (PDI), Standardized Precipitation Index (SPI) and Reconnaissance Drought Index (RDI).

The Palmer Drought Index (PDI) has some forms of variations; Palmer Drought Severity Index (PDSI), Palmer Hydrologic Drought Index (PHDI) and the Z index. PDI could lead to erroneous conclusions when spatial and temporal scales are of interest. The error could result because it is temporally fixed, spatially variant and difficult to interpret because of its complexity (Guttman 1998). Another commonly used drought index is the Reconnaissance Drought Index (RDI) (Vangelis, Spiliotis & Tsakiris 2010). RDI is used to assess drought severity based on Precipitation to Potential Evapotranspiration ratio (P/PET) and is based on certain assumptions that are not likely be valid in this study (Vangelis, Spiliotis & Tsakiris 2010).

The Standardized Precipitation Index (SPI) has been noted to be relatively consistent unlike the Palmer Drought Severity Index that is more complex and largely variable (Guttman 1998). It is therefore a better indicator of wetness than the Palmer indices besides being generally simple to understand than the other indices and has been recommended for use in risk and decision analysis because of its probabilistic nature. However, unlike the other indices mentioned above, it does not capture soil moisture or evapotranspiration but could be used on any time scale.

The index used in this study is a variation of the SPI in that it accumulates SPI over a given period of time and so is called the Cumulative Standardized Precipitation Index (CSPI). This accumulation of sub-seasonal SPI is a major advantage of the index over the others like the Reconnaissance Drought Index, Palmer Drought Index and Precipitation to Potential Evapotranspiration Ratio discussed above. This type of index was adopted by Chantarat (2009) based on Normalized Difference Vegetative Index (NDVI) by accumulating the standardized values of the satellite readings of rainfall (NDVI) over a certain period. The index was called Cumulative Standardized Normalized Vegetative Index (CZNDVI) and was used to design insurance contracts for Kenyan pastoralists. Since several locations are involved and the effect of temporal nature of the contracts is of interest, the CSPI was considered most appropriate for this study. Heim (2002) further affirmed that the new drought indices in the post Palmer era may have addressed some inadequacies of the Palmer model but are not necessarily superior to relegate its usage. Details of the criticism could be found in literature (Heddinghaus & Sabol 1991).

Therefore, several indices could be useful for different purposes and an examination of different indices would be appropriate. Kapphan (2012) examined four different indices for only one location in Switzerland. The Cumulative Standardized Precipitation Index (CSPI) was used in this study because it is relatively simple.

Besides, the outcomes of simple indices are comparable to those of more complex ones (Leblois & Quirion 2011).

The focus of this study is broader on a spatial and temporal basis and therefore would not permit the design of several indices but attempts were made to analyse the use of variations of SPI given the limitations of time and resources available to the researcher. Indices that capture available soil moisture may be considered in future studies. In this study, given the very wide variance in soil typology within the shires for which the rainfall measures are considered representative, the researcher left other forms of variables for further and future studies. The sole interest of the researcher is managing rainfall deficit rather than its interaction with other variables although these variables cannot be ignored in crop physiology.

3.4 A brief overview of the study areas and crop

The Commonwealth of Australia consists of six states and territories that were originally separate colonies of the United Kingdom, with a population of 23,461,749 as at September 2013 on the latitude 10°41 to 43°38 south and 113°09E to 153°38 east (Philip & Son 2008; Botterill 2012; ABARE 2014). Queensland is at the eastern side of Australia and Western Australia, as the name suggests, is on the western side. Its land mass has been noted to be relatively poor for agricultural purposes and is characterized by high annual and monthly rainfall variability. It is indeed a land of droughts and flooding rains.

Queensland and Western Australia were selected because they are climatologically different and at extreme departure in space from each other. The probability of occurrence of the same event in both states is therefore lower than selecting states that are in close proximity to each other. The bipolarity of the two locations will be useful in analysing the prospects of diversification for a portfolio of weather index insurance contracts. There are three states in the far eastern part of Australia. They are; Queensland, New South Wales and Victoria. Previous researches on the viability of weather index insurance in Australia have focused on New South Wales (Bardsley, Abey & Davenport 1984) and Victoria (Patrick 1988). Making the choice of Queensland and Western Australia could therefore facilitate the possible understanding of the spatial effect of the insurance contracts and contribute to literature.

Although, Australia is largely urbanized, it is highly dependent on its rural industry (Hirst in Bashford and McIntyre 2013). The country has been largely a commodity-based economy. There are several crops grown by Australian farmers including wheat and sorghum. The choice of wheat was necessitated by the fact that it contributes to the Australian economy more than the other crops (ABARE 2014). Furthermore, Australia produces only 3% of global wheat but contributes 12% of the global wheat trade because of its miniscule consumption. In particular, about 70% of Australia's wheat is exported and approximately 50% are produced by about 10% of the farmers (Craik & MacRae 2010; Botterill 2012).

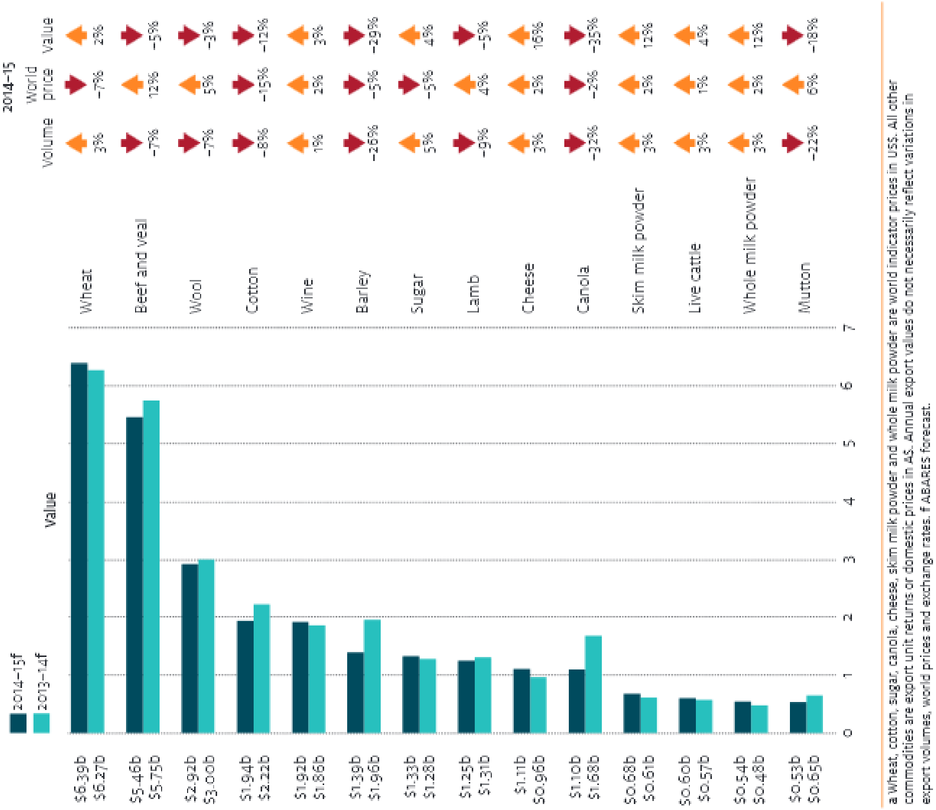


Figure 3-1: Major Australian commodities exports

(Source: ABARE 2014, p. 23).

Also, given the wide expanse of Australian agricultural land, the occurrence of drought over the whole country will be rare. A typical example of such occurrence was evident in 2010/2011 season when there was drought in Western Australia and flood in Queensland (Agnew 2011; Hicks 2011). The recent drought that lasted for 18 months ending in January 2014 also showed that while there was drought in Queensland, Western Australia experienced sufficient rainfall for plant growth (ABARE 2014, p. 24).

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3.6 Quantitative data collection and procedures

3.6.1 Data and data collection

In order to model the impact of weather insurance on the farmers' revenue, rainfall was taken as the major weather variable of interest impacting on yield and wheat crop was selected because of its relative importance in Australia. Since shire-wide prices are not available, national prices were taken. The choice of price to use could be challenging given that these prices were not available on shire level basis or most appropriately at the farm gate. A national price could also be export or domestic (ABS 2012). As much as 80% of Australian wheat may be exported in a year (Craik & MacRae 2010; ABARE 2012). The annual average price for Australian wheat on the free export market is an option but the national domestic price was preferred because it may be closer to the price that the farmers took at the farm gate level and yet be reasonably reflective of external shocks.

Yield is available on a shire–to–shire basis whereas the national inflation adjusted price was assumed for all locations. Malcolm (1985) affirmed that it is possible to price insurance contracts using historical data and shire level yield could be used as a proxy for individual farm level yield because of the general unavailability of farm level yield data. This pricing is referred to as Historical Burns Analysis (Jewson & Brix 2005). It should be noted that there will be error in the estimation because the experience of the individual farmer may not accurately match with that of the representative farmer in the shire. The danger of using amalgamated shire-level yield is that amalgamation of farm-level data at the shire level will inherently conceal some variations (Malcolm 1985). The use of shire-level yield and the national price implies that the individual farmer's experience will differ from that of the representative farmer's experience modelled in this study in terms of yield and price. However, this is the best data resolution that could be attained by the researcher. Despite these limitations, it is believed that the research findings would be of some relevance to policy makers.

Similarly, the price data was adjusted for inflation by using the consumer price index (CPI) for cereals with 1990 as the base year (ABS 2013a). The inflation adjusted prices were averaged over the forty–year period and multiplied by the yield outcome for the years to arrive at the revenue of the farmer for that year. The product of the average price and the yield was taken as constant price. Also, the product of the inflation adjusted prices for each year and the yield outcomes in each shire was taken as the revenue of the farmer under the variable price assumption. These prices were used in the analyses for all the locations. Consequently, the revenue of a representative farmer in a particular location is the product of the inflation adjusted price and the yield for that season. To the best of the researcher's knowledge, analysis of weather index insurance till date has focused on the assumption of a constant price. In this study, a contrast was made between the constant and variable price assumptions.

Hence, if a constant price is assumed, the farmer basically hedges the yield variability whereas capturing a variation in price from year to year would imply that the contract implicitly hedges the price variation as well. This implied price hedging and adjustment of the price taken by the farmer for inflation is lacking in previous studies (Vedenov & Barnett 2004; Chantarat 2009; Kapphan 2012). Implicit in these studies is that price was hedged at no cost. In this study, both a constant price and a stochastic price were assumed. The stochastic price assumption is closer to reality than a constant price across the years. It would be expected that analysis under a variable price assumption would capture the covariance structure of price and yield and improve the robustness of the analysis. This additional variability is the cost of price stabilization implicit in previous models and should translate into a reduction in the value of the willingness of farmers to pay. In essence, the value of the insurance should reduce when the cost of price stabilization is accounted for. Another way of looking at this is to say that a farmer will have less incentive to insure if prices are likely to serve as a natural hedge for yield shortfall.

The rainfall data used is based on the available data from the Bureau of Meteorology of Australia (BoM 2012a) and the yield data from the Department of Primary Industry and Fisheries based on the model developed by Potgieter, Hammer and Doherty (2006). The actual yield data is not available for a sufficiently reasonable period of time. The unavailability of sufficient yield data has been well acknowledged (DAFWA 2009; Hatt et al 2012). In the report, the data from the Australian Bureau of Statistics (ABS) was merged with those from Co-operative Board Handling Group (CBH) to produce data for the period from 1981 to 2009. The data from the ABS was discontinued from the year 2009 (Hatt et al 2012). In this study, the Oz-Wheat simulated data was used because of the insufficiency of actual yield data.

It has been observed that the Oz-Wheat model showed significant ability to model actual shire-wide wheat yields. In the absence of complete yield data for a sufficiently reasonable length of time from the Australian Bureau of Statistics, the Oz-Wheat model was used. The 40–year period was from 1971 till 2010. The Oz-Wheat is an agro climatic model and is capable of mimicking actual shire-scale wheat yields (Potgieter, Hammer & Butler 2002; Potgieter, Hammer & Doherty 2011). Although, the Oz-Wheat data is available for 245 shires in Australia, 65 locations in Western Australia and 35 in Queensland, only 40 and 23 locations were analysed from each state respectively given the insufficiency of the rainfall data from both states. Only those locations with more than 95% of daily rainfall data were analysed. Many shires did not have sufficient data considered reasonable for analysis and were therefore omitted from the analysis. Missing daily rainfall data were taken to be zero in that it may be more risky to estimate them. That is, estimating such missing data based on average rainfall for the day will most likely deliver a non-zero value whereas it is more likely it did not rain on that day more so that such days are very rare because most of the shires analysed had very close to 100% daily rainfall data (See Appendix 1).

There are different types of indices that could be used in the design of weather index insurance as discussed in Section 3.1 (Turvey 2001; Dai, Trenberth & Qian 2004; Chantarat et al. 2012; Kapphan, Calanca & Holzkaemper 2012). However, the Standardized Precipitation Index (SPI) was used because it is relatively simple as noted earlier. The SPI is calculated using the standardized values of rainfall. The season was divided into dekads (ten day periods) and the SPI for each dekad was summed up to form the Cumulative SPI (CSPI) which was used for benchmarking. The benchmarking was done at percentile levels. For example, the 5th percentile benchmark will imply that the contracts will pay out twice in the 40–year period, the 10th percentile pays out in four years with the lowest SPI in the period while the 30th percentile pays out in 12 years of the 40 years.

The analysis was done with equal weightage of the dekads in the season and then with optimized weightage. In this study unlike in most other studies, efforts were made to capture a wide range of locations. Obtaining expert weights for each of the locations could be a daunting task. The researcher then made conscientious efforts to obtain expert weightage for the eight shires in the analysis from the South East region of Queensland for the purpose of illustration which unfortunately could not be obtained from the agronomist. Consequently, only the optimized weights were contrasted with the equally weighted contracts. The equal weighting implies that each 10–day period in the season equally influences crop yield whereas the optimized weightage implies that some dekads have more impact than the others. The optimal weightage has been adopted in previous studies (Stoppa & Hess 2003; Nieto et al. 2012). It was difficult to adjust the optimal weights because of the several locations involved in this study unlike previous studies. It is therefore suggested that future studies should capture such adjustments. The GRG nonlinear algorithm in Microsoft Excel package was used to allocate weights that maximize the yield-index relationship in such a way that the weights are non-negative but could be zero (See Appendix 1). Theoretically, it may not be possible to say that there is a dekad that the plant will require no water, but given the constraints of the researcher, the optimal weights were adopted for illustrative purposes.

The commencement of the season for Queensland shires is around the 1st of June while it is approximately 1st of May in Western Australia. These dates were estimated from previous studies (Potgieter, Hammer & Doherty 2006; Karine, Deihimfard & Chapman 2013). The 180-day life cycle of wheat plant was based on the work of Stapper (2007, p. 3). Following the period over the life cycle, the dates were translated into the context of the states used. Therefore, a six month period from 1st May was adopted for Western Australian and from 1st June for Queensland.

Although, planting dates vary from shire to shire and year to year based on available moisture (Coventry et al. 1993; Gomez-Macpherson & Richards 1995; Hocking & Stapper 2001), the expected sowing dates were used rather than tracing the yearly planting dates from shire to shire over the forty year period analysed. Such an exercise could be too cumbersome for the scope and time constraints of the researcher. Similarly, the researcher could not determine to fine details the wheat varieties sown every year.

The periods covered by the contracts were from sowing to the commencement of maturity over an approximately 180–day period from the commencement of the season. The rainfall (in millimetres) was accumulated in dekads (10 days). The maximum water retention capacity of the soil from each shire is expected to vary; however 60mm was considered an acceptable limit, as discussed with an expert, across the shires under investigation since it is not within the time and resource capacity of the researcher to visit all shires for such information. The following optimization problem was adopted to obtain the weights for the dekads:

$$r_i \equiv \max\left[r^*_i, CAP_i \right] \quad (1)$$

Where r_i* is the actual rainfall in period *i*, and CAP_i is the amount of rainfall in the particular dekad or period *i* above which additional rainfall will not increase wheat yield. The caps adopted were 50mm and 60mm but the 60mm cap was reported extensively while the 50mm cap along with the uncapped contracts were analysed for the purpose of comparison (sensitivity analysis).

$$R_{cz_t} = \sum_i^n \omega_i r_{it} \quad (2)$$

Where n is the total number of 10-day periods in the growing season which in this study is 18 ten-day periods, ω_i, is the weight assigned to the period *i* of the growing season, r_{it} is the effective rainfall in period *i* of year *t* and $\text{R}_{\text{cz}_\text{t}}$ = Cumulative Standardized Precipitation Index for each year (*t*), The weights, ω_i, were chosen to maximize the sample correlation between the rainfall index and yield based on the yield data from 1971 to 2010.

$$\max_{\omega_i} corr(R_{cz}, Y) = \frac{\sum_{t=1971}^{2010} (R_{cz_t} - \bar{R}_{cz})(Y_{z_t} - \bar{Y}_z)}{\left[\sum_{t=1971}^{2010} (R_{cz_t} - \bar{R}_{cz})^2 \right]^{1/2} \left[\sum_{t=1971}^{2010} (Y_{z_t} - \bar{Y}_z)^2 \right]^{1/2}} \quad (3)$$

$$\textit{Subject to the constraint}; 0 \le \omega_i, \forall_i$$

Where: Y_t is the yield in year *t*, $\bar{Y}$ = average yield. These values vary from shire to shire across both states. It should be noted that the uncapped contracts were not capped at 60mm and the equally weighted contracts did not involve optimization. The 50mm capped optimized contract was presented only for the purpose of sensitivity analysis to consider the effect of capping by comparing the 50mm, 60mm and uncapped optimized contracts). The outcome of the optimization process for the 60mm capped optimized contracts could be found in Appendix 2. The Appendix shows the weights allocated to each of the dekads over the growing season in each shire. The emphasis in this thesis is on the 60 mm capped optimized contracts to keep the report tractable. However, the other contracts were conducted for the purposes of making some comparisons.

3.6.2 The contract design

The contract design follows a put option design (Turvey 2001; Stoppa & Hess 2003). The indemnity structure in Stoppa and Hess (2003) was adopted. The rainfall index derivative based on the Cumulative Standardized Precipitation Index (R_{cz_t}) must be below an alpha (5th, 10th and 30th) percentile threshold ($T_{\propto}$) for payout to occur. The payment was designed to be proportional to the extent to which the index is below the threshold. The value of R_{cz_t} is the sum of the values obtained by multiplying the rainfall index in each period (*i*) of a particular year (*t*) by the specific weight (ω_i) assigned to the period *i*.

$$Indemnity = \begin{vmatrix} 0 \text{ if } R_{cz_t} \geq T_\alpha \\ \frac{T_\alpha - R_{cz_t}}{T_\alpha} \, if R_{cz_t} \leq T_\alpha \end{vmatrix} * Liability \tag{4}$$

Where:

$R_{cz_t} = Cumulative\ Standardized\ Precipitation\ Index\ for\ each\ year\ (t)$;

$T_\alpha =$ percentile threshold, $\alpha =$ 5^{th}, 10^{th} and 30^{th} percentiles

The liability is the insurable interest or the value of a hectare of wheat which was estimated using the average yield and the average monetary value of wheat. The price is assumed to be the same for all shires because the national domestic price was used but average yield differs from shire to shire. It is expected that the domestic price was closer to the price accepted by the farmer. Hence, the effect of insurance on the revenue of a representative wheat farmer in each shire who took the annual inflation adjusted national average price of $225 per hectare of wheat harvested under constant price and variable price ranging from $121.54 to $482.67 over the 40-year period was analysed.

3.6.3 Data Analyses by research questions

3.6.3.1 Objective 1: To determine the relationship between the weather index and yield

The Ordinary Least Square Regression (OrdReg) was adopted in an attempt to find the relationship between the weather index and yield. The Adjusted R-square was adopted because it adjusts for the number of covariates in the model and therefore makes the model more comparable to other models that may have more than one covariate (Glantz & Slinker 1990; Draper & Smith 1998).

However, the relationship between yield and weather variables has been found to be non-linear. In Kapphan, Calanca and Holzkaemper (2012), it could be noted that excess rainfall and rainfall deficit are both capable of causing yield losses. Consequently, the yield-rainfall relationship is inverted U-shaped and therefore payouts of the contract would be U-shaped. Turvey and McLaurin (2012) in recognition of this relationship adopted the quadratic model and Vedenov and Barnett (2004) included quadratic terms in their models.

In this study, three benchmarks of the indices were used in creating the contracts (5th, 10th and 30th percentiles) so the Quantile Regression (QuantReg) was used in establishing the yield-rainfall relationship at these and other quantiles. The QuantReg is an extension of the median regression based on the work of Laplace (1818) by Koenker and Bassett (Chernozhukov 2005). With QuantReg, it is possible to estimate the conditional quantiles of a response variable Y on X. The QuantReg estimates multiple fits for the relationship unlike other models that estimate only one fit across the distribution. In particular, the OrdReg, like the Quadratic Regression (QuadReg), estimates only one fit across the continuum of the relationship. Furthermore, the QuantReg is more robust to distributional assumptions than the OrdReg and consequently, it is not sensitive to outliers.

The expectation is that the QuantReg will give more specific information about the relationship at the respective quantiles unlike the OrdReg. Therefore, the QuantReg is preferred to the OrdReg and the Quadratic model (QuadReg) adopted in Vedenov and Barnett (2004) in that it specifically estimates statistical efficiency at the tails (Koenker 2005'Adeyinka & Kaino 2012). Since the interest of the researcher is on drought, the left tail of the yield distribution is of particular interest. It is worth noting that the observations in Vedenov and Barnett (2004) and Turvey and McLaurin (2012) that high statistical efficiency does not guarantee hedging efficiency is based on a singular fit across the yield-index continuum. For example, when the hedging efficiency of a contract in a specific location is compared to statistical efficiency, it is only compared across the whole model. Vedenov and Barnett (2004) considered the statistical efficiency at different alpha levels of Value at Risk (VaR) but these efficiencies were compared to each regression fit for the crop-location and yield-weather relationship. In this study, the QuantReg was used to analyse the statistical relationships at the tails with respect to the Conditional Value at Risk (CVaR) corresponding to those tails. Hence, it is possible to comment to a relatively more specific detail on the statistical versus hedging efficiency of weather index insurance at the tails rather than analysing relationship for the whole continuum and calculating efficiencies based on the tails.

Another statistical measure of relationship adopted in this study is Panel Regression analysis (PanReg) (Hsiao 2003). Frees (2004) defined panel data as a marriage of time series and cross-sectional regressions that allows researchers to study both the dynamic and cross-sectional properties of data sets. The advantages of PanReg over OrdReg are that it allows the researcher to capture both the dynamic and heterogeneity properties inherent in the data. The major disadvantage is attrition which is not a problem in this study. The Hausman test was adopted in testing the more appropriate model between the Fixed Effect (FE) and Random Effect (RE). The PanReg (Panel Regression) analysis was used to determine the effect of location on the analysis. In essence, attempt was made to know whether or not different indices are required for different locations (Panel effect) (Chantarat 2009). Although, the researcher is aware of copulas as a tool to measure tail dependence structures, studies have shown that it depends on the correct specifications of all margins thereby inducing very strict limitations on the interest in working with them (Fermanian 2004).

3.6.3.2 Objective 2: Hedging efficiency

3.6.3.2.2 Introduction

Three measures of hedging efficiency were adopted namely, Conditional Tail Expectation, (CTE), Mean Root Square Loss (MRSL) and Certainty Equivalence of Revenue (CER). The results from these analyses were further analysed using statistical analyses that are based on mean tests and categorical analysis.

3.6.3.2.3 Measures of hedging efficiency

Utility in this study is measured in terms of the revenue of the representative farmer in each location. The revenue of the farmer for a particular year is the product of the yield and price. The farmer is also interested in minimizing the variability associated with the revenue. In essence, the farmer's utility is more complete when the variability of the revenue is also considered as in the usual mean-variance theory. That is, if an actuarially fair insurance contract reduces the risk of an expected utility maximizing farmer, the farmer will prefer the insurance. However, since the interest is in minimizing the downside risk, the standard deviation may not be appropriate (Estrada 2007). Estrada (2007) noted that, until recent years, scholars and practitioners have been using the variance minimization approach because they are more familiar with it when in actual fact the semi-variance is a better measure of risk.

Earlier, Markowitz (Markowitz 1952, Markowitz 1959, Markowitz, 1991, Markowitz, et al. 1993) noted that analyses that are based on the semi variance minimization tend to produce better results than those based on the full variance because investors are interested in minimizing underperformance. According to Jin, Markowitz and Zhou (2006) the major limitation of the mean-variance measure is that it only measures volatility because it penalizes the upside deviations as much as the downside deviations. Hatt, Heyhoe and Whittle (2012) affirmed that the position of farmers as utility maximisers and downside risk minimisers is the same as those of other investors.

Jin, Markowitz and Zhou (2006) presented two forms of the semi variance analysis. The first is the expected squared negative deviation from the expected value also known as the below-mean semi variance. The second is the expected squared deviation from some fixed value. The fixed value could be benchmarked as a zero return or another target value like the median or a given level of return. Several authors have alluded to the attractive features of the mean-target semi variance model as noted in Fishburn (1977, p. 116). The models in a portfolio context as put forward by Jin et al (2006, p.55) are as follows:

The total return of the ith security during the period is a random variable ξi meaning that the payoff of one unit investment in security i is ξi units, i = 1, 2. . . , n. Suppose $E(\xi i) = ri$ and $Var(\xi i) < +\infty$.

$$\text{minimize} E[(\sum_{i=1}^{n} x_i \mathcal{E}_i - E\left(\sum_{i=1}^{n} x_i \mathcal{E}_i\right))^{-}]^2 \qquad (5)$$

Subject to the constraints $\sum_{i=1}^{n} x_i = a$ and $\sum_{i=1}^{n} x_i r_i = z$

where xi ∈ R represents the capital amount invested in the ith security, i = 1, 2, . ., n

(hence x := (x1, . . . , xn) is a portfolio), a ∈ R is the initial budget of the investor, and z ∈ R a pre-determined expected payoff. Here x−:= max (-x, 0) for any real number x. This problem is also referred to as below-mean semi variance model.

In contrast, the second problem, termed below-target semi variance model, is the following:

$$minimize\ \mathrm{E}[(\sum_{i=1}^{n} x_i\, \mathcal{E}_i - b)^{-}]^2 \tag{6}$$

Subject to the constraint: $\sum_{i=1}^{n} x_i = a$

Where b ∈ R represents a pre-specified target.

The Mean Root Square Loss (MRSL) adopted by Vedenov and Barnett (2004) is of the first model presented above. Vedenov and Barnett (2004) used the MRSL as another measure of risk and it was found to be appropriate in this context because the minimization of the semi-variance rather than the full variance is of relevance since farmers are mainly interested in managing their downside losses like all rational investors. In this study, the MRSL based on the mean was adopted because the market concern is below average revenue. Given the different contracts (5th, 10th and 30th percentile contracts); the MRSL was calculated in an attempt to observe the extent to which the downside risk below the mean is minimized. Hence, if the MRSL reduces with insurance, then the contract is efficient at that strike level or contract for that location.

The revenue without contract is given by:

$$I_t = pY_t \tag{7}$$

and with contract is:

$$I_{t\alpha} = pY_t + \beta - \theta \tag{8}$$

Where; I_t = revenue at time *t* without insurance, *p* = price of wheat, $I_{t\alpha}$ = revenue at time t with alpha percentile level of insurance, Yt = yield at time t, βαt = insurance payout for that level of insurance in that year and θα = the yearly premium for that level of insurance and is constant throughout the years in question, MRSL is the Mean Root Square Loss without insurance and MRSLα is the Mean Root Square Loss with an alpha level of insurance. These values differ by location but a location subscript is not included in the formula for simplicity.

$$\text{MRSL} = \sqrt{\frac{1}{T}\sum_{t=1}^{T}[\max(p\bar{Y} - I_t, 0)]^2} \quad (9)$$

$$\text{MRSL}\alpha = \sqrt{\frac{1}{T}\sum_{t=1}^{T}[\max(p\bar{Y} - I_{t\alpha}, 0)]^2} \quad (10)$$

Another measure of risk is the Value at Risk (VaR). The VaR emphasizes the maximum reduction in revenue that will not be exceeded at a given level of probability. In finance literature, the VaR is typically used to analyse the risk to portfolio returns because volatility does not discriminate between the downside and upside of the revenue distribution whereas, the VaR captures the downside risk at a given alpha level. The VaR could be estimated by historical method, variance–covariance method or with monte-carlo simulation. The essence of calculating VaR is to assess the worst cases over a given period of time at a pre-specified level of probability. This method was equally adopted by Vedenov and Barnett (2004). However, VaR is not without its shortcomings.

The VaR is considered incoherent and does not satisfy the required axioms of an appropriate risk measure (Acerbi & Tasche 2001). Therefore, the Conditional Value at Risk (CVaR) is preferred. Alternative names for CVaR are Conditional Tail Expectation (CTE) and Expected Shortfall (ES). The CVaR improves on the VaR because it captures the expectation beyond the VaR. In essence, while the VaR tells us that the farmer's loss may not exceed a certain amount, the CVaR tells us about the expectation of the loss should the VaR be exceeded. Rockafellar and Uryasev (2002) also derived some fundamental properties of the CVaR that makes it a better measure of risk than the VaR. Some of these include coherence and stability.

The CVaR analysis in this study is measured at the 5th, 10th and 30th percentiles. In essence, the expected revenue in the worst 2, 4 and 12 years in the 40–year period under both constant and variable wheat price assumptions were analysed. The purpose of this analysis is to know whether or not insurance will increase the revenue of farmers in the worst two years of rainfall, the worst four years of rainfall and the worst 12 years of rainfall in the 40-year period. If the contract is efficient, then, the utility of the farmer, measured in terms of revenue, should increase in years when droughts are experienced. Should the contracts be triggered in years that did not match with the years of drought, the CTE decreases due to the deduction of the premium. Should the payout be equal to the premium every year when the contract was triggered, the farmer will be indifferent and if the payouts outweigh the premiums for those years, the farmer would have derived value from the contract.

Based on the work of Brazauskas et al. (2008, p. 3591), the CTE risk measure, or function, can be defined as follows: given a loss variable X (which is a real-valued random variable) with finite mean **E**[X], let F_X denote its distribution function. Next, let F_X^{-1} be the left-continuous inverse of F_X called the quantile function in the statistical literature. That is, for every t $\in$ [0, 1], we have:

$$F_X^{-1}(t) = inf\{x: F_X(x) \geq t\} \quad (11)$$

With the above notation, the CTE function is defined by;

$$CTE_X(t) = \boldsymbol{E}[X/X > F_X^{-1}(t)] \quad (12)$$

Some scholars have used these methodologies in the analysis of the efficiency of weather index insurance. In particular, Kapphan (2012) adopted both the VaR and the CTE in the analysis of optimal insurance contracts in Schaffhausen Switzerland. Vedenov and Barnett (2004) adopted the VaR, MRSL and Certainty Equivalence of Revenue (CER) in the analysis of a range of contracts designed for different crops at diverse locations in the US.

Furthermore, the value of the insurance contracts was examined in terms of Certainty Equivalence of Revenue (CER). Since the value and cost of shifting risk is derived from the tendency to be risk averse (Arrow 1996) researchers have attempted to quantify this value in utility terms (Arrow 1964, Arrow 1971, Henderson & Hobson 2002). The value of the insurance therefore explains why an individual will be willing to pay an actuarially unfair price to have the insurance. By paying the actuarially unfair price, the individual has paid an additional premium on that which he will obtain should disaster strike. Hence, the individual may be able to pay the actuarially fair premium if the insurance is only reasonably valuable but may not be able to pay the actuarially unfair price if it is not much more valuable in terms of utility maximization and downside risk minimization.

Based on experience, individuals who accept a price under a voluntary insurance scheme without subsidy creates interests not only for themselves but also for the insurer (Arrow 1996). Therefore, a necessary condition for insurability is the willingness of the representative farmer to pay for an actuarially fair contract because the willingness to pay for a fair contract is a necessary but insufficient condition to pay for an unfair contract. A useful concept in the analysis of the utility of risky alternatives is an expression of the willingness to pay for a certain equivalence of the risky alternative. In this study, the CER of actuarially fair contracts was analysed. If the CER increases with the insurance contracts, then, the insurance contracts have made the farmer to opt for an additional value as a certain equivalence implying that the contracts have added value to the revenue distribution of the farmer.

There are different models that could be adopted in the context of individual's risk aversion under the assumption that an individual is non-satiated. By non-satiation, the utility of X+1 > X. This implies that more revenue is preferred to less revenue. However, it should be noted that marginal utility of a unit increase in wealth may differ. In essence, an increase of a dollar for someone who owns no money is different from the same unit increase for someone who already owns $100. The individual with an initial wealth of $100 may select a fair gamble on the $1 increase whereas the individual with a zero initial wealth may not be able to take as much risk but would prefer to have a certain equivalence of the increment. In this study, the implication of initial wealth is ignored by selecting a utility model that expresses certainty equivalence of revenue with assumptions that are compatible with the context of this study.

Since the farmer prefers higher revenue and lower risk as modelled using the Conditional Tail Expectations and mean-semi variance, the logarithmic utility model of CER was adopted. This model assumes that the farmer is risk averse, prefers more to less and that the percentage of wealth invested into production is constant irrespective of changes in wealth (Elton et al 2003). The risk aversion of Australian farmers and the differences in their risk attitude have been well affirmed in literature (Bardsley & Harris 1991; Ghadim & Pannell 2003; Khuu & Weber 2013). It was assumed that the representative farmer in each shire exhibits a constant relative risk aversion (CRRA) (Henderson & Hobson 2002). Kapphan (2012) similarly assumed CRRA in the analysis of optimal weather insurance contracts for a region in Switzerland. However, the model adopted in this study is less complicated than Kapphan (2012). Quiggin and Chambers (2004, p. 249) has shown that;

> *In some applications, the additive functional form associated with the expected-utility model proves useful as a simplifying assumption, but for most purposes the assumption of risk-aversion is sufficient to permit a simple and informative analysis.*

The Constant Relative Risk Aversion, based on the model of in (Elton et al. 2003, p. 219):

$$\frac{1}{T}\sum_{i=1}^{T} \text{Ln}\, I_{t\alpha} \tag{13}$$

Where all variables are as defined earlier.

The three models, Conditional Tail Expectations (CTE), Mean Root Square Loss (MRSL) and Certainty Equivalence of Revenue (CER) reflected the efficiency of the contracts. The impact of the insurance was analysed by finding the percentage difference between the revenue of the farmer without insurance and with insurance at the different strike levels. The percentage difference if positive for CTE and CER implies that the contract was efficient whereas a negative difference implies efficiency for MRSL since the objective of the contract is to reduce the downside risk of the farmer's revenue. With 63 locations under study, it was appropriate to further analyse the efficiency results.

3.6.3.2.4 Statistical analysis of hedging efficiency results

The methods adopted in the analysis of the efficiency results were both parametric and non-parametric in nature. First, the Binomial test of proportion was implemented as a way of finding out whether the proportion of shires that was efficient was significantly different from those that were not. In addition, the Chi-square and odds ratio analyses were adopted to consider the dependence of the efficiency counts on states and price assumption. The Chi-square and the Odds Ratio analyses attempted to shed lights on the likelihood of the dependence of efficiency on state or pricing assumption. Furthermore, the contingency tables were arranged in such a way that will allow the report to reflect the possible existence of Simpson's Paradox.

Simpson's Paradox allows the researcher to interpret the aggregate results without losing the constituent meanings that form the aggregate table (Agresti 2002). Nevertheless, the efficiency counts may not be sufficient and therefore some parametric tests were adopted.

For parametric tests to be implemented, there is need for some assumptions to be met (Tabachnick, Fidell & Osterlind 2001; Finch 2005) most prominent of which are the normality and equality of variances of the groups assumptions. However, these assumptions are rarely satisfied in researches and alternative non-parametric techniques are often limited in containing the challenges posed by the violation of these assumptions. When the alternatives are used, they tend to leave some other issues to be resolved (Finch 2005).

The other alternative is to transform the data to deal with the non-normality and unequal variances and then run the parametric tests. Possible transformations are logarithmic, square root, reciprocal and reverse transformations. The logarithmic transformation is not possible for value less than zero and the square root transformation is not ideal for the same reason. The other two alternatives would make interpretations of the results more complicated (Field 2009).

One way of handling the complication is to adopt the bootstrap or jacknife methods (Field 2009). Lanyon (1987) affirmed that it is relatively sure that investigators will not be able to conclude more from their data even with these sophisticated efforts. Since the two methods are still based on the initial sample they may not reproduce the original population and estimates based on their outputs may not necessarily be worth the efforts (Shao & Tu 1995).

In this study, the assumptions required for a parametric test were rarely violated. These assumptions are:

- Normal distribution of the data
- Homogeneity of variances
- Interval data
- Independence

(Field 2009, p. 133).

Given the trade-offs documented in literature between the choice of parametric and non-parametric tests and transforming the data, it was considered more appropriate to adopt the parametric tests without transformation rather than their non-parametric equivalence. This choice is further attested to by Glass, Peckham and Sanders (1972). According to the authors, the violations of these assumptions are inevitable. The question to ask therefore is the importance of the violations rather than asking whether or not the assumptions were met. Asking the wrong question has led to an unnecessary preference of the non-parametric techniques which are not necessarily a panacea for curtailing the violation of the assumptions (Finch 2005).

Other scholars have contributed to this area of statistical debate (Games & Lucas 1966; Levine & Dunlap 1982, 1983; Games 1983, 1984; Grayson 2004) as noted in (Field 2009). Levine and Dunlap (1982) specifically noted that the distribution of the shape, the within group variances and the differences between the means are altered by transformation. The most relevant conclusions from their findings were that transformation could actually change the construct under investigation in that the researcher may be testing a wrong hypothesis. This change may have implications for the conclusions drawn from the findings of the research.

The first among the parametric tests adopted is the One-sample t-test. With this test, a benchmark of zero per cent difference was set and the efficiency results were compared with this benchmark. In the case of the Conditional Tail Expectation (CTE), when insurance produces a positive difference relative to the uninsured condition, then, the insurance has added value to the revenue distribution of the farmer. When the difference is negative, it translates to the fact that the insurance has reduced the average revenue of the farmer at the selected alpha level which also corresponds to the strike level of the insurance. The implication of a positive difference is that the revenue of the farmer in years of drought has exceeded that of no insurance. In a situation where the difference is zero, then, since the model assumes that the insurance is actuarially fair, the farmer will be indifferent. Should the result of the one-sample t-test be significant ($p < 0.05$), then it could be concluded that the farmer is significantly well off (worse off) with the insurance if the mean is above (below) zero. The results from the Certainty Equivalence of Revenue (CER) follow the same line of interpretation with the CTE. The case of Mean Root Square Loss was however opposite in interpretation since the target was downside risk reduction.

In the analysis of the differences in efficiency measures (the impact of insurance), the mixed design was selected among the factorial ANOVA designs. In the context of statistical analysis, the mixed design is a mix of both independent factorial ANOVA design and repeated measures factorial ANOVA design. It would have been ideal to analyse the results of the efficiency tests with only the Repeated Measures Analysis of Variance but the analysis between the independent variables (e.g. states – Queensland and Western Australia) is also of interest. Running the analysis separately would ignore the interaction between state and the impact of the insurance at the respective strikes. The mixed design therefore permits the analysis of the impact of efficiency for the same locations across strikes and between states.

However, for the mixed design analysis to be conducted, the sphericity assumption has to be fulfilled (Field 2009). Should this assumption be unfulfilled, the MANOVA results are preferred since it does not require the sphericity assumption (O’Brien, Ralph & Kaiser 1985). Unfortunately, MANOVA does not assume repeated measurement as in repeated measure ANOVA. The Statistical Packages for Social Sciences (SPSS) produces both mixed design and the MANOVA results when the mixed design model is adopted. However, whenever, the sphericity assumption is violated, the results of the MANOVA were reported and should the results differ from that of the mixed model, the areas of differences were explained.

The post-hoc multiple comparison test is required to follow up on the mixed design or MANOVA outcomes as a test of between subject effects. The choice of the type of post-hoc test is important. Although there are many options to choose from, the Bonferroni post-hoc was preferred. The choice of the Bonferroni test stemmed from the fact that it strikes a balance between power and control for Type I error (Field 2009). Field (2009) further documented that the Bonferroni test is appropriate when the number of comparisons made is small as is the case in this study with at most three comparisons.

The Pearson correlation coefficient (r) and the R^2– square (and Pseudo R square) are measures of effect size, the effect sizes of the contrasts performed in the mean test analyses were calculated as well as the effect sizes for the categorical data. The effect size of the categorical analysis was calculated using Odds Ratio. The effect size of the mean tests was based on the effect sizes of the focused comparisons (r) between contrasted groups rather than the overall effect size (omega squared) more so that the sample sizes between the two states were not equal. The effect sizes were necessary in that in addition to understanding that there were significant differences in the means or dependence in the case of the categorical analysis, they could facilitate the appreciation of how large the difference or dependence is (Field 2009). The rule of thumb for the sizes is; low effect is below 0.2, medium effect is about 0.3 and from 0.5 is a large effect for r.

In this study, the mixed design results were reported except when the sphericity assumption is violated. To test for sphericity, Mauchly's test was adopted. When the Mauchly's test statistic is significant ($p < 0.05$), then, the sphericity condition is not met. In some instances, the Greenhouse-Geisser or Huynh-Feldt corrections were used to correct the model. Where these corrections were not possible, the MANOVA results were adopted. Details of the corrections could be found in Field (2009).

3.6.3.3 Objective 3: To determine the diversifiability of a portfolio of weather index insurance

The Loss Ratio (Lt) is the ratio of the indemnity paid to premiums collected. Pooling the premiums and indemnities across different shires and over time helps to examine the spatial and temporal covariate structure of the risk. The L_t is calculated as follows:

$$L_t = \frac{\sum_{l \in L} \Pi_{lt}}{\sum_{l \in L} P_{lt}} \qquad (14)$$

and when pooled over time, it becomes;

$$L_t = \frac{\sum_{t \in \tau} \sum_{l \in L} \Pi_{lt}}{\sum_{t \in \tau} \sum_{l \in L} P_{lt}} \qquad (15)$$

Π=Indemnities, P = Premium, L = locations (18 shires, 8 from Queensland and 10 from Western Australia), τ = time (the pooling was based on 1, 2, 5 and 10 years).

If L_t is lower than 1 (L_t<1) , it indicates that the premium collected is more than the indemnities paid and therefore the insurer makes a profit, when it is 1 (L_t = 1), it implies a breakeven in that the indemnities paid is exactly equal to the premium and when it is above 1 (L_t >1), it means that the insurer experienced a loss for that period in that indemnities paid is more than the premium collected (See Chantarat 2009 pp. 108 – 110). The loss ratios were further analysed with the aid of graphs for each state at the three strike levels and the years of risk pooling. A look at the graphs therefore reflected the risks across space and time and is presented in Chapter 6 of this thesis.

3.7 Qualitative data and analysis

3.7.1 Data and data collection

Semi-structured interview schedules were used to gather information from the respondents. Different schedules were designed for different groups of participants. Experience has shown that survey of farmers do not yield swift and sufficient responses (DAFWA 2003, 2009; Hatt, Heyhoe & Whittle 2012). Given the time limit of this study, interviews were preferred.

Most ideally, an iterative process could have been adopted in gathering the data (Newing et al 2011), but for the difficulty in obtaining consents of farmers who are in a depressive season of drought at the time of interview and the difficulty in locating them. Similarly, some stakeholders were reluctant in providing responses because of the political nature of the issues at stake.

The data was collected through telephone interviews from representatives of five financial services providers (insurers and bankers), three other stakeholders and nine farmers. Since these interviewees represent different service groups, different interview schedules were developed for them. Their responses were recorded and then transcribed. The interviews were semi-structured in nature.

3.7.2 Sampling techniques

The sampling of the interviewees was done using snowball sampling because it was difficult to obtain the targeted groups particularly among the farmers (Myers 2013; Patton 2005). Since the intention of the researcher is to gain an in-depth understanding of the risk management landscape of Australian agriculture, individuals who were considered useful for this purpose were specifically targeted. It was not the intention of the researcher to gather a representative sample rather a knowledgeable few with relevant information. Another reason for the use of interview method was that previous researchers who have attempted to use questionnaires have gotten too little to justify their efforts (Hatt, Heyhoe & Whittle 2012). Telephone interview has been associated with some bias but focus group interview was also conducted face-to-face with some farmers to contain the bias with telephone interview and in order to triangulate the information collected (Novick 2008; Sinkovics & Ghauri 2008). Three farmers responded to the interview by returning written responses to the interview schedule.

The farmers in the Focus Group were between the ages of 35 and 60 years. The venue of the interview was at Cecil Plains in Millmerran shire less than an hour drive from the University of Southern Queensland where the researcher resides. The interview took place on the property of one of the participating farmers and was attended by 6 farmers and one agronomist. The discussions were recorded, kept safely and transcribed after the interview. The data analyses of the interviews and the

Focus Group interview were done thematically (Rubin & Rubin 2011) on the basis of five major themes namely;

- Risk and risk management in Australian agriculture
- The need for policy change
- Insurance options and associated challenges
- Debts and attrition from the agricultural sector – challenges and solutions
- Suggestions

Table 3-1: A breakdown of interviewees

Interview mode	Stakeholder groups (Code)	Number of respondents
Interviews	Bankers	2
	Insurers	3
	Farmers	10
	Other stakeholders	3
Focus group interview	Farmers	6
	Agronomist	1

3.7.3 Data analysis

The analysis of the perceptions on agricultural risk management in Australia was conducted using the qualitative approach. The method was considered appropriate alongside the quantitative method adopted so that one method could bridge the gaps in the other (Sarantakos 1993; Olsen 2004).

The qualitative section of this study follows a phenomenological design in that it allows for the subjective construction of realities as experienced by farmers with different demographic characteristics (Kvale 1994; Groenewald 2004). The qualitative analysis could therefore be a pilot to an anticipated broader study that could converge stakeholder groups in a bid to find solutions to the risk management issues facing Australian farmers.

3.8 Chapter summary

In this Chapter, the research design was justified and the sources and collection procedure for both quantitative and qualitative data were highlighted. The design of the contracts was explained and the processes for analysing the relationship between yield and the insurance contracts designed. Explanations were made for the justification of the analytical techniques adopted and issues concerning the necessary assumptions were documented. Similarly, the analytics adopted in the examination of the systemic nature of the risk was fully explained from the insurer's perspective. Finally, the processes for the analysis of the primary data collected through interviews were enumerated.

4 CHAPTER FOUR: DESCRIPTIVE STATISTICS AND RELATIONSHIP BETWEEN YIELD AND INDEX

4.1 Introduction

This chapter is divided into five sections. In the first section (this section), the chapter is introduced. In Section 2, the preliminary analyses consisting of descriptive statistics for the yield and rainfall data are presented. The details of the descriptive analysis of the actual yield and rainfall data results are presented in Appendix 1. The third section features an analysis of the relationship between yield and rainfall index. The relationship analyses were done using four different regression methods. In the fourth section, the results of the relationship measures were correlated with some of the hedging efficiency results obtained in Chapter 5. In the final section, the results from this chapter are summarized. In some of the analysis, the effect size (r) was presented to elucidate on the size of the differences between contrasted groups.

4.2 Descriptive statistics

The descriptive analyses of the yield and rainfall data are presented in Appendix 1 in the Appendices section. The yield and rainfall data presented are the averages over the forty year period from 1971 to 2010 for each shire. The station numbers of the weather stations whose gauges were used and the amount of available data are also presented in Appendix 1. The yield and rainfall data are analysed in this section. There were 23 shires in Queensland and 40 from Western Australia making a total of 63 shires in the analysis.

Given the size of this sample, further statistical tests were conducted on the results of the relationship measures. The average skew of the yield distribution was -0.57 and 0.22 for seasonal rainfall. The skewness of mean wheat yield in Queensland (0.09) was significantly higher than that of Western Australia (-0.95) [t (61) = 3.96, r = 0.45, $p < 0.05$]. There were no statistically significant differences in the seasonal rainfall between the two states [t (61) = 0.32, r = 0.04, $p > 0.05$] as Queensland had an average skewness of 2.04 and Western Australia 1.98. Further details of the descriptive statistics could be found in Appendix 1.

The yield analysis shows that there were significant differences in the mean of wheat yields between Queensland (1.90 t/ha) and Western Australia (2.28 t/ha) although the effect size (r) is approximately moderate [t (61) = -2.83, r = 0.34, $p < 0.05$]. Significant differences were also observed in the Coefficients of Variation (CV) of the mean yields [t (61) = 9.96, r = 0.79, $p < 0.05$] with variation in yield per unit of production being higher in Queensland (0.27) than in Western Australia (0.09). The effect size (r = 0.79) in variation in differences was much stronger for the variation in yield than for yield (r = 0.34) itself between the two states.

Analysis of the seasonal rainfall shows that the mean difference of 19.21 between Queensland (257.17mm) and Western Australia (276.37mm) was not significant [t (61) = 0.77, r = 0.10, $p > 0.05$]. However, the variance per unit of seasonal rainfall measured as Coefficient of Variation (CV) indicated significance [t (-0.77) = 0.08, r = 0.00, $p < 0.05$] between the states of Queensland (0.41) and Western Australia (0.25).

Further analysis was conducted on the dependence between yield and seasonal rainfall. It was found that there was a positive correlation between wheat yield and seasonal rainfall [$r = 0.36$, $p < 0.05$] but the relationship of yield with variability in seasonal rainfall (CV) was negative [$r = - 0.50$, $p = 0.05$]. Further analyses were conducted with the Chi-square test of dependence and it was found that there was a statistically significant dependence between wheat yield and CV of seasonal rainfall [χ^2 (4) = 22.86, $p < 0.05$] as shown in Table 4.1 below. The dependence affirmed the negative relationship between rainfall variability and wheat yield. In essence, farmers in locations with high rainfall variability tend to experience low yield.

Table 4-1: Cross tabulation of wheat yield and seasonal rainfall variability

	Yield	Low	Moderate	High	Total
Rainfall variability	Low	2	6	13	21
	Moderate	6	12	3	21
	High	13	3	5	21
	Total	21	21	21	63

4.3 Relationship between yield and weather index

Four methods were adopted in the analysis of the relationship between yield and weather index. These are the Ordinary Least Square Regression (OrdReg), Quadratic Regression (QuadReg), Quantile Regression (QuantReg) and Panel Regression (PanReg). Only the results from the 60mm capped optimized contracts are reported. The details of the analysis from the other contracts (50mm capped optimized, 60mm capped equally weighted, uncapped optimized and uncapped equally weighted contracts) are qualitatively similar.

The Random Effect (RE) was preferred over the Fixed Effect (FE) in the PanReg because the Hausman test indicated the choice of RE. The analysis indicated that there was a panel effect [$R^2 = 0.55$, $p < 0.05$]. The implication of the panel effect was that each shire will require different indices to capture the relationship between weather and yield and so a generic index will not suffice. This diversity may be due to differences in soil types and other variations across the locations. The results of the RE for each of the states and both states indicated that there was a very strong relationship between the index and yield and therefore weather index could be a viable proxy for yield in calculating insurance.

The analysis of the relationship was also conducted based on OrdReg and QuadReg. It was found that the relationship was strongest in Gayndah shire for OrdReg [$R^2 = 96.93$, $p < 0.05$] and QuadReg [$R^2 = 96.86$, $p < 0.05$]. The result from the QuadReg was surprisingly lower than the OrdReg by 0.07% in Gayndah. Additionally, in Banana shire, the QuadReg indicated that rainfall index accounted for 36.78% of the variance in yield while the OrdReg accounted for 38.00%. However, on average, the QuadReg indicated that rainfall index accounted for 4% additional variance in yield than the OrdReg (See Table 4.2 below). It was expected that the QuadReg will capture the relationship between yield and rainfall index better than the OrdReg but it was found that this was not true in all cases. The reason for the expectation is that low rainfall should lead to poor yield and excess rainfall could have a similar effect thereby leading to a quadratic trend in the yield index relationship rather than a linear trend.

Across all the quantiles, the QuantReg was also found to be strongest in Gayndah shire with the strongest OrdReg yield-index relationship. However, Booringa shire had a Pseudo - R^2 of 90.26 for the OrdReg but the relationship measure based on the QuantReg (Pseudo - R^2) were not sufficiently close to the results from those of Gayndah as the OrdReg results will suggest.

The patterns in the distribution of the Pseudo-R^2 across the quantiles indicated that in some shires the relationship strengthens towards the median (50th percentile) and declines towards the 95th percentile. The Gayndah shire typifies this trend from 81.5% at the 5th quantile up to 83.39% at the median. This rise declined to 81.61% at the 95th percentile. The trend in the QuantReg analysis for Boddington shows a consistent steep decline from the 5th percentile (56.75%) to the 95th percentile (0.32%). These are the two prevalent trends in the distribution of the QuantReg results. The result suggests that the shires were more susceptible to drought than flood except for Irwin and Mount Marshal where there were slight deviations from the norm. The results from the QuantReg therefore suggest that there may be disparity by location in the strength of the yield-index relationship which may have some impact on hedging efficiency since the proxy for yield (weather index) is diversely related to yield.

The means of the relationship measures at the end of Table 4.2 for each of the states and all states combined indicated that the relationship reduced towards the higher quantiles for QuantReg and was stronger with QuadReg than the OrdReg. The mixed model results were rejected because the sphericity assumption failed and could not be corrected. The MANOVA results, based on Pillai's statistics, were therefore reported. There was a significant effect of regression methodology on yield index relationship [F (8, 54) = 81.31, p < 0.05] as would be expected particularly because the QuantReg results were disaggregated. The state effect was significant [F (1, 61) = 4.16, p < 0.05] but its interaction with the regression methodologies was not [F (8, 54) = 1.82, p < 0.05]. This insignificant interaction suggests that the differences in the regression results did not differ between the states.

The effect of weighting was also analysed based on the 60mm capped optimized contract at the 5th, 10th and 30th percentiles of the quantile regression because they were relevant to the analysis in the next chapter. It was found that the weighting of the dekads (See Chapter 3) has an impact on the strength of the relationship [F (5, 305) = 99.93, p < 0.05]. It is expected that the effect of weighting could be evident in the hedging efficiency results as well (See Chapter 5). There was a significant interaction between weighting and state [F (5, 305) = 7.45, p < 0.05] and the main effect of state was not significant [F (1, 61) = 0.07, p < 0.05]. In essence, weighting differs between the two states and should be expected to differ by shire.

The analysis of the effect of rainfall caps adopted was also tested based on the comparison among 50mm capped optimized contract, 60mm capped optimized contract and uncapped optimized contract. MANOVA results were more appropriate for the analysis because of the violation of the sphericity assumption which could not be corrected but the outcome of the mixed model result indicated otherwise. It was found that capping had a significant effect on the yield-index relationship at the 5th, 10th and 30 percentiles [F (8, 54) = 2.34, p < 0.05]. This result should however be taken with caution since it differs from the most appropriate model. However, the main effect of state did not indicate any significant difference [F (1, 61) = 1.41, p < 0.05]. The interaction between capping and state shows that the capping effect did not differ between the two states [F (8, 54) = 1.73, p < 0.05]. Hence, the capping effect could be said to be the same between the two states.

#Table 4-2: Regression analyses of yield and weather indices for 60mm capped optimized contracts

Shires	Pseudo R^2 for Quantile Regression at different quantiles							Adjusted R square for OrdReg	QuadReg
	5th	10th	30th	50th	70th	90th	95th		
Balonne	**57.06**	**55.85**	**52.08**	**50.04**	**41.2**	**23.24**	**21.87**	**69.62**	**71.19**
Banana	**45.55**	**45.12**	**27.59**	**25.23**	**24**	**18.25**	11.38	**38.00**	**36.78**
Bauhinia	**49.26**	**49.96**	**39.29**	**33.69**	**29.36**	5.56	2.26	**47.00**	**45.63**
Bendemere	**62.91**	**66.67**	**67.77**	**70.6**	**72.87**	**72.68**	**72.18**	**90.24**	**90.64**
Booringa	**44.77**	**52.42**	**58.14**	**66.09**	**72.86**	**79.15**	**76.71**	**90.26**	**91.78**
Bungil	**58.97**	**55.91**	**54.55**	**58.19**	**59.58**	**52.62**	**47.72**	**80.50**	**81.05**
Cambooya	**58.82**	**55.73**	**45.68**	**44.91**	**36.93**	**19.26**	14.64	**64.40**	**67.35**
Clifton	**67.4**	**63.6**	**60.00**	**58.89**	**54.07**	**41.26**	**39.34**	**81.20**	**82.97**
Duaringa	**17.01**	**25.14**	**24.63**	**24.18**	**28.54**	**30.5**	**36.47**	**45.18**	**44.39**
Emerald	**18.08**	**19.09**	**28.53**	**30.48**	**29.7**	**18.24**	16.97	**42.12**	**41.42**
Gayndah	**81.5**	**82.85**	**83.21**	**83.39**	**82.91**	**83.1**	**81.61**	**96.93**	**96.86**
Inglewood	**58.22**	**57.36**	**57.13**	**62.79**	**63.75**	**71.22**	**74.03**	**84.49**	**84.71**
Jondarayan	**39.33**	**43.73**	**45.55**	**35.29**	**38.47**	**26.74**	**26.27**	**61.81**	**65.52**
Kilkivan	**36.3**	**36.33**	**25.64**	**29.46**	**26.11**	20.33	30.58	**44.23**	**42.81**
Kingaroy	**16.83**	**29.05**	**32.07**	**38.66**	**37.17**	20.49	**9.25**	**51.74**	**50.67**
Millmerran	**48.04**	**43.28**	**46.26**	**48.31**	**41.99**	**41.62**	**46.33**	**68.90**	**72.77**
Munduberra	**48.79**	**50.38**	**54.5**	**57.03**	**63.97**	**57.94**	**53.8**	**82.16**	**81.71**
Pittsworth	**29.58**	**31.08**	**33.57**	**29.76**	**21.67**	11.07	4.42	**45.33**	**49.63**
Rosalie	**41.33**	**31.39**	**25.85**	**21.78**	18.69	4.62	0.5	**37.67**	**38.84**
Tara	**55.17**	**53.47**	**59.76**	**62.92**	**67.56**	**58.32**	**52.26**	**85.11**	**84.89**
Waggamba	**52.38**	**52.45**	**58.34**	**59.14**	**53.74**	**45.14**	**38.91**	**79.24**	**78.69**
Waroo	**43.76**	**47.85**	**43.13**	**42.7**	**41.76**	**25.82**	12.76	**63.02**	**64.35**
Wondai	**65.37**	**65.17**	**61.71**	**58.89**	**56.29**	**50.11**	**38.13**	**81.81**	**84.12**
Boddington	**56.75**	**44.45**	14.15	3.42	0.29	0.18	0.32	**46.56**	**72.96**
Broomehill	**43.2**	**28.88**	8.67	5.86	0.58	1.18	1.97	**26.28**	**42.05**
Bruce Rock	**62.7**	**58.21**	**41.82**	**42.05**	**36.75**	**23.01**	16.12	**67.64**	**81.86**
Carnamah	**46.64**	**47.8**	**53.15**	**44.89**	**33.53**	16.09	13.23	**68.15**	**69.78**
Chapman	**52.17**	**55.64**	**50.64**	**48.08**	**40.32**	**34.98**	**33.13**	**71.56**	**73.68**
Coorow	**42.11**	**44.11**	**48.83**	**44.19**	**30.11**	11.62	11.09	**65.11**	**65.76**
Corrigin	**63.19**	**58.14**	**54.14**	**57.81**	**54.69**	**34.81**	**25.1**	**78.31**	**81.83**
Cunderdin	**63.55**	**58.81**	**58.81**	**56.7**	**49.49**	**27.74**	**23.2**	**76.59**	**78.91**
Dalwallinu	**53.4**	**52.01**	**45.18**	**47.7**	**42.98**	18.43	13.82	**64.33**	**63.37**
Dumbleyung	**48.32**	**36.45**	**27.29**	**29.44**	**23.65**	11.97	9.84	**48.76**	**58.69**
Esperance	**48.94**	**47.7**	**38.68**	**30.03**	**22.61**	**15.53**	**12.31**	**48.57**	**49.09**
Goomaling	**68.23**	**58.09**	**52.08**	**50.82**	**46.62**	**32.5**	23.34	**73.43**	**77.52**
Irwin	0.57	0.18	0.21	**10.76**	14.51	12.68	10.89	**13.77**	**11.69**
Jerramungup	2.16	1.57	4.79	5.66	**3.95**	5.24	16.51	**37.03**	**52.9**
Katanning	0.39	0.93	4.77	4.76	5.57	0.04	1.19	**26.65**	**47.09**
Kellerberin	**52.82**	**45.5**	**26.5**	**28.7**	**30.69**	**21.64**	**13.29**	**48.74**	**52.01**

Kent	26.97	19.4	7.28	7.61	**7.19**	1.47	0.53	**17.41**	**18.22**
Kondinin	**58.93**	**56.53**	**49.49**	**45.5**	**41.85**	**39.66**	**43.36**	**68.28**	**68.24**
Koorda	**60.5**	**61.65**	**53.49**	**52.54**	**45.24**	**29.48**	**26.45**	**72.71**	**73.98**
Kulin	**56.09**	**58.07**	**55.9**	**52.81**	**42.99**	**25.91**	**21.38**	**75.01**	**77.8**
Lake Grace	**73.08**	**65.22**	**57.32**	**5.25**	**42.67**	**31.97**	**23.77**	**78.33**	**83.62**
Merredin	**40.08**	**34.01**	**31.92**	**35.78**	**40.21**	**34.86**	23.75	**82.23**	**85.58**
Moora	**16.92**	**34.38**	**48.51**	**45.9**	**31.86**	**18.02**	**11.56**	**59.38**	**59.26**
Morawa	**58.98**	**60.29**	**55.96**	**53.5**	**50.53**	**37.09**	**27.83**	**75.54**	**75.01**
Mount Marshal	8.8	**17.8**	**20.14**	**24.46**	**26**	**27.39**	**20.82**	**37.28**	**35.83**
Mukinbudin	**54.04**	**59.41**	**60.48**	**60.52**	**58.67**	**57.4**	**52.88**	**82.28**	**82.15**
Narembeen	**68.13**	**65.67**	**59.75**	**58.12**	**57.7**	**47.58**	**41.89**	**81.84**	**84.04**
Narrogin	**12.12**	9.54	2.95	4.08	2.52	6.37	6.27	**2.32**	0.76
Northam	**42.27**	**22**	**11.21**	**14.2**	**16.09**	**8.93**	0.57	**30.34**	**42.46**
Northampton	**50.5**	**54.05**	**42.16**	**31.45**	14.26	3.38	2.8	**58.11**	**68.81**
Nungarin	**60.64**	**59.62**	**60.6**	**64.45**	**68.3**	**68.38**	**66.18**	**86.98**	**87.19**
Pingelly	**60.91**	**62.27**	**58.41**	**51.38**	**48.29**	**38.82**	**32.48**	**77.58**	**80.48**
Quairading	**44.67**	**36.16**	**21.74**	**19.93**	10.54	3.57	0.37	**39.92**	**50.46**
Ravensthorpe	**56.15**	**46.93**	**30.73**	**19.52**	**15.39**	3.47	2.7	**46.75**	**58.31**
Tammin	**48.31**	**43.85**	**30.9**	**33.35**	**19.69**	7.99	6.2	**47.55**	**54.44**
Trayning	**69.57**	**65.34**	**61.68**	**60.94**	**62.31**	**61.74**	**61.11**	**84.91**	**84.53**
Westonia	**33.78**	**36.64**	**46.71**	**53.68**	**55.78**	**53.84**	**47.52**	**73.14**	**72.55**
Wickepin	**48.62**	**45.34**	**22.19**	7.96	4.66	1.72	0	**40.28**	**66.6**
Yilgarn	**61.05**	**59.32**	**61.61**	**59.62**	**58.62**	**50.18**	**48.23**	**81.44**	**80.98**
York	**29.69**	**19.45**	**20.74**	**18.54**	**18.1**	4.09	3.37	**37.29**	**61.69**
QLD	*47.67*	*48.43*	*47.17*	*47.50*	*46.23*	*38.14*	*35.15*	*66.56*	*67.34*
WA	*47.65*	*44.52*	*38.26*	*35.33*	*32.03*	*23.15*	*19.52*	*57.46*	*63.30*
All	*47.65*	*45.95*	*41.51*	*39.77*	*37.21*	*28.62*	*25.22*	*60.78*	*64.78*

[#] *Bold values are significant at 95% confidence interval. The average values for each of the states and the two states were not in bold but italicised.*

4.4 Summary

In this chapter, it was found that there were disparities in the yield and rainfall variability between the two states. Also, the relationship measures were found to differ across the quantiles and methods of regression analyses adopted. Overall, the shires were found to be more susceptible to drought than flood given that the relationship is stronger at the lower quantiles than at the upper quantiles. Similarly, it was found that yield outcome was influenced by rainfall variability.

5 CHAPTER FIVE: HEDGING EFFICIENCY

5.1 Introduction

This chapter (Chapter 5) addresses the second research question on the hedging efficiency of weather index insurance contracts. The previous chapter (Chapter 4) was on the first research question about the relationship between the weather indices and yield. The relationship between yield and weather indices was a preliminary assessment of the prospects of the hedging efficiency of the contracts which is tested in this chapter. The Quantile Regression (QuantReg) analysis in the previous chapter was an attempt to capture the implications of the yield-index relationship at the tails. In particular, a previous study by Vedenov and Barnett (2004) considered the implications of the yield-index relationship across the whole continuum with hedging efficiency at different levels. Disaggregating the relationship continuum at the quantiles corresponding to the alpha levels of the hedging efficiency was expected to improve the correlation between yield-index relationship and hedging efficiency.

The chapter is divided into eight sections. The first section introduces the chapter. In the next three sections, the hedging efficiency of weather index insurance contracts were analysed using each of the three analytical methods in each section. The first method used was Conditional Tail expectations (CTE) in Section 5.2, next the Mean Root Square Loss (MRSL) in Section 5.3 and the willingness of farmers to pay was analysed with Certainty Equivalence of Revenue (CER) assuming Constant Relative Risk Aversion (CRRA) in the fourth section. In the fifth section (Section 5.5), results from the three measures of hedging efficiency discussed in the preceding three sections were compared. Section 5.6 features a graphical illustration of the Balonne shire given its consistently positive results. In Section 5.7, the correlation analysis of hedging efficiency with the regression results are presented while in the concluding section (Section 5.8) the results from the chapter are summarized.

The first method, CTE, was used to examine whether the contract payouts match with years of low yield. That is, if the farmer gets a payout from the insurance contracts in years of drought, there should be an increase in his revenue if the payout exceeds the premium paid that year. In normal years, the farmer will have to forfeit his premium. Should there be a mismatch in payouts, that is, there were payouts in years when there were no droughts, then, there will be a decrease in CTE leading to a negative change in revenue between the non-insured farmer and the insured farmer. This assessment was done under two price assumptions. The first price assumption being constant price and the second a variable price assumption.

Since the evaluation of hedging efficiency is based on changes in the revenue of the farmer, it could be influenced by the interaction between yield and price. The constant price assumption tacitly suggests a zero correlation between yield and wheat prices while the variable price assumption implies a non-zero correlation. A comparative analysis of hedging efficiency results based on the constant and variable pricing of wheat is expected to contribute to knowledge. The reason for this comparison is necessitated by the fact that researchers assumed that commodity prices were constant in previous studies (Turvey 2001; Vedenov & Barnett 2004; Kapphan, Calanca & Holzkaemper 2012). The assumption tacitly suggested that price hedging was costless and ignores the covariate structure of yield and price which serves as a natural hedge. It is expected that a comparative analysis of the efficiency results based on variable and constant price would contribute to knowledge.

MRSL, the second method, was adopted in the analysis of the downside risk reduction effects of the contracts. If the contracts pay out in the years of low yields, then it amounts to cutting resources from years of high yield through premium payments by the farmer to compensate in years of low yield through a net payment from the insurer to the farmer. Consequently, the revenue of the farmer should be more stable in that the variance will reduce. In particular the downside risk was considered because farmers like all rational investors only want to minimise their downside risk. This analysis (MRSL) was also conducted under assumptions of constant and variable commodity prices. In this case, negative values of MRSL were considered efficient because it implies a reduction in the downside risk.

The third analysis examines the Certainty Equivalence of Revenue (CER) of the farmer. The CER is an analysis of the willingness of farmers to pay for the insurance. A positive change implies that the CER increases with insurance and therefore the representative farmer in the shire is willing to pay for the insurance. In other words, one could conclude that the farmer would have derived value from the insurance over the forty year period under consideration and therefore be willing to pay for it. The analyses were also based on the assumptions of constant and variable pricing of wheat.

Each of the three methods discussed above (CTE, MRSL and CER) was adopted in the analysis of 50mm capped optimized, 60mm capped optimized, 60mm equally weighted, uncapped optimized and uncapped equally weighted contracts. The capping supposes that the actual rainfall over the ten day period (dekads) will not be in effective use by the plant and the cap is the maximum that will be effectively utilized. That is, rainfall in excess of the caps (50mm and 60mm) is of no use to the crop. The uncapped rainfall implies that actual rainfall data over the ten day period were considered. Based on expert suggestions, the 60mm cap was adopted. For instance, an agronomist who was a part of the Focus Group Interview suggested 50mm cap for Cecil Plains which is in Millmerran shire in Queensland. When the results from the 50mm and 60mm caps were compared for the shire, the 60mm cap yielded better results for the shire. Since there were no documented evidences of the appropriate decadal rainfall caps for Australian shires, the 60mm cap was taken and was acceptable to other experts. It was not within the time and resource constraints of the researcher to acquire the necessary information across all the shires from experts. Even if such information were collected from experts, the experience with Millmerran suggested that the information may not necessarily add value to the analyses.

Hence, the focus of the analysis was based on the 60mm-capped optimized results in order to keep the analysis tractable. The results from the 60mm cap were however contrasted with those from the 50mm optimized contracts and uncapped optimized contracts as a form of sensitivity analysis. Also, the effect of weights (optimized and equally weighted) was examined particularly between the 60mm capped optimized and the 60mm equally weighted contracts. The results of the efficiency were also examined across the three methodologies and with respect to seasonal rainfall variability.

The analyses of the *capped optimized contracts* (60mm) are tabulated in this chapter but the results from the other contracts are shown in the appendix. Further statistical analysis of the impact of insurance on the revenue of the farmer was conducted using the three analytical techniques (CTE, MRSL and CER) with the assumption of constant and variable (stochastic) prices for the five (50mm capped optimized, 60mm capped optimized, equally weighted, uncapped optimized and uncapped equally weighted) contracts. The statistical analyses adopted were; categorical count tests (Binomial test of proportions and chi-square), the one sample t-test and the mixed model that captures the use of the same samples over different strike levels, price assumptions and other conditions. However, the results from the mixed model were compared with those of the Multivariate Analysis of Variance (MANOVA) when the sphericity assumption is violated and could not be corrected (Field 2009). When the results were similar to the MANOVA's, they are accepted as valid even if the sphericity assumptions were violated. See Chapter 3 (Methodology) for details. There were 23 shires from Queensland and 40 from Western Australia making a total of 63 locations in the analyses.

Additional analyses were conducted as a robustness test to the mixed method design. The count tests were conducted because differences may exist between the proportions of shires that were efficient and those that were not whereas the mean tests may not reveal this if the proportions that were efficient have higher impacts of insurance than those that were inefficient. In essence, if 50 locations indicated efficiency and 13 were inefficient but the impact, measured in terms of percentage changes to the revenue, were much higher in the 13 shires that are inefficient, the mean tests may not signal significance or could indicate a net inefficiency. Should a significant difference be flagged between the two groups, the proportion effect may be hidden. The Binomial test of proportions was therefore considered to unveil this effect. Although, the mixed model/MANOVA may capture the interaction effects between certain variables of interest, the chi-square analysis was also adopted to consider the dependence in terms of proportions rather than means and to elucidate the complex interactions that may exist among the variables. Notwithstanding the efforts to ensure that all statistical rules were adhered to, the researcher concurs with Field (2009, p.478) that; Statistics is not a recipe book and that sometimes we have to use our own discretion to interpret data.

5.2 Hedging efficiency results from Conditional Tail Expectations (CTE)

5.2.1 Analysis of CTE based on mean tests

The Conditional Tail Expectation (CTE) analysis was conducted in order to know whether or not insurance would increase the gross revenue of the representative farmer at the respective strike levels in years of rainfall deficit. The analysis presented in this section is based on Table 5.1 below and details on how to derive the values were explained in Chapter 3 (Methodology). The CTE values were derived based on constant and variable price assumptions as shown in the table. Under each price assumption, the contracts were designed at the 5^{th}, 10^{th} and 30^{th} percentile strikes. The 'None' columns represent the revenue of the farmer (in Australian dollars) without insurance contract at the alpha levels corresponding to the strike levels while the changes to the revenue, in percentages, as a result of the insurance contracts were presented in the columns following the 'None' columns. These columns (Δ^{5th} (%), Δ^{10th} (%), Δ^{30th} (%) in the table) represent the columns representing the changes in percentages to the revenue (where n = 5th, 10th and 30th percentile strikes corresponding to).

Where the changes were positive, the farmers' revenue streams were improved by the insurance over the forty year period and negative otherwise. The table has three panels (Panels a to c). In Panel a, the actual results of the CTE were presented at each strike level under the two price assumptions. In Panel b, the descriptive analyses of the CTE results were presented while the last panel presents the outcomes of the One-Sample t-test for the changes in CTE resulting from the insurance contracts. Only the changes in CTE were analysed. The table represents the CTE analysis for the 60mm capped optimized contracts. The results of the other contracts (50 mm capped optimized, uncapped optimized, capped equally weighted and uncapped equally weighted) could be found in the Appendices (Appendix 3 to 6). Since the initial revenue streams of the farmers were the same without insurance at all strikes and price assumptions as in Table 5.1, only the percentage changes were presented in the Appendices.

The 5th percentile contract was evaluated at the 5% alpha level and the other strikes were also evaluated at their corresponding alpha levels. The nature of the analysis of the CTE presented in Table 5.1 is different from those of Mean Root Square Loss (MRSL) and Certainty Equivalence of Revenue (CER) because the values of CTE were calculated with and without insurance at each strike level. The values of MRSL and CER were calculated for the none insured state and then compared with the insured states at the respective percentiles. Therefore, for the CTE, there were none insured and insured values at each strike level. The insured values of MRSL and CER at each strike were compared with only one uninsured value under each price assumption.

The CTE results from the 60mm capped optimized contracts are presented in Table 5.1 below. Under the constant price assumption, as could be seen in Table 5.1, the capped optimized insurance contracts at the 5th percentile increased the CTE by 2.13% on average (SD = 5.22) when insurance was taken. The highest reduction in CTE was 4.23% experienced by the representative farmer in Pittsworth while the highest increment in CTE (21.46%) was experienced in Quairading. It was observed that the mean CTE at the 5th percentile strike was \$369.54 and this increased to \$374.49 with a 5th percentile insurance contract. At the 10th percentile strike, there was a decrease in the net increment in CTE relative to the 5th percentile contract. At this strike level, the CTE increased by approximately 0.97% (SD = 4.45) compared to 2.16 at the 5th percentile. At the 30th percentile strike, there was a net decrease in CTE by approximately 2.96% (SD = 4.43). One sample t-test analyses showed that the increase at the 5th percentile strike [t (62) = 3.24, $p < .05$] and the decrease at the 30th percentile strike [t (62) = -5.31, $p < .05$] were significantly different from the indifference point of zero. The effect of insurance, in terms of the difference it makes, has lower standard deviations along the strike levels. In essence, the results were more closely knitted together at the higher percentile strikes than at the lower strikes. One could say that the variation in the impact of insurance as measured by CTE was higher when drought was very intense in comparison to when drought was mild. Based on the analysis above, it is obvious that the increase in revenue due to insurance was more prominent with the 5th percentile contract. This means that insurance would be most beneficial for a once in 20 year drought than milder droughts as intuition suggests.

Under the variable price assumption, the results were generally negative. At the 5th percentile strike, insurance reduced the average revenue of the representative farmer as measured by CTE by 2.00% (*SD* = 5.24). At the 10th and 30th percentile strikes the insurance reduced the outcomes by 2.85% (*SD* = 4.46) and 0.34% (*SD* = 3.20) respectively. These differences were significantly above the zero cut off (the indifference point) using one-sample t-test at the 5th [t (62) = -3.03, $p < .05$) and at the 10th [t (62) = -5.07, $p < .05$] percentiles but not significant at the 30th percentile [t (62) = -0.85, $p > .05$]. The trend in the decrease in standard deviations with insurance and across the strikes was also observed under the variable price assumption as it was under the constant price assumption. The standard deviations of the CTE with insurance were found to reduce relative to the case of no insurance.

The analyses above may be better understood by looking at Figure 5.1 below. The figure shows that with the assumption of a variable price, the effect of insurance reduced relative to the constant price assumption. For example, under the 5th percentile contract, CTE was 3.55% above zero in Queensland but 1.32% above in Western Australia when prices were constant. At the same strike under variable pricing, all shires experienced a reduction in CTE. The last panel of Table 5.1 indicated that significance of these and other results unveiled in Figure 5.1. By implication, analysis based on constant price at the 5th percentile strike would be different from reality. The situation is somewhat different across the higher strikes. Therefore, the definition of drought and price assumption has implications for the hedging efficiency of weather index insurance. Further analyses were conducted to ascertain the validity of these observations. The differences between groups of interest were contrasted using effect sizes (r) reported in parentheses.

The efficiency of the 60mm Capped Optimized Insurance contract was analysed using the mixed-model statistical technique. The sphericity assumption was corrected with Greenhouse-Geisser statistics. This implies that the Mixed-model results could be accepted. It is also worth noting that the conclusions that were drawn from the mixed-model analysis were the same with the Multivariate Analysis of Variance (MANOVA) results. All results are presented at the 95% level of significance.

Overall, the effect of the insurance was negative in that there was a net reduction in CTE by 0.34%. However, the main effect of price was significant [F (1, 61) = 54.74]. The contrasts revealed that constant price assumption resulted in a significantly higher CTE value than when the variable price was assumed [F (1, 61) = 54.74, r = 0.69]

In particular, the pairwise comparison revealed that efficiency was higher when constant price was assumed than under the variable price assumption by 1.90%. The interpretation of this significance is that constant price assumption would be more profitable for farmers than variable price assumption. The variable price assumption actually made the farmer worse off while the constant price model analysis shows that the farmer could at least be marginally better off with insurance when the results were aggregated. However, there were differences among the locations in terms of hedging efficiency based on CTE.

On the basis of this analysis, the assumption of a variable price reduces the incentives of farmers to insure because of the interaction between yields and commodity prices. Therefore, previous models that assumed constant price might have overestimated the benefits of insurance since in reality the inverse relationship between yield and price may offset some of the risks. The main effect of state showed that there was a significant difference in the impact of insurance between the two states based on CTE analysis [F (1, 61) = 17.146].

While Queensland had a net positive result of 1.51% net increase in CTE, Western Australia had a net decrease of 2.20%. Analysis of the contrast affirmed that this difference is significant [F (1, 61) = 18.34, r = 0.48]. Based on this result, one would expect that there will be differences in the efficiency results within each shire if farm-level analyses were conducted. The differences may be due to variability in rainfall and differences in soil type. In practice, the differences will be further aggravated by the differences in farm-gate prices and individual farmer's management practices.

The main effect of strike levels was found to be significant [F (1, 61) = 3.68]. The contrasts revealed that there were differences in the results between the 5th and the 30th percentile strikes [F (1, 61) = 4.66, r = 0.27] and between the 5th and 10th [F (1, 61) = 4.34, r = 0.26] percentile strikes but not between the 10th and 30th percentile strikes [F (1, 61) = 1.20, r = 0.14]. The result suggests that efficiency results differ by the strike levels.

The interaction between price assumptions and strike levels indicated a significant effect [F (2, 122) = 213.86]. The implication of this result is that the hedging efficiency outcomes based on CTE is influenced by strike levels and the influence differed between the two price assumptions. To breakdown this interaction, contrasts were performed comparing each pair of strike levels. These revealed significant interactions when comparing constant and variable price assumptions for 5th percentile strike compared to 30th percentile strike [F (1, 61) = 258.83, r = 0.90], and for 10th percentile compared to 30th percentile strike [F (1, 61) = 317..89, r = 0.92]. Contrast was also performed for the 5th and 10th percentile strikes across the two price assumptions. The difference was found to be insignificant [F (1, 61) = 1.445, r = 0.15]. The effect sizes revealed a very strong impact of price assumption on the outcomes based on strike levels. In essence, the impact of price assumptions on hedging efficiency is evidently large enough to note in that it is certainly not due to any form of randomness in the data but a definite effect. The disparity due to price assumption was however insignificant between the two lowest strikes. In essence, price effect is not very different between very intense (5th percentile strike) and intense (10th percentile strike) droughts but differences exist in the effect of price between these two levels of drought and when drought is milder at below average rainfall (30th percentile strike).

In other words, the assumption made about commodity price could affect the CTE hedging efficiency results and this outcome also varies by strike levels. The effect seems to be closely related between once-in-twenty-year drought and once-in-ten-year drought. In particular, the constant price showed a positive CTE at the 5th percentile strike but a negative CTE at the same strike level when variable price was assumed (See Figure 5.1 below). Higher strikes indicated positive results under the constant price assumption and negative results under the variable results. This result suggests that price variability provides a natural hedge for the farmer particularly when drought is very severe. Put in another form, if farmers were assumed to operate under a price stabilization scheme that made price to be constant over the forty year period considered, then the benefit of the price hedge will be an intrinsic part of the value of insurance should the price stabilization be free. If the cost of the price stabilization is deducted from the value of insurance, then, the actual value of insurance remains. Hence, the value that is attributable to insurance should be expected to be lower when variable price is assumed than when a constant price assumption is made because it excludes the benefit attributable to price stabilization. The means revealed that when constant price was assumed, CTE was 0.60% higher with insurance but 1.28% lower when prices were variable leading to a mean difference of 1.88%.

The interaction between states and strike levels also indicated a significant effect [F (2, 122) = 10.41]. The implication of this result is that the CTE efficiency outcomes by strike levels differed between the two states. To breakdown this interaction, contrasts were performed comparing each pair of strikes. Significant interactions were observed when comparing Queensland and Western Australia among all the pairwise contrasts; between the 5^{th} percentile strike and the 30^{th} percentile strike [F (1, 61) = 13.51, r = 0.43], and the 10^{th} percentile compared to 30^{th} percentile strike [F (1, 61) = 7.43, r = 0.33] as well as the 5^{th} and 10^{th} percentile strikes [F (1, 61) = 6.81, r = 0.32]. However, the effect sizes were relatively small compared to the effect of price assumptions by strike levels. The results suggest that the difference between states noted in the main effect of state persists across all pairwise comparison of the strike levels. That is, state effect is prominent irrespective of the extent of drought. In essence, Queensland famers would have benefited more from the weather index insurance than Western Australian farmers.

The price-strike-state interaction was nonetheless insignificant [F (2,122) = 0.35]. The insignificance indicated that the interaction between price and strike did not differ between the two states. It could then be said that the impact of price on the efficiency of the contracts across the strikes is the same in Queensland and Western Australia. Since the interaction between CTE hedging efficiency results and state was noted to be significant, and differences were noted in the Coefficient of Variations (CV) of rainfall between the two states (See Chapter 4), it was deemed fit to analyse the data using the seasonal rainfall variability as a variable. The CV was divided into three levels low, moderate and high. The 21 shires with the lowest CV were considered to have low rainfall variability while the moderate and high variability shires were the next 21 higher CVs and the shires with the highest CVs were considered to be shires with high rainfall variability. This analysis was conducted under the variable price assumption only.

It was evident that rainfall variability has a significant impact on hedging efficiency as measured by CTE [F (2, 60) = 3.95]. The Bonferroni pairwise comparison of the *'Between-Subjects Effects'* of the three levels of rainfall variability indicated that the disparity was between the low and high rainfall variability regions with a difference of 2.81%. That is, farmers located in shires that were known to experience very high seasonal rainfall variability will benefit from insurance much more than those from low rainfall variability. The tendency therefore is that famers will move from locations that were experiencing lower rainfall variability to stabilize the effect of seasonal rainfall variability on their revenue. Such differences may cause a weatherinduced disparity in land value across Australian regions. The interaction between strike level and rainfall variability was also statistically significant [F (4, 120) = 3.80] but the complex interaction is best captured in the form of categorical analysis presented in Table 5.3.

The F-test analysis of the effect of capping was conducted only for results from variable price assumption because it was more realistic than the constant price model. It was found that capping had no significant impact on CTE [F (2, 122) = 18.23, $p > 0.05$]. The effect of the weighting scheme on hedging efficiency was examined by analysing the 60mm capped optimized and 60mm capped equally weighted contracts. It was found that optimally weighted contract and the equally weighted contracts differ by 0.469% and this mean difference was not significant [F (1, 61) = 1.77, $p > 0.05$]. The weight-state interaction also indicated no statistical significance meaning that differences in the weighting scheme will not be expected to differ by location [F (1, 61) = 3.23, p > 0.05] and the weight-state relationship is the same across the strikes [F (2, 122) = 1.66, $p > 0.05$].

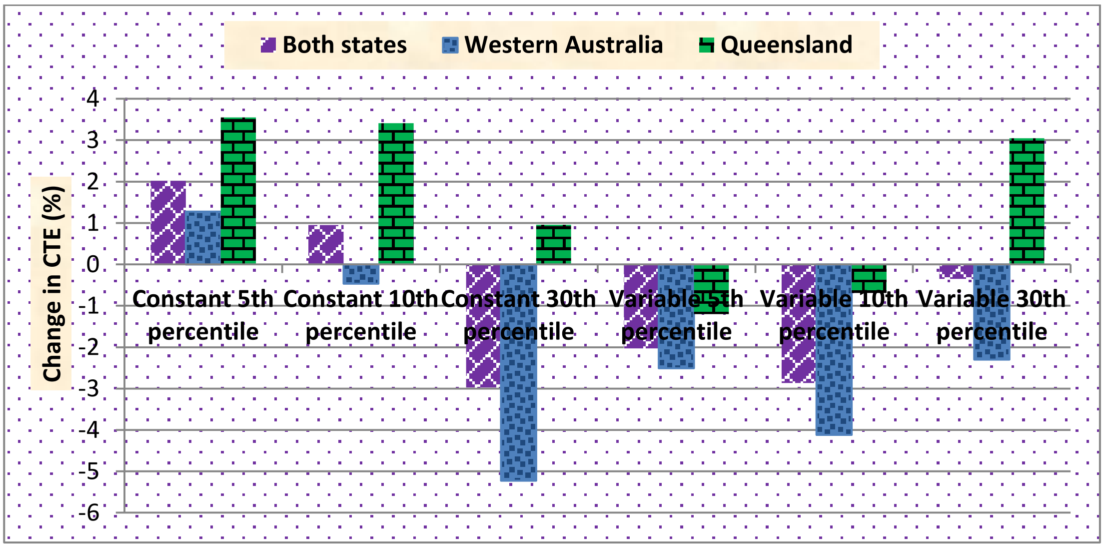

Figure 5-1: CTE results for 60mm capped optimized contract

The result in the graph above is more efficient under constant price because the trigger was based on the rainfall index which has a direct effect on yield when price was held constant. When prices were allowed to vary, though the triggers remained the same in that insurance was triggered in the same years as under the constant price model, the variability in prices reversed the benefit across the levels of drought intensity in QLD in particular. The trend in the reduction in the benefit of insurance was prominent when price was constant but the trend was distorted by price variability. In essence, price variability should be expected to distort the insurance market if it is not priced-in to the product design. Variable pricing reduces the impact of insurance at the 5th and 10th percentiles but increases it at the 30th percentile for QLD. In essence, variable pricing which is closer to reality inverts the outcomes of insurance particularly in Queensland. It seems that insurance benefits were least when drought is most intense under variable pricing but the converse is true under constant pricing. However, it may not be correct to say that in reality, farmers will not want to pay for insurance when drought is most intense, rather, insurance benefits will not be sufficient to make up for farmers' losses at the most extreme risk. They will therefore be at higher risk without insurance. This result could have resulted from basis risk causing mismatches in payments or variable price effect. When the analysis of the constant price is examined, it is evident that the mismatches in insurance payments alone could not have been the issue, rather the effect of price.

#Table 5-1: Hedging efficiency using Conditional Tail Expectations (CTE) for 60 mm capped optimized contracts

Panel a	Constant price						Variable price					
Strikes	5th		10th		30th		5th		10th		30th	
Shires	None ($)	Δ^{5th} (%)	None ($)	Δ^{10th} (%)	None ($)	Δ^{30th} (%)	None($)	Δ^{5th} (%)	None ($)	Δ^{10th} (%)	None ($)	Δ^{30th} (%)
Balonne	70.32	11.80	110.87	16.79	225.37	5.30	71.37	5.61	92.69	15.50	191.80	6.23
Banana	206.81	2.79	244.68	6.16	316.32	-1.13	170.63	-3.89	202.43	.87	280.83	2.35
Bauhinia	167.50	11.22	208.16	7.90	307.81	-1.17	165.49	4.35	191.17	.15	265.38	4.25
Bendemere	159.06	20.29	203.87	12.36	303.82	4.27	139.99	15.65	174.39	9.08	266.20	4.96
Booringa	145.97	1.72	167.86	3.38	228.57	2.85	117.15	-3.75	135.40	-.24	208.47	2.05
Bungil	178.33	-.44	208.91	1.21	309.83	4.33	132.95	-8.26	169.53	-4.49	277.60	4.14
Cambooya	468.32	5.99	516.34	1.72	621.64	-1.78	353.43	-.88	391.00	.29	527.43	2.25
Clifton	421.20	3.14	462.54	3.28	564.01	.20	317.61	-2.42	348.41	-4.32	480.08	3.31
Duaringa	303.13	.43	329.28	-1.21	388.61	-2.20	234.22	-3.41	259.01	-4.12	341.95	.97
Emerald	191.19	-1.75	202.14	-3.71	252.10	-.34	143.49	-.12	157.66	-3.93	222.71	4.45
Gayndah	197.33	4.14	225.16	7.73	305.02	4.01	148.52	-2.07	178.34	.80	273.30	3.02
Inglewood	220.57	3.32	236.44	2.17	283.85	.46	164.74	-4.35	176.81	-4.57	246.27	1.95
Jondarayan	191.19	-1.75	202.14	-3.71	252.10	-.34	143.49	-.12	157.66	-3.93	222.71	4.45
Kilkivan	576.47	-3.75	607.60	-5.80	666.57	-11.66	440.41	-6.70	487.53	-9.59	632.23	-3.35
Kingaroy	221.25	-.58	265.57	2.74	377.66	1.86	172.10	-9.35	215.58	-3.43	329.32	1.69
Millmerran	369.61	4.07	397.32	2.11	473.47	.78	271.86	-3.90	301.55	-4.56	402.55	1.42
Munduberra	302.45	1.11	330.75	.34	400.33	2.25	233.31	-5.76	261.48	-1.86	359.17	2.21
Pittsworth	405.90	-4.23	456.63	-.56	576.77	-2.34	339.99	-6.07	368.78	-4.83	486.61	2.33
Rosalie	224.10	5.21	273.38	5.59	400.14	.86	176.38	-2.14	218.03	1.54	340.36	3.14
Tara	162.71	2.34	178.62	5.12	259.39	4.64	117.54	-3.98	139.83	-1.81	232.33	4.18
Waggamba	140.10	8.99	173.30	5.58	270.77	3.99	120.68	9.74	145.98	2.00	235.11	4.57
Waroo	162.71	2.34	178.62	5.12	259.39	4.64	117.54	-3.98	139.83	-1.81	232.33	4.18
Wondai	326.82	-.33	356.68	.98	441.10	1.36	245.69	-4.81	283.56	-.54	386.23	2.54
Boddington	480.19	5.47	538.75	3.75	600.23	-3.23	335.53	4.57	374.58	2.10	505.26	0.04
Broomehill	447.51	10.79	530.40	5.91	616.00	-5.10	316.47	-1.18	369.42	2.53	528.44	-1.01
Bruce Rock	316.80	10.22	360.94	5.24	424.69	-.86	249.38	2.24	280.25	-.48	363.45	.04

Carnamah	488.18	.08	503.26	-2.13	543.71	-5.02	340.94	-3.33	361.56	-6.06	457.30	-4.31
Chapman	506.23	-1.87	513.52	-2.09	528.24	-7.37	323.73	-4.17	346.07	-5.32	442.50	-3.15
Coorow	503.35	-2.16	514.86	-2.94	552.14	-8.88	348.33	-4.58	370.37	-6.92	464.72	-6.38
Corrigin	336.89	7.76	379.72	3.93	445.35	-.15	249.99	3.87	287.12	1.56	387.58	-1.00
Cunderdin	543.25	-.65	553.99	-1.47	581.08	-2.47	348.28	-2.48	381.26	-2.95	495.65	.30
Dalwallinu	407.70	-3.31	422.22	-2.52	461.91	-8.39	288.35	-4.68	312.11	-6.27	393.09	-6.29
Dumbleyung	493.82	.68	514.16	-.60	547.17	-4.27	322.30	-.72	355.21	-2.80	464.68	-.91
Esperance	449.68	-2.39	459.50	-1.73	500.03	-6.03	312.14	-5.07	339.98	-4.68	424.87	-2.41
Goomaling	607.38	-2.56	613.25	-4.41	624.71	-9.99	384.00	-5.24	408.00	-7.40	524.93	-3.74
Irwin	673.46	-2.87	674.61	-4.78	686.43	-10.95	419.06	-4.61	446.40	-6.38	580.09	-1.88
Jerramungup	506.14	4.79	538.42	-.17	579.56	-6.23	356.63	-6.21	379.16	-7.89	486.74	-4.67
Katanning	477.71	1.16	532.10	4.19	602.31	-7.58	339.81	-1.36	386.55	-.84	510.71	-1.56
Kellerberin	377.46	.83	407.79	1.45	448.73	-3.83	270.16	-5.16	294.33	-3.76	383.50	-2.53
Kent	500.82	-1.91	516.43	-2.94	539.04	-8.04	328.04	-4.22	351.14	-5.15	453.41	-3.13
Kondinin	391.32	.25	410.57	-.31	452.14	-4.30	272.00	-2.45	306.45	-3.30	391.17	-1.32
Koorda	317.80	2.84	340.70	-.14	381.91	-1.90	234.55	-5.53	255.68	-3.75	330.80	-.43
Kulin	379.04	2.19	403.15	.89	452.85	-3.18	263.04	-1.19	298.99	-3.80	387.12	-1.07
Lake Grace	457.71	1.19	471.82	-2.08	499.54	-7.51	304.15	-4.13	329.82	-6.07	421.20	-.96
Merredin	290.17	1.99	306.74	-.45	341.45	-2.17	213.20	-5.67	238.17	-5.66	297.06	-2.47
Moora	555.48	-3.49	559.65	-4.61	572.01	-8.74	352.15	-5.78	373.72	-7.92	479.29	-3.86
Morawa	401.43	-3.03	415.29	-3.97	456.34	-5.33	280.82	-6.33	306.16	-8.44	389.23	-2.38
Mount Marshal	297.85	-2.76	315.45	-3.39	350.88	-5.75	218.23	-6.29	236.82	-4.30	304.99	-.29
Mukinbudin	314.55	-.97	328.27	.47	367.93	-2.55	234.32	-5.15	250.30	-3.17	318.83	-2.29
Narembeen	380.89	1.03	398.95	-.44	438.40	-2.23	265.95	-.54	295.79	-3.10	378.66	-1.80
Narrogin	568.52	-3.81	572.13	-5.76	580.41	-12.15	353.96	-6.12	375.38	-7.00	488.99	-2.26
Northam	432.03	7.48	485.20	1.35	550.69	-4.71	313.96	6.19	348.63	-3.26	467.21	-.51
Northampton	624.26	-1.46	632.75	-2.23	645.60	-7.82	395.82	-3.92	420.63	-5.32	539.16	-4.67
Nungarin	244.05	2.35	258.31	.33	300.97	-1.96	194.24	-6.22	208.97	-7.22	265.82	-3.00
Pingelly	526.18	-1.62	532.55	-1.92	549.57	-7.24	339.16	-3.48	360.84	-3.26	462.32	-.29
Quairading	321.09	19.68	386.06	10.52	470.43	-0.88	243.20	18.00	293.77	8.42	407.25	-.58
Ravensthorpe	454.65	.97	469.99	-.54	499.92	-7.78	315.28	-4.23	337.48	-5.38	423.89	-5.67

Tammin	469.95	.28	505.06	.41	556.33	-4.34	327.92	-.03	360.34	-3.86	474.46	-1.06
Trayning	373.90	1.18	392.97	-2.67	432.94	-3.29	269.35	-6.31	294.76	-6.39	378.44	-3.17
Westonia	287.78	-3.27	301.14	-1.04	334.47	-3.01	205.10	-6.48	228.02	-6.49	291.65	-4.38
Wickepin	520.09	-.76	537.24	-3.10	560.82	-9.50	342.00	-4.96	364.88	-8.38	472.04	-3.15
Yilgarn	302.22	-2.25	308.90	-1.92	337.78	-2.53	212.05	-5.69	237.24	-5.33	293.22	-4.80
York	440.43	9.00	484.34	3.47	554.22	-1.69	314.42	8.09	354.14	-.96	477.77	1.11
Panel b: Descriptive statistics for all shires												
Mean	369.54	2.02	395.68	0.95	451.64	-2.97	262.49	-2.03	290.75	-2.86	388.07	-0.35
Min	70.32	-4.23	110.87	-5.80	225.37	-12.15	71.37	-8.26	92.69	-9.59	191.80	-6.38
Max	673.46	20.29	674.61	16.79	686.43	5.30	440.41	18.00	487.53	15.50	632.23	6.23
Standard deviation	141.60	5.20	139.01	4.44	125.82	4.43	86.43	5.19	88.86	4.44	104.47	3.20
Panel c: One sample t-test statistics for changes in CTE												
All shires	t	3.21		1.70		-5.32		-3.11		-5.11		-0.86
QLD shires	t	3.08		3.20		1.25		-1.02		-0.63		7.66
	Mean	3.55		3.41		0.96		-1.20		-0.69		3.05
	(SD)	5.53		5.12		3.68		5.64		5.21		1.91
WA shires	t	1.65		-0.88		-10. 88		-3.24		-7.63		-7.76
	Mean	1.28		-0.46		-5.22		-2.51		-4.12		-2.30
	(SD)	4.89		3.31		3.04		4.91		3.41		1.87

[#]*The change (Δ) is the difference between insured revenue and the uninsured revenue relative to the uninsured revenue expressed in percentage terms but the insured revenue values are not stated here. They could be derived from the values in the table. The derivation of the impact of insurance on CTE (Conditional Tail Expectations) requires that there should be a calculation for CTE at the respective percentiles (5th, 10th and 30th) with and without insurance. The 'None ($)' values are the values of CTE without insurance and the* Δ^{5th} (%), Δ^{10th} (%) and Δ^{30th} (%) are the differences in the values of CTE with insurance relative to that of no insurance at each strike level. *For Balonne, the CTE value was $70.32 when uninsured at the 5th percentile under constant price. This increased by 11.8% to $78.62 with insurance. At the 10th percentile, $110.87 increased to $129.49. Therefore, 16.79% was recorded under the '*Δ^{10th} *(%)' column. The values in Appendix 3 – 7 are based on the uninsured values in this table.*

5.2.2 Categorical analysis of CTE hedging efficiency results by state, price assumption and strike levels

Table 5.2 shows the analysis based on categorical counts. It presents the analysis based on Chi-square statistics. The counts could be used to derive the data reported for the Binomial test of proportion statistics between efficient and inefficient contract for each state but the p-values are not reported in the table. Where significance is indicated, it is at the 95% confidence level ($p < 0.05$). The categorical analyses, was based on the efficiency counts between the two states under each price assumption. The data presented under the constant and variable price assumptions in Panels *a* and *b* were combined in Panel *c* (all states) and split by price assumptions as shown in Table 5.2.

Analysis of the count data with Binomial test of proportions indicated that a significant proportion (74%, n = 17) of the shires in Queensland would have been efficient under the insurance contract with a constant price assumption in contrast to Western Australia where only 55% (n = 22) were efficient without any significance. With the assumption of a variable price, 22% (n = 5) of Queensland shires flagged efficient hedging at the 5th percentile strikes because the CTE results were above zero. For Western Australian shires, 15% (n =6) were efficient at the 5th percentile strike while 10% (n = 4) were efficient at the 10th and 30th percentiles each. All proportions were significant in Western Australia except at the 5th percentile under constant price while the proportions were significant in Queensland except at the 30th percentile strike under constant pricing and at the 10th percentile strike under variable price assumption.

The Odds Ratio (OR) based on the analysis at the 5th percentile strike showed that Queensland shires were two times more likely to benefit from weather insurance than Western Australian shires when constant price was assumed. However, this likelihood was not statistically significant [χ^2 (1) = 2.22, $p < 0.05$]. A similar observation was noted under the variable price assumption albeit to a lower extent [χ^2 (1) = 0.46, $p < 0.05$] with an odds ratio of approximately 2(1.57). For the 10th percentile contract, Queensland shires were about seven times more likely to experience profitability than their Western Australian counterparts but the likelihood reduced to six under the variable price assumption. The chi-square statistics shows that these odds were significant at this strike for both price assumptions. At the 30th percentile strike, the odds were undefined (or infinite) under the constant price assumption and they were found to be 198 under the variable price as shown in Table 5.2 below.

Furthermore, the analysis of hedging efficiency for both states based on price assumptions was noted to be significant across all strikes. The analysis presented in Panel *c* (All states) could be derived by summing the counts from the two states under each price assumption. There were fewer shires that indicated efficiency under the variable price assumption in comparison with the constant price assumption at the 5th and 10th percentile strikes. The odds of farmers benefiting from insurance however reduced towards the higher strikes and the variable price assumptions actually returned results in favour of the variable price model at the 30th percentile strike. More specifically, efficiency was approximately eight times more likely under the constant price assumption with a 5th percentile strike insurance and this was halved to approximately four times at the 10th percentile strike. The variable price was however two times more likely to produce an efficient result at the 30th percentile strike. All results of the comparative analysis of price assumptions were significant at all strike levels.

The general trend that emerged from this analysis is that the variable price assumption reduces the number of shires that would have benefited from the insurance in comparison to the constant price assumptions particularly at the lower strikes. The state of Queensland was also more likely to produce efficient result because of the higher rainfall variability it experienced in comparison with Western Australia as indicated in Chapter 4. It could be said that the main effects and interactions observed in the mean test (See Section 5.2) analyses were also prominent in the categorical analysis. Therefore, the effects observed in the mean tests were not simply due to some outliers from some shires rather a phenomenon that cuts across the data sets. The CTE results were not just reduced due to the price variation but actually inverted the results in some shires.

These results affirmed the findings in the mean tests based on the mixed model that efficiency as measured by CTE is influenced by price assumption, strike levels and locations. That is, disaggregating the overall analysis according to the states indicated that the results from the efficiency of weather index insurance based on CTE should not be generalized. It also suggests that the extent of drought may also determine the efficiency and this may differ from location to location. Most importantly, the count results affirmed the need to make appropriate assumptions about commodity prices and that there was an interaction between price and strike levels.

Table 5-2: Chi–square analysis of efficiency using CTE by price and locations

Strike		**Panel a** **Constant price**		**Panel b** **Variable price**		**Panel c** **All states**	
		QLD	WA	QLD	WA	Con	Var.
5th	Efficient	17	22	5	6	39	11
	Inefficient	6	18	18	34	24	52
		χ^2 = 2.22, OR = 2.32		χ^2= 0.46, OR= 1.57		χ^2=26.00*, OR = 7.68	
10th	Efficient	18	13	9	4	31	13
	Inefficient	5	27	14	36	32	50
		χ^2= 12.24*, OR= 7.48		χ^2=7.57*, OR = 5.79		χ^2=11.32*, OR = 3.73	
30th	Efficient	15	0	22	4	15	26
	Inefficient	8	40	1	36	48	37
		χ^2=34.24*, OR = ^		χ^2=44.20*, OR = 198		χ^2 =4.34*, OR= 0.44	

OR = Odds Ratio, ^ = undefined, * Significant at alpha = 0.05.

5.2.3 Categorical analysis of CTE hedging efficiency results and rainfall variability by strike levels

Furthermore, only the results of the 60mm capped optimized contracts were used to illustrate the effect of rainfall variability on efficiency to keep the report tractable as shown in Table 5.3 below. The rainfall variability was based on the variability (Coefficient of Variation) of a 60mm capped seasonal rainfall. The results were derived by splitting the CV into three with 21 shires with the lowest CV in the low variability group; the 21 shires in the middle variability group were clustered into the moderate group and the 21 shires with the highest CVs in the high variability group.

Table 5.3 below shows that rainfall variability did not influence efficiency at the 5th [χ^2 (2) = 0.22, p > 0.05] and 10th [χ^2 (2) = 3.10, p > 0.05] percentile strikes. However, at the 30th

percentile strike [χ^2 (2) = 32.35, $p < 0.05$], rainfall variability had a significant impact on efficiency. It is therefore evident that high variability in rainfall influences the efficiency of weather index insurance but not when rainfall deficit is relatively severe. The result is intuitive in that variability in the rainfall of a shire may not be an important factor influencing the benefits of insurance when drought is very intense or intense. It is also very clear that the number of efficient shires were higher when the Coefficient of Variation was very high and this decreased across the shires when variability in rainfall is low whereas the number of efficient shires grew with strike levels when variability in rainfall is high. These results imply an interaction between hedging efficiency based on CTE and strike levels with rainfall variability.

Table 5-3: Chi–square analysis of efficiency using CTE by rainfall variability

Strike		Low	Moderate	High
5th	Efficient	4	3	4
	Inefficient	17	18	17
		$\chi^2 = 0.22$		
10th	Efficient	3	3	7
	Inefficient	18	18	14
		$\chi^2 = 3.10$		
30th	Efficient	2	5	19
	Inefficient	19	16	2
		$\chi^2 = 32.35$*		

* Significant at alpha = 0.05.

5.3 Hedging efficiency results from Mean Root Square Loss (MRSL)

5.3.1 Analysis of MRSL based on mean tests

The Mean Root Square Loss (MRSL) analysis was conducted in order to know whether or not insurance would decrease the downside risk of the farmer at the respective strike levels and under the two price assumptions in years of rainfall deficit. The MRSL results from the 60mm capped optimized contracts were presented in Table 5.4 below. The changes in revenue were favourable when the results were negative. Positive changes imply that the insurance contract increased the downside risk of the farmer. The MRSL values were presented in Australian dollar value. The initial values presented under the heading 'None' at the respective strike levels and under the two price assumptions were the MRSL values without insurance which is the same for all contracts. Only the changes in these values due to insurance were presented in the Appendices (Appendix 7 to 10).

The table has three panels (Panels *a* to *c*). In Panel a, the actual results of the MRSL were presented at each strike level under the two price assumptions. In Panel b, the descriptive analyses of the MRSL results were presented while the last panel presents the outcomes of the One-Sample t-test for the changes in MRSL resulting from the insurance contracts. Low values of MRSL implied that the insurance reduced the downside risk. That is, negative values implied downside risk reduction.

Under the constant price assumption, as could be seen in Panels b and c of Table 5.4, the 60mm capped optimized insurance contracts at the 5th percentile increased the downside risk by 12.54% (*SD* = 41.26). This increased to 19.82% (*SD* = 65.82) and 63.54% (*SD* = 157.89) at the 10th and 30th percentile respectively. The One-Sample t-test revealed that the increase in the downside risk resulting from the insurance is significant at the 5th [t (62) = 2.41, p < 0.05], 10th [t (62) = 2.39, p < 0.05] and the 30th [t (62) = 3.19, p < 0.05] percentile strikes. The standard deviations also showed a consistent increase across the strikes. Quairading shire consistently had the highest downside risk reduction at all strike levels as shown in the Table for the 5th (-34.69%), 10th (- 43.54%) and 30th (- 38.01%) percentile strikes.

The results from the MRSL under the variable price assumption also indicated that Quairading consistently had the highest benefit from insurance at the 5th (-16.04%) and 10th (-5.43%) percentiles but Balonne shire had the highest benefit (-26.28%) at the 30th percentile strike. The One-Sample t-test shows that there were significant increases in the downside risk due to insurance at the 5th [*M* = 5.83, *SD* = 7.43, t (62) = 6.30, p < 0.05], the 10th [*M* = 7.96, *SD* = 9.84, t (62) = 6.42, p < 0.05] and the 30th [*M* = 17.00, *SD* = 19.73, t (62) = 6.84, p < 0.05] percentile strikes under the variable pricing model.

Overall, the analyses revealed that if hedging efficiency was measured in terms of downside risk reduction using MRSL, the contracts did not reduce risk rather, the risk was increased to a significant extent at all strike levels. The comparison of the results between the constant and variable price assumption indicated that the average increment in the downside risk is higher under constant price assumption but lower when variable price assumption is made. It is suffice to say therefore that the variability in prices reduced the downside risk in comparison to the constant pricing assumption. In Figure 5.2, it was evident that the risk increased in all cases when both states were combined. The case of Queensland shows some reduction in downside risk but the converse was the case for Western Australia. Similarly, the trend across the strikes shows that risk increased across the strikes increased in Western Australia but decreased along the strikes in Queensland. The overall trend however follows the same trend with Western Australia.

Furthermore, the downside risk reduction results (MRSL) for the 60mm Capped Optimized Insurance contract was analysed using the mixed-model statistical technique. Overall, the effect of the insurance was unfavourable because it increased the downside risk by as much as 16.34%. The main effect of price was surprisingly found to be insignificant [F (1, 62) = 2.27, p > 0.05] but the increase in risk due to insurance under the constant price assumption was about twice that of the variable price. The contrast between the two price assumptions indicated that the effect size (r = 0.25) from the MRSL result is much smaller in comparison to that of the CTE (r = 0.69). The reduction in hedging efficiency due to variability in price is still evident under MRSL analysis albeit to a relatively lower extent in comparison to CTE. There were therefore some similarities and disparities in the results produced from the two methods. The results from each of the three methods adopted in this study are compared in Section 5.5. The main effect of strike was found to be statistically significant [F (2, 122) = 10.127, p < 0.05] but the main effect of state [F (1, 61) = 9.40, p < 0.05] was significant with Queensland having a net reduction of 1.37% in downside risk while Western Australia's risk increased by 34.04%.

The interaction between the price assumption and the state was found to be significant [F (1, 61) = 4.23, p < 0.05]. Queensland farmers could have experienced reduction in downside risk if the contract had been adopted under the constant price analysis of MRSL while their counterparts in Western Australia could have experienced increment in their downside risk

(See Figure 5.2 below). This result suggests that charging the same premium could be misleading in that experiences of farmers will differ from location to location.

The strike-price interaction was significant [F (1, 61) = 5.18, p < 0.05]. Contrasts revealed that the differences in downside risk reduction were between the 10th and 30th percentile strikes [F (1, 61) = 4.88, r = 0.27, p < 0.05], 5th and 30th [F (1, 61) = 5.95, r = 0.30, p < 0.05] but not between the 5th and the 10th [F (1, 61) = 1.55, r = 0.16, p > 0.05] percentile strikes. In essence, risk reduction effect of the insurance contracts did not differ between the 5th and the 10th percentile contracts. The three-way interaction between price assumptions, strikes and state [F (2, 122) = 5.22, p < 0.05] was found to be significant and is better illustrated in Table 5.5 with categorical expressions of the same results. However, based on previous analyses reported above, it is not surprising that the effect of price across the strikes did not differ between the two states in contrast to the results from the CTE in the previous section. This is because the trends were similar but to a relatively different extent as indicated in Figure 5.2.

The effect of rainfall variability on downside risk reduction was also analysed. The risk was classified into three namely; low, moderate and high risk based on equal division of the Coefficient of Variation (CV) of the actual seasonal rainfall data of the 63 shires analysed. It was found that rainfall variability had a significant impact on MRSL [F (2, 60) = 5.15, p < 0.05]. This analysis was based on the more realistic assumption of a variable price. The details of the interactions are best captured in the categorical analysis in Table 5.5 below.

The effect of capping was conducted based on variable pricing. It was found that capping had a significant impact on downside risk reduction [F (2, 122) = 29.12, p < 0.05] The contrasts indicated that the effect was across each of the three pairwise comparisons for uncapped, 60mm cap and 50 mm cap optimized contracts. The 50mm cap increased the downside risk by 13.194%, the 60mm cap by 7.04% while the uncapped contract reduced the downside risk by 5.11%. It seems that the pattern of the effect of capping on the downside risk reduction was favourable towards the higher caps because the downside risk reduced towards the higher caps.

The effect of the weighting scheme on hedging efficiency was examined by analysing the optimized and equally weighted 60mm capped contracts. It was found that optimally weighted contract increased risk but to a significantly lower extent than the unweighted contract [F (1, 61) = 5.38]. The impact of the weighting did not differ between the two states [F (1, 61) = 3.97, p < 0.05]. In essence, a weighting scheme would be required in the design of weather index insurance contracts irrespective of the location. It was however impossible to obtain such weights across the shires given time and resource constraints.

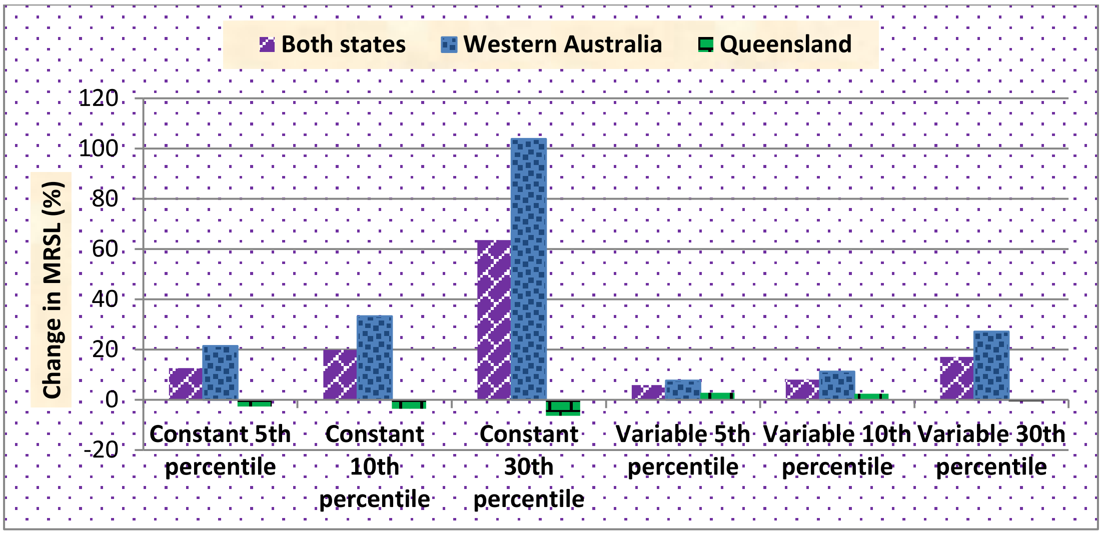

Figure 5-2: MRSL results for 60mm capped optimized contract

Variable pricing reduced the downside risk reduction effect of insurance in QLD but the converse was true for WA and all shires. The assumption is that farmers exhibit constant relative risk aversion. In reality, this may not be true.

First, the prices of wheat were taken to be constant. The trend in WA shows that there was an overall increase in downside risk. That is insurance served to increase the volatility of the revenue of the farmer in WA. This increase was higher as drought becomes less intense. One could say that at least, insurance was moving towards being beneficial as drought becomes intense in WA. In Queensland, the converse is the case. It could be observed that insurance reduced the downside risk at all levels of drought considered but more beneficial when drought is less intense. These results are in stark contrast to that of WA.

When prices of wheat were taken to be variable, it was noted that there was a general decrease in the effects observed under the constant pricing model. It could be observed that the mean MRSL was higher when prices were allowed to vary but the downside risk reduction results were more favourable with the same price assumption (Table 5.4b). The MRSL value without insurance under constant price assumption was $48.25 but this has increased to $72.83 when price was assumed to be variable. However, the impact of insurance when measured as percentage difference between the uninsured and the insured states at the respective strikes relative to the uninsured state showed that while MRSL generally increased under both price assumptions it was relatively lower under the variable price assumption. For example, there was an increase in the downside risk by 12.54% at the 5th percentile under constant price but 5.83% at the same strike under the constant price (See Table5.4b). The implication is that while it would be correct to imagine that downside risk is higher when prices were allowed to vary, the effect of insurance in reducing the downside risk is aided by price variation.

#Table 5-4: Hedging efficiency using Mean Root Square Loss (MRSL) for 60 mm capped optimized contracts

Panel a	Constant price				Variable price			
Shires	None ($)	Δ^{5th} (%)	Δ^{10th} (%)	Δ^{30th} (%)	None ($)	Δ^{5th} (%)	Δ^{10th} (%)	Δ^{30th} (%)
Balonne	95.66	-8.03	-9.93	-30.49	77.58	-7.42	-8.84	-26.28
Banana	59.14	-3.98	-13.65	-.55	50.99	5.36	-3.88	11.41
Bauhinia	73.36	-9.36	-10.28	-9.11	52.26	-2.98	-4.77	2.59
Bendemere	76.20	-13.47	-15.26	-35.21	67.84	-11.34	-3.57	-15.88
Booringa	44.63	.20	-5.39	-3.25	61.39	1.71	.67	-1.74
Bungil	81.93	-1.27	-3.50	-20.26	86.94	5.50	3.83	-11.00
Cambooya	92.80	-8.07	-6.34	-6.50	95.69	1.85	.58	6.85
Clifton	82.50	-9.98	-10.81	-19.64	89.81	3.11	9.19	-.73
Duaringa	45.02	-1.88	8.45	20.69	51.58	6.30	13.48	35.88
Emerald	38.29	2.84	10.00	19.41	45.51	1.86	5.37	11.34
Gayndah	64.83	-5.45	-12.48	-22.11	90.51	.35	-2.87	-5.71
Inglewood	39.80	-2.82	-6.85	-5.53	50.40	5.28	6.29	.87
Jondarayan	75.60	4.95	7.04	4.59	77.34	13.86	18.40	11.10
Kilkivan	59.88	17.96	30.94	46.67	101.73	12.49	23.10	14.31
Kingaroy	93.14	-5.76	-7.25	-19.57	85.01	-2.19	-5.36	-15.71
Millmerran	68.65	-4.03	-7.95	-7.79	63.04	9.95	12.77	-1.42
Munduberra	45.45	2.51	3.66	-.70	69.69	10.52	5.21	-3.92
Pittsworth	98.78	3.14	3.55	-1.03	84.84	8.24	8.10	1.23
Rosalie	115.24	-5.83	-8.43	-5.21	92.08	.75	-3.81	-5.93
Tara	55.98	-3.44	-8.04	-7.04	78.52	1.54	-.27	-1.45
Waggamba	82.99	-7.79	-7.33	-20.87	64.42	-6.24	-2.99	-6.36
Waroo	75.39	-.30	-9.51	-18.72	84.41	-.16	-4.84	-13.76
Wondai	70.81	-2.52	-3.29	-6.34	82.14	5.64	-.01	-.38
Boddington	61.28	-17.62	-28.94	-25.01	103.23	-3.55	-5.37	-1.90
Broomehill	87.87	-13.23	-31.31	-19.23	115.81	1.61	-5.07	7.81
Bruce Rock	56.53	-16.97	-20.82	-24.03	62.64	-.76	1.31	15.73
Carnamah	39.32	7.23	16.39	36.77	70.25	9.99	17.72	35.96
Chapman	11.56	57.54	66.70	254.93	67.17	9.87	14.31	32.32
Coorow	35.56	18.94	27.82	94.66	64.94	15.29	22.41	61.94
Corrigin	52.42	-13.32	-18.52	-33.02	71.21	-7.82	-.57	4.21
Cunderdin	25.52	19.59	18.94	28.15	75.95	5.36	6.27	14.49
Dalwallinu	33.34	17.83	19.53	76.14	58.69	13.12	17.10	57.31
Dumbleyung	30.70	2.67	.79	26.09	86.45	3.13	6.08	10.88
Esperance	32.60	20.34	16.29	56.47	74.77	10.97	11.30	28.54
Goomaling	10.23	119.77	215.58	489.45	85.33	10.28	19.18	37.86
Irwin	10.48	127.94	212.69	622.71	98.57	11.35	13.98	42.85
Jerramungup	38.45	-15.07	-6.48	35.38	90.39	13.61	19.18	36.56
Katanning	71.20	-3.25	-32.18	9.38	93.68	2.64	-2.72	21.94
Kellerberin	35.59	4.15	-14.14	4.13	55.96	14.52	11.51	24.44
Kent	19.42	27.96	50.40	153.67	77.48	7.63	12.81	33.15
Kondinin	35.52	9.29	2.72	28.53	64.69	8.59	11.03	25.07
Koorda	35.45	-.12	-.69	9.73	50.53	11.96	11.41	24.79
Kulin	44.00	.61	-4.01	-.80	69.92	6.53	8.45	14.25
Lake Grace	24.31	.09	36.30	98.00	67.93	9.67	15.69	22.68
Merredin	27.62	.43	.22	11.81	41.75	14.47	19.90	31.85
Moora	10.83	129.14	190.87	364.51	74.13	16.94	22.99	34.57
Morawa	35.63	7.97	12.93	34.91	45.00	10.50	17.96	38.71

Mount Marshal	25.88	19.10	23.29	61.92	49.22	13.91	11.14	37.60
Mukinbudin	35.63	4.76	0.00	16.16	45.00	13.08	10.91	36.48
Narembeen	32.80	3.85	4.99	10.74	60.77	4.58	10.51	19.69
Narrogin	7.12	218.14	349.13	829.49	80.39	11.86	19.14	46.87
Northam	65.65	-20.85	-13.59	-3.91	100.24	-4.36	2.71	11.01
Northampton	11.22	75.90	110.65	351.52	86.18	8.99	13.87	28.32
Nungarin	33.07	-1.78	1.11	13.61	44.11	11.73	21.72	31.88
Pingelly	14.04	39.32	56.63	211.91	74.06	5.56	5.32	22.64
Quairading	76.08	-34.69	-43.54	-38.01	99.61	-16.04	-5.43	-8.25
Ravensthorpe	24.75	.29	5.74	98.57	70.81	10.67	14.53	43.18
Tammin	46.36	5.54	-3.23	7.59	83.14	3.46	9.50	18.34
Trayning	31.19	5.36	23.03	34.39	59.40	13.85	20.34	27.79
Westonia	23.67	20.23	13.52	35.89	47.26	17.00	19.73	44.01
Wickepin	21.39	36.84	79.98	172.28	80.76	10.62	21.54	32.83
Yilgarn	22.50	18.69	18.58	41.04	46.12	12.77	16.37	39.19
York	67.06	-30.17	-25.68	-24.82	91.07	-10.20	-3.06	-2.09
Panel b: Descriptive statistics of MRSL for all shires								
Mean	48.25	12.54	19.82	63.54	72.83	5.83	7.96	17.00
Min	7.12	-34.69	-43.54	-38.01	41.75	-16.04	-15.43	-26.28
Max	115.24	218.14	349.13	829.49	115.81	17.00	23.10	61.94
Standard deviation	26.38	41.26	65.82	157.89	17.82	7.43	9.84	19.72
Panel c: One sample t-test statistics for changes in MRSL								
All shires	t	2.41	2.39	3.19		6.23	6.42	6.84
QLD shires	t	-2.01	-1.67	-1.74		2.13	1.31	-0.24
	Mean (SD)	-2.71 (6.47)	-3.59 (10.31)	-6.46 (17.86)		2.78 (6.27)	2.43 (8.86)	-0.64 (12.71)
	t	2.71	2.648	3.51		6.36	7.83	11.11
WA shires	Mean SD	21.32 (49.67)	33.28 (79.49)	103.79 (186.82)		7.59 (7.55)	11.14 (9.00)	27.14 (15.45)

 # The calculation of MRSL (Mean Root Square Loss) requires that there should be only one calculation at the respective percentiles (5th, 10th and 30th). The value of MRSL was calculated without insurance (None ($)). The values of MRSL with insurance at the respective strikes were then calculated and compared with the values without insurance. For example, the value of MRSL without insurance in Balonne was 95.66 at the 5th percentile strike when constant price is assumed. When insurance was taken, the MRSL reduced by 8.02% to 87.98, This comparison explains the 8.03% in the Δ5th (%) column under the constant price model. Only the initial values (None ($)) and the impact of insurance (measured in percentage difference relative to 'none') are presented in the table. The results in Appendix 7 – 10 are based on the uninsured values (None ($)) presented in this table.

5.3.2 Categorical analysis of MRSL hedging efficiency results by state, price assumption and strike levels

The Table 5.5 below shows the analysis of the MRSL based on categorical counts. It presents the analysis based on Chi-square statistics. Similar to Table 5.3, the counts could be used to derive the data reported for the Binomial test of proportion statistics but the p-values are not reported in the table. Where significance is indicated, it is at the 95% confidence level ($p < 0.05$). The categorical analyses, was based on the efficiency counts between the two states under each of constant and variable price assumptions. The data presented under the constant and variable price assumptions in Panels *a* and *b* were combined in Panel *c* (all states) and split by price assumptions as shown in Table 5.5.

The count data were analysed based on Binomial test of proportions. Overall, the proportion of shires that experienced downside risk reduction (51%, $n = 32$) with the insurance was not significantly different from those that did not experience a risk reduction at the 5th percentile when constant price was assumed (See column 1 of Panel *c* in Table 5.5). This outcome persists at all strike levels under the constant price assumption. Generally, there was a decline in the proportion of shires that benefited from the insurance when price was assumed to vary and the decline led to a significant difference in the proportions across all strikes.

In particular, only 19% ($n = 12$) were efficient at the 5th percentile and 27% ($n = 17$) at each of the 10th and 30th percentile strikes. When the results were disaggregated by states, it was found that in Queensland, a significantly larger proportion of shires experienced downside risk reduction at all strike levels under the constant price assumption. When prices were allowed to vary, the proportion of shires that were significant reduced in comparison to the constant price assumption but the proportions were significantly different only at the 5th percentile strike. The case of Western Australia indicated that most of the shires did not derive utility from the contracts at all strikes under the constant pricing model but the disparity was not statistically significant. The gap in the proportion of efficient and inefficient shires increased with variable pricing and was found to be statistically significant across all the strikes.

The Chi-Square and Odds Ratio (OR) analyses shows that Queensland shires were more likely to experience downside risk reduction in their revenue with weather insurance as designed in this study under both price assumptions and across all strikes. However, the odds reduced from approximately 5 to 2 when variable price was assumed at the 5th percentile [$\chi^2 (1) = 1.16$, $p > 0.05$]. Please, see Table 5.5 for details of other results. The Pearson Chi-square result shows that the odds were significant with constant pricing but not significant when price was allowed to vary.

In contrast, price variability increased the odds in favour of Queensland at higher strikes. That is, when drought was modest, the value that Queensland farmers would derive will increase than when price was constant. This contrast in utility reduction across the strikes relative to the 5th percentile was most pronounced at the 30th percentile where the odds increased from 6.42 under constant pricing to 19.18 when price varied. In essence, locational differences in hedging efficiency tended to fade away with commodity price variability when drought is very intense but the converse is the case when drought is milder. It is expected that disparity in farm-gate prices will aggravate the differences. Hence, irrespective of price location or availability of price stabilizing schemes, farmers are likely to benefit from hedging very intense drought notwithstanding the natural hedge that price variability provides. Subsequent analyses (See Chapter 6) indicate that insurers will be more likely to offer products for less intense drought thereby creating a mismatch in demand and supply between farmers and insurers. Policy initiatives to bridge this chasm are presented in the concluding chapter.

The effect of price assumptions therefore differs across location and strikes as noted in the previous analysis in this section. The results from Panel c is another form of presenting those from Panels a and b and it affirms the conclusion that the disparity in the effect of price assumption on hedging efficiency is most prominent at the extreme tail because it has the highest odds of 4.39 in comparison to the 10^{th} and 30^{th} percentile strikes which were 3.38 and 3.6 respectively. These effect sizes (odds ratio) were significant across all strikes.

Table 5-5: Chi–square analysis of efficiency using MRSL by price and locations

Strike		**Panel a Constant price**		**Panel b Variable price**		**Panel c All states**	
		QLD	WA	QLD	WA	Con	Var.
5^{th}	Efficient	17	15	6	6	32	12
	Inefficient	6	25	17	34	31	51
		χ^2 = 7.75*, OR = 4.72		χ^2= 1.16, OR= 2		χ^2= 13.97*, OR = 4.39	
10^{th}	Efficient	17	18	11	6	35	17
	Inefficient	6	22	12	34	28	46
		χ^2= 4.94*, OR= 3.46		χ^2= 7.99*, OR = 5.19		χ^2= 10.61*, OR = 3.38	
30th	Efficient	19	17	14	3	36	17
	Inefficient	4	23	9	37	27	46
		χ^2= 9.59*, OR = 6.42		χ^2= 21.11*, OR = 19.18		χ^2 = 11.76*, OR= 3.6	

* Significant at alpha = 0.05.

5.3.3 Categorical analysis of MRSL hedging efficiency results and rainfall variability by strike levels

As was done under the CTE, only the results of the 60mm capped optimized contract were used to illustrate the effect of rainfall variability on hedging efficiency in this case downside risk reduction. The details of the analysis are presented in Table 5.6 below. As in the previous section (Section 5.2), the results were derived by splitting the Coefficient of Variation into three with 21 shires in each based on the Coefficient of Variation.

It was found that at the extreme tail when drought was most intense, rainfall variability did not impinge on hedging efficiency as measured by Mean Root Square loss as an indicator of downside risk reduction [χ^2 (2) = 0.00, $p > 0.05$]. The case was somewhat different at the 10th percentile [χ^2 (2) = 2.10, $p > 0.05$] where drought was milder but most prominent at the 30th percentile [χ^2 (2) = 10.80, $p < 0.05$] because the result was found to be statistically significant at this level (See Table 5.6).

Table 5-6: Chi–square analysis of efficiency using MRSL by rainfall variability

Strike		Low	Moderate	High
5th	Efficient	4	4	4
	Inefficient	17	17	17
		$\chi^2 = 0.00$		
10th	Efficient	5	4	8
	Inefficient	16	17	13
		$\chi^2 = 2.10$		
30th	Efficient	2	4	11
	Inefficient	19	17	10
		$\chi^2 = 10.80$*		

* Significant at alpha = 0.05.

5.4 Hedging efficiency results from Certainty Equivalence of Revenue (CER)

5.4.1 Analysis of CER based on mean tests

The Certainty Equivalence of Revenue (CER) analysis was conducted in order to know whether or not farmers will be willing to pay for the insurance contracts. Constant Relative Risk Aversion (CRRA) was assumed in this analysis as explained in the methodology chapter (Chapter 3). The CRRA assumption requires a logarithmic transformation of the original revenue distribution as discussed in Chapter 3. The CER results presented here were based on 60mm capped optimized contracts as presented in Table 5.7 below. The table has three panels (Panels *a* to *c*). In Panel a, the actual results of the CER were presented at each strike level under the two price assumptions. In Panel *b*, the descriptive analyses of the CER results were presented while the last panel presents the outcomes of the One-Sample t-test for the changes in the willingness of farmers to pay for the insurance contracts at the respective strikes or levels of intensity of droughts. Positive changes in CER implied that farmers were willing to pay for the insurance while negative values implied a reduction in the willingness to pay for insurance.

Table 5.7 details the results from the CER analysis of the 60mm capped optimized insurance contracts at the three strike levels from the 5th percentile to the 10th and the 30th percentile for the two price assumptions in Panel a. Panel b details the descriptive analysis of the CER results and Panel c shows the outcomes based on the One-Sample t-test for the same results. The 'None' column indicates the Certainty Equivalence of Revenue of the farmer without insurance and the 5th, 10th and 30th are the CER value with the 5th, 10th and 30th percentile strike insurance contracts respectively. The threshold (cut off) in the One-sample t-test analysis was taken as zero, which is the point at which insurance does not lead to any change in the revenue distribution of the farmer. The percentage change in CER values, relative to the uninsured states, are indicated by Δ^{5th} (%), Δ^{10th} (%), Δ^{30th} (%) for the respective strike levels.

Under the constant price model, the CER values were above zero for the 5th [t (62) = 0.38, M = 0.03, SD = 0.66, p > 0.05] and 10th percentile [t (62) = 0.24, M = 0.028, SD = 0.92, p > 0.05] contracts but not to statistically significant extents. The result from the 30th percentile strike was different from those from the lower strikes. In particular, there was a net decrease of 0.15% in farmers' willingness to pay at this strike level [t (62) = -0.62, M = -0.15, SD = 1.94, p > 0.05]. The results suggest that farmers will be more willing to pay for once in 20 or once in 10 year droughts but not for the mildest of the drought levels considered to occur thrice in 10 years. Albeit, these results were not statistically significant.

Furthermore, the Balonne farmers were found to have the most marked changes in willingness to pay for the contract with an increase of 2.43% in CER at the 5th percentile and 3.03% and 8.98% at the 10th and 30th percentile strikes respectively. The farmers in Westonia, Trayning and Dalwallinu had the highest reduction in willingness to pay at the 5th, 10th and 30th percentile strikes respectively. The results, as shown in Table 5.7 indicated that while willingness to pay increases across the strikes in Queensland, it decreased in Western Australia.

The CER results based on the variable price assumption indicated a significant reduction in willingness to pay across all the strikes as shown in Panel *c* of Table 5.7. It suffices to say therefore that price assumption has an impact on the outcome of the willingness of farmers to pay for insurance contract. The common trend in the results of the CER is that willingness reduces with strike level. That is to say, farmers will be more willing to pay for weather insurance according to the intensity of the drought as intuition may suggest although the natural price hedge may reduce this willingness.

Additional analyses were conducted to determine the impact of geographical location (states), price assumption and strike levels using repeated measures/MANOVA. The overall result indicated a marginal decrease in CER (-0.02%). The main effect of state was found to be significant [F (1, 61) = 39.47, p < 0.05]. There was a significant difference between the willingness of Queensland farmers and Western Australian farmers to pay for insurance by as much as 1.51% with Queensland farmers experiencing a net increase of 0.73% and Western Australian farmers a net decrease of 0.77%. The main effect of strike was insignificant [F (2, 122) = 0.09, p > 0.05]. The main effect of price was significant [F (1, 61) = 54.54, p < 0.05] with the constant price producing a 0.16% increment in willingness to pay while there was a reduction of 0.20% when prices of commodities were assumed to vary.

There was a significant interaction effect between strike and state [F (1, 61) = 58.15, p < 0.05]. This indicates that the extent of drought has different effects on the willingness of farmers to pay for insurance contract depending on location specific characteristics. In order to breakdown this interaction; contrasts were performed between the two states. A significant interaction was observed between the two states between the 5th and the 30th percentile strikes [F (1, 61) = 66.73, r = 0.72, p < 0.05], the 10th and the 30th [F (1, 61) = 53.84, r = 0.68, p < 0.05] and the 5th and the 10th percentile strikes [F (1, 61) = 20.13, r = 0.50, p < 0.05]. This shows that there were differences in the willingness to pay for insurance across all pairwise comparison of drought intensity. Hence, willingness to pay for insurance depends on the intensity of drought and the response of farmers to insuring will differ across the levels of drought intensity.

However, the price-strike interaction was not significant [F (2, 122) = 0.28, p > 0.05]. By implication, the risk reducing effect of commodity price variability is evident irrespective of the strike level. The three-way interaction between price, strike and state was however found to be statistically significant [F (2, 122) = 9.99, p < 0.05]. This three-way interaction suggests that the two-way interaction of price across the strike, though insignificant, could differ between the two states. It could therefore be said that in reality, differences in farm-gate prices of commodities will exacerbate the price-strike effect on the willingness of farmers to insure across different farms.

Figure 5.3 presented after Table 5.7 below shows the trend in the analysis of the CER across the strikes by location. Under both price assumptions, willingness to pay (CER) increased across the strikes for Queensland but decreased for Western Australia. By implication, the impact of weather index insurance on the revenue of the farmer differs by location. Similarly, there was a marked reduction in CER when prices were allowed to vary at the 5^{th} and 10^{th} percentile strikes in each of the two states. The overall trend followed that of Western Australia. The trend in Figure 5.3 is opposite to that of the Mean Root Square Loss (MRSL) (See Figure 5.2 in Section 5.6 above) in that farmers derive utility from downside risk reduction and they will therefore want to pay for the contracts.

The effect of rainfall variability on willingness to pay for weather index insurance was analysed by rainfall variability based on the 60mm capped optimized contract. The results indicated that seasonal rainfall variability had an impact on the choice to insure [F (2, 60) = 8.65, p < 0.05]. In particular, the between-subject pairwise comparison based on the Bonferroni statistics indicated that the differences in the willingness to pay is prominent between the low and high and moderate and high variability in rainfall with mean differences of 1.26% and 0.91 % respectively. Farmers from regions experiencing more severe variability in rainfall are therefore expected to be more willing to pay for insurance as intuition will suggest.

The effect of capping was conducted based on variable pricing only. The uncapped optimized contracts at their respective strike levels were compared with those of the 60mm capped and 50mm capped contracts. It was found that capping did not have a significant impact on the willingness of farmers to pay for insurance [F (2, 122) = 0.02, p > 0.05]. The interaction between capping and states were not different [F (2, 122) = 84.17, p > 0.05] as well as the cap-strike interaction [F (4, 244) = 0.58, p > 0.05] and the cap-strike-state interaction also did not show any significance [F (4, 244) = 0.51, p > 0.05]. The implication of this result is that the willingness of farmers to pay for insurance is not responsive to the rainfall cap adopted and this irresponsiveness is similar across the strikes and states.

The effect of the weighting scheme on hedging efficiency was examined by analysing the 60mm capped optimized and 60mm capped equally weighted contracts in the presence of state under the assumption of a variable price. It was evident that CER results differ by weighting schemes to a statistically significant extent [F (1, 61) = 7.91, p < 0.05] with a mean difference of 0.13% between the optimally weighted (-0.28%) and the equally weighted (-0.41%) contracts although they both indicated a net reduction in willingness to pay. The interaction of weighting with state flagged significance [F (1, 61) = 6.6, p < 0.05] which by implication suggests that there would be need for location-specific weights for the contracts. However, it was not within the capacity of the researcher to find such weighting scheme across the shires. Such a weighting scheme was compared with optimal weighting scheme in Stoppa and Hess (2003) but was noted to deliver a lower relationship with yield outcome than the optimal scheme. However, higher relationship did not necessarily imply higher efficiency (Vedenov & Barnett 2004), such a scheme may be trialled in future studies.

#Table 5-7: Hedging efficiency using Certainty Equivalence of Revenue (CER) for 60 mm capped optimized contracts

Panel a	Constant price				Variable price			
Shires	None ($)	Δ^{5th} (%)	Δ^{10th} (%)	Δ^{30th} (%)	None ($)	Δ^{5th} (%)	Δ^{10th} (%)	Δ^{30th} (%)
Balonne	231.71	2.43	3.03	8.98	221.04	2.40	2.76	7.39
Banana	342.40	.28	.70	.00	324.48	-.31	.76	.10
Bauhinia	336.49	1.03	1.11	.89	314.86	.50	1.01	1.21
Bendemere	333.71	1.62	1.78	3.88	317.39	1.80	2.14	3.30
Booringa	264.37	.22	.69	1.27	251.39	-.08	.02	1.18
Bungil	346.75	.35	.74	3.13	329.27	-.76	-.32	2.49
Cambooya	646.77	.25	.24	.09	613.50	.16	.33	.14
Clifton	588.41	.35	.33	.71	558.35	.00	-.30	.87
Duaringa	418.02	.00	-.31	-.50	395.26	-.19	-.25	-1.41
Emerald	278.70	.04	-.14	-.65	264.17	.14	.08	.19
Gayndah	335.20	.53	1.05	1.95	320.31	.02	.70	1.65
Inglewood	303.29	.08	.25	.47	287.90	-.43	-.38	.49
Jondarayan	627.86	-.22	-.28	-.08	595.68	-.71	-.80	-.05
Kilkivan	765.96	-.55	-.81	-1.09	724.23	-1.07	-1.65	-.59
Kingaroy	407.14	.66	.81	1.99	386.77	.59	1.12	2.66
Millmerran	495.73	.12	.25	.48	470.26	-.51	-.69	.38
Munduberra	442.40	.00	.05	.59	419.51	-.64	.01	1.01
Pittsworth	599.30	-.20	-.23	-.13	568.31	-.30	-.25	.45
Rosalie	418.42	.63	1.32	.92	397.75	.13	1.13	1.73
Tara	290.00	.74	1.17	1.81	276.75	.00	.29	1.21
Waggamba	292.40	1.61	1.66	3.64	279.00	1.47	.95	1.92
Waroo	255.18	.62	2.43	4.33	243.04	.56	1.70	3.19
Wondai	473.73	.16	.29	.56	449.57	-.37	.18	.80
Boddington	604.90	.20	.29	.24	572.04	.33	.35	.13
Broomehill	628.21	.21	.81	.37	594.38	-.03	.78	-.56
Bruce Rock	440.35	.39	.50	.02	415.20	-.12	.01	-.72
Carnamah	552.34	-.27	-.33	-1.29	522.13	-1.07	-1.53	-2.59
Chapman	533.19	-.39	-.43	-1.17	504.04	-.63	-.97	-2.13
Coorow	561.19	-.37	-.55	-2.39	530.56	-1.20	-1.68	-4.05
Corrigin	464.55	.29	.31	.41	438.42	.63	-.02	-.25
Cunderdin	592.25	-.30	-.31	-.31	559.83	-.07	-.06	-.42
Dalwallinu	474.67	-.38	-.90	-3.03	448.67	-1.14	-1.37	-4.10
Dumbleyung	554.94	-.25	-.28	-.38	524.72	.00	-.29	-.76
Esperance	513.96	-.43	-.41	-.90	484.96	-.81	-.80	-1.79
Goomaling	629.20	-.56	-.82	-1.83	594.61	-.43	-1.10	-2.58
Irwin	699.27	-.50	-.71	-1.87	660.20	-.63	-.67	-2.71
Jerramungup	589.79	-.20	-.85	-1.99	556.08	-1.09	-1.60	-3.10
Katanning	613.03	-.06	.44	-.50	579.72	-.06	.56	-1.43
Kellerberin	460.99	-.35	-.22	-.39	435.39	-.92	-.79	-1.30
Kent	544.03	-.36	-1.00	-2.19	514.07	-.89	-1.15	-2.46
Kondinin	470.68	-.34	-.51	-1.55	443.39	-.81	-.83	-1.33
Koorda	398.17	-.09	-.12	-.62	376.40	-.85	-.70	-1.02
Kulin	466.76	-.21	-.20	-.68	439.88	-.68	-.69	-1.00
Lake Grace	506.81	-.21	-.69	-1.06	478.31	-.58	-1.15	-1.11
Merredin	358.01	-.17	-.11	-.69	337.45	-.97	-1.17	-1.54
Moora	575.40	-.70	-.88	-1.21	543.78	-1.42	-2.10	-2.49
Morawa	385.36	-.29	-.32	-1.94	363.22	-1.07	-1.24	-2.31
Mount	367.22	-.52	-.53	-1.15	346.79	-.74	-.57	-1.83

Marshal								
Mukinbudin	385.36	-.16	-.11	-.95	363.22	-.57	-.52	-1.75
Narembeen	455.76	-.16	-.30	-.83	429.63	-.39	-.82	-1.20
Narrogin	587.71	-.78	-1.05	-2.41	554.98	-.96	-1.19	-3.07
Northam	561.98	.39	.09	-.23	532.14	.30	-.29	-.90
Northampton	648.42	-.39	-.43	-1.37	612.79	-.46	-.87	-2.44
Nungarin	324.68	.02	-.93	-1.95	305.26	-.81	-1.37	-2.09
Pingelly	554.65	-.36	-.39	-.82	524.19	-.15	-.04	-.93
Quairading	483.87	1.54	1.76	1.06	455.57	2.02	1.94	1.20
Ravensthorpe	507.95	-.20	-.25	-1.94	479.38	-.90	-1.11	-3.37
Tammin	568.44	-.25	-.27	-.51	538.03	.00	-.47	-.99
Trayning	455.21	-.24	-2.09	-2.16	429.24	-1.03	-1.62	-1.78
Westonia	353.11	-2.06	-1.93	-2.19	332.28	-1.64	-1.72	-3.14
Wickepin	564.97	-.59	-.89	-1.49	533.90	-1.04	-1.94	-2.54
Yilgarn	355.59	-.36	-.36	-1.49	334.71	-1.09	-1.31	-2.79
York	568.34	.68	.57	.49	538.32	1.08	.67	.76
	Panel b: Descriptive statistics of CER for all shires							
Mean	473.89	0.03	0.03	-0.15	448.20	-0.29	-0.33	-0.61
Min	231.71	-2.06	-2.09	-3.03	221.04	-1.64	-2.10	-4.10
Max	765.96	2.43	3.03	8.98	724.23	2.40	2.76	7.39
Standard deviation	123.40	0.66	0.92	1.94	116.49	0.81	1.04	2.04
	Panel c: One sample t-test statistics for changes in CER							
All shires	t	0.38	0.24	-0.62		-2.90	-2.54	-2.36
QLD shires	t	3.32	3.66	3.14		0.59	1.79	3.59
	Mean (SD)	0.47 0.68)	0.70 (0.92)	1.45 (2.21)		0.10 (0.83)	0.37 (1.0)	1.32 (1.76)
	t	-2.74	-3.37	-7.29		-4.71	-5.631	-9.09
WA shires	Mean SD	-0.22 (0.51)	-.36 (0.68)	-1.07 (0.93)		-.52 (0.70)	-.74 (.83)	-1.71 (1.19)

 # The calculation of CER (Certainty Equivalence of Revenues) requires that there should be only one calculation at the respective percentiles (5^{th}, 10^{th} and 30^{th}). The value of CER was calculated without insurance; the values of MRSL with insurance at the respective strikes were then calculated and compared with the values without insurance under each price assumption. For example, the value of CER without insurance in Balonne was $231.31 when constant price was assumed. When insurance was taken this increased by 2.04% to CER of $237.34. The impact of insurance was an increase in the willingness to pay by 2.04% ($5.62) on top of the initial value (CER without insurance of $231.31). Only the initial values (none or uninsured) and the impact of insurance (measured in percentage difference relative to none) are presented in the table. The results presented from Appendix 11 – 14 are also based on the none insured values in this table.

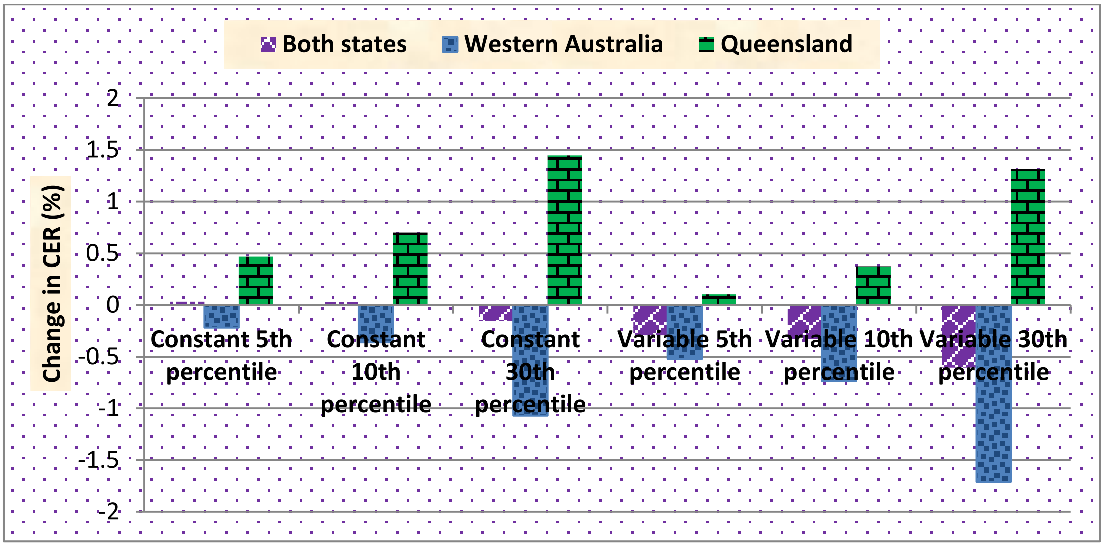

Figure 5-3: CER results for 60mm capped optimized contract

The overall result under constant pricing shows that farmers will be willing to pay for the most intense drought at the 5th percentile but this willingness reduces as drought becomes less intense as intuition suggests. It was however interesting to note that when the results were disaggregated by states, there was a divergence across the strike levels between the two states. Under the constant price assumption, insurance was profitable in Queensland but less profitable when variable prices were assumed at all percentiles. In WA, insurance was generally unprofitable but more unprofitable with the assumption of variable pricing. It may not be possible to say that farmers will be willing to pay for less intense drought than more intense drought. Hence, the results of hedging efficiency of insurance may not be generalized across locations. Yield risk and rainfall risk were higher in QLD than in WA (See Appendix 1) and is therefore understandable if QLD farmers were more willing to pay for insurance than their counterparts in WA.

The disparity could also stem from other unique characteristics of the locations like soil type and farmers characteristics including risk aversion. In reality, the differences in the results of willingness to pay will be exacerbated by farmers' initial wealth and portfolio of existing assets. The trend in Queensland across the strikes suggests that insurance may be least beneficial at the most extreme tail because the cost-benefit analysis of insurance may be lowest when drought is most intense.

5.4.2 Categorical analysis of CER hedging efficiency results by state, price assumption and strike levels

Table 5.8 shows the analysis of the CER based on categorical counts. The analysis based on Chi-square statistics are presented in Table 5.9 and the counts are also used to report the Binomial test of proportion statistics. However the significance test for the Binomial test of proportions are not presented in the table but where significance is mentioned in the report, it was at the 95% confidence level ($p < 0.05$).

Overall, the proportion of shires with improved willingness to pay (efficient shires) was higher in Queensland than in Western Australia as noted in previous sections for CTE and MRSL. The Binomial test of proportions indicated that the proportion of shires that would have been willing to pay for insurance was lower when aggregated across all strikes and price assumptions but the proportion was significantly lower only when variable price was assumed because the number of efficient shires reduced with the assumption of changes in commodity prices. For example, 43% (*n* = 27) of the shires indicated improved willingness to pay at the 5th percentile under constant price model but the proportion reduced to 24% (*n* = 15) at the same strike level when variable price was assumed (See Panel *c* of Table 5.8 below).

The Chi-Square and Odds Ratio (OR) analyses show that Queensland farmers were significantly more likely to be willing to take insurance than their counterparts in Western Australia at all strike levels. Similarly, when prices were allowed to vary, the disparity in the willingness to pay significantly differs between the two states at all strikes (See Table 5.8 below). The odds increased consistently across the strikes when variable price was assumed and the differences in the odds across the strikes were more remarkable than when constant price was assumed as shown in the table. The analysis presented in Panel c of the table is a combination of the results from both states but disaggregated by price assumption. It was noted that there was a significant difference in the changes to the willingness of farmers to pay between the constant and variable prices [χ^2 (1) = 5.14, p < 0.05] only when drought is very intense at the once in twenty year level (5th percentile strike). The effect size as measured by the odds ratio indicated that the assumption of a constant price was two times more likely to be profitable for farmers than when commodity prices were assumed to be constant.

Table 5-8: Chi–square analysis of efficiency using CER by price and locations

Strike		Panel a Constant price		Panel b Variable price		Panel c All states	
		QLD	WA	QLD	WA	Con	Var.
5th	Efficient	19	8	10	5	27	15
	Inefficient	4	32	13	35	36	48
		χ^2 = 23.37*, OR = 19		χ^2= 7.73*, OR= 5.4		χ^2= 5.14*, OR = 2.4	
10th	Efficient	18	8	15	6	26	21
	Inefficient	5	32	8	34	37	42
		χ^2= 20.45*, OR= 14.4		χ^2= 16.57*, OR = 10.63		χ^2= 0.85, OR = 1.41	
30th	Efficient	18	6	20	3	24	23
	Inefficient	5	34	3	37	39	40
		χ^2= 24.78*, OR = 20.4		χ^2= 39.77*, OR = 82.22		χ^2 = 0.03, OR= 1.07	

* Significant at alpha = 0.05.

5.4.3 Categorical analysis of CER hedging efficiency results and rainfall variability by strike levels

Only the results of the 60mm capped optimized contract were used to illustrate the effect of rainfall variability on the willingness of farmers to pay for insurance. The details of the analysis are presented in Table 9 below. As in the previous sections

(Section 5.2 and 5.3), the results were derived by splitting the Coefficient of Variation into three equal segments. Rainfall variability did not influence the willingness to pay for insurance when drought is very intense [χ^2 (2) = 1.58, p > 0.05] whereas at the 10th [χ^2 (2) = 8.14, p < 0.05] and 30th percentile strikes [χ^2 (2) = 27.25, p < 0.05] the converse was the case. In all cases, the number of locations that indicated increase in CER increased as variability increased, a trend that became more prominent as strike level increases.

Table 5-9: Chi–square analysis of efficiency using CER by rainfall variability

Strike		Low	Moderate	High
5th	Efficient	4	4	7
	Inefficient	17	17	14
		χ^2 = 1.58		
10th	Efficient	4	5	12
	Inefficient	17	16	9
		χ^2= 8.14*		
30th	Efficient	2	4	17
	Inefficient	19	17	4
		χ^2= 27.25*		

* Significant at alpha = 0.05.

5.5 A comparative analysis of the hedging efficiency results

From the analyses above, it has been observed that the outcomes of the hedging efficiency based on the three results were similar. That is, the trends were related but different in some ways. Overall, the results on the hedging efficiency results were mixed in that the contracts were efficient in some locations but not efficient in others and these differ across the strike levels. A major similarity however is that the hedging efficiency tended to reduce when wheat price was assumed to vary in comparison to a constant price assumption. However, it is important to statistically establish the similarities and differences in the hedging efficiency results.

Therefore, the three methods, CTE, MRSL and CER were compared between the two states and across the strikes for the 60mm capped optimized contracts under the assumption of a variable price. The results from the MRSL were inverted. That is, negative values of MRSL were meant to indicate that there was a reduction in the downside risk, inverting this would imply that positive values of MRSL actually reduced the risk. The inversion was necessary so that the results from MRSL will be compatible with those of CTE and CER for the purpose of comparison. The sphericity assumption was correctable and therefore the results from the mixed model were accepted without any recourse to the MANOVA results.

The main effect of methodology was significant [F (2, 116) = 20.60, p < 0.05]. The difference was between all methodological pairs that is, between the CTE and CER

[F (1, 58) = 4.52, r = 0.27, p < 0.05], MRSL and CER [F (1, 58) = 19.80, r = 0.50, p < 0.05] and CTE and MRSL [F (1, 58) = 24.39, r = 0.54, p < 0.05]. The differences between MRSL and the other two methods were very prominent even after the inversion of the results to make them comparable. The interaction between the methods and the levels of drought (strike levels) were not statistically significant [F (4, 116) = 0.74, p > 0.05]. By implication, it could be said that the methodological differences were relatively the same across the rainfall variability levels. The interaction between methodology and state was however significant [F (2, 116) = 12.80, p < 0.05] meaning that the differences in methodology differs between the two states, therefore, one methodology may be more efficient in one state than the other. Since each of these methodologies measures different objectives of drought risk management, it may be reasonable to say that the objectives of drought risk management will differ across the locations.

Hence, the objectives of drought policy may differ from one location to the other and therefore a one-size-fit all policy may not be an appropriate policy for agro-risk management in Australia. The insignificant differences in the efficiency results based on the methodology across the rainfall variability levels did not differ between the two states [F (2, 116) = 0.08, p > 0.05]. Finally, the four-way interaction between the methods, rainfall variability and states across the three strike levels was insignificant [F (4, 232) = 0.38, p > 0.05]. Based on this four-way interaction, the differences observed in the results based on the methodologies although differ by states were consistent across the states and rainfall variability.

5.6 Curve fitting illustration of the hedging efficiency of weather insurance

In this graphical illustration, the most consistently efficient shire across all the three methods, price assumptions and strikes (Balonne shire) was used to illustrate the efficiency of weather index insurance contract. The Balonne shire was found to belong to the high rainfall variability zone and therefore may be a good example to model the effect of an efficient contract. There were other shires that could be used to demonstrate this effect but only one was chosen to make the analysis tractable.

The graphs presented in Figures 5.8 to 5.11, were based on constant price assumption while Figures 5.12 to 5.15 were based on variable price assumption. Figure 5.8 represents the curve fitting for the revenue without insurance and the others (5.9, 5.10 and 5.11) represent the curve fittings for the 5^{th}, 10^{th} and 30^{th} percentile contracts respectively.

It is obvious from Figure 5.8 that there was a positive relationship between yield and the index. However, a closer look reveals the tendency of the relationship to be non-linear. At the lower end of the carpet-like graph, a linear relationship is implied whereas at the upper end the relationship seems to be quadratic. This result is not surprising because when the index is very low, it suggests low rainfall and consequently low yield and at the upper end the index is high but the rate of increase in yield seems to have dropped because excess rainfall does not facilitate crop growth. The points were obviously closely knitted at the tails. The above explanation unveils the essence of the comparison between the Quantile Regression and both Ordinary Least Square Regression (OrdReg) and Quadratic Regression (QuadReg). Similarly, one could observe the increase in revenue due to yield and index increase.

In Figure 5.9, there was a lift at the lower end of the tip implying that the 5th percentile contract increased the revenue of the farmer in the lowest two years of the index. If the result was interpreted in the context of Conditional Tail Expectation (CTE) it could be said that the average revenue of the farmer increased with insurance in the lowest years of the index. Figure 5.10 indicated that the higher percentile strike contract further lifted the carpet in the lowest four years of the index and the lift was more prominent with the 30th percentile strike contract presented in Figure 5.11. The 30th percentile contract showed the semi-variance (MRSL) reduction effect of the insurance contract. It could be noted that the curve was concave to the origin in Figure 5.8 without insurance whereas it pointed downward (convex to the origin) with the 30th percentile contract in Figure 5.11. The insurance contracts have served to amend the distribution of the revenue in such a way that when the yield was low, the revenue was not too low. In essence, the insurance contracts served to normalize the revenue distribution. It could therefore be expected that for an efficient contract, revenue increased at the lower tails but decreased at the upper tail.

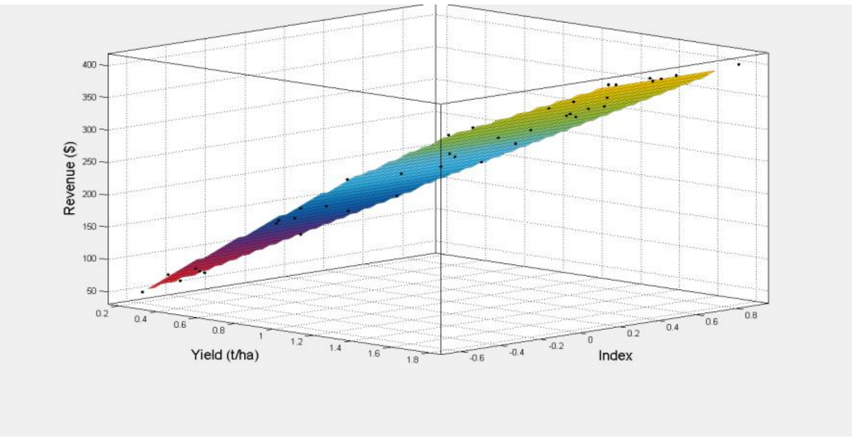

Figure 5-4: Revenue with no insurance contract - constant price assumed

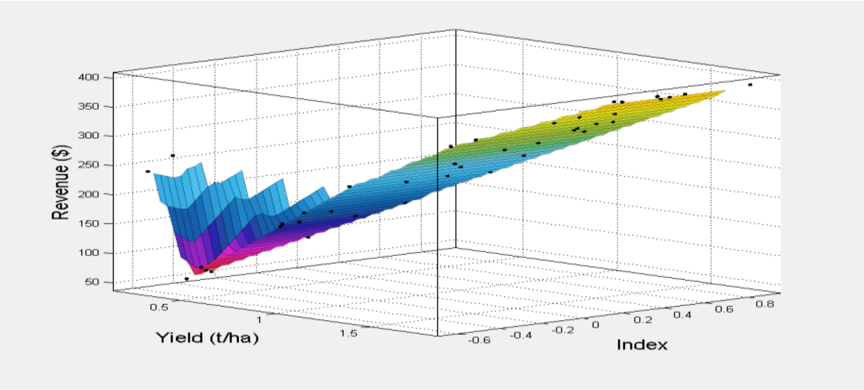

Figure 5-5: Revenue with 5th percentile insurance contract-constant price assumed

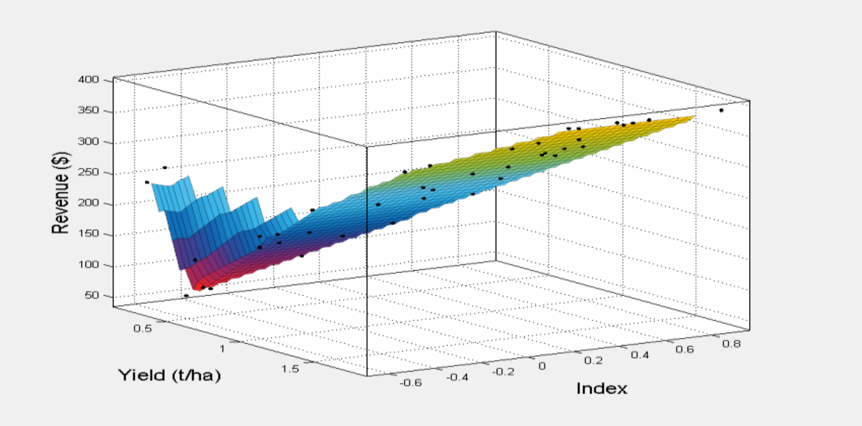

Figure 5-6: Revenue with 10th percentile insurance contract-constant price assumed

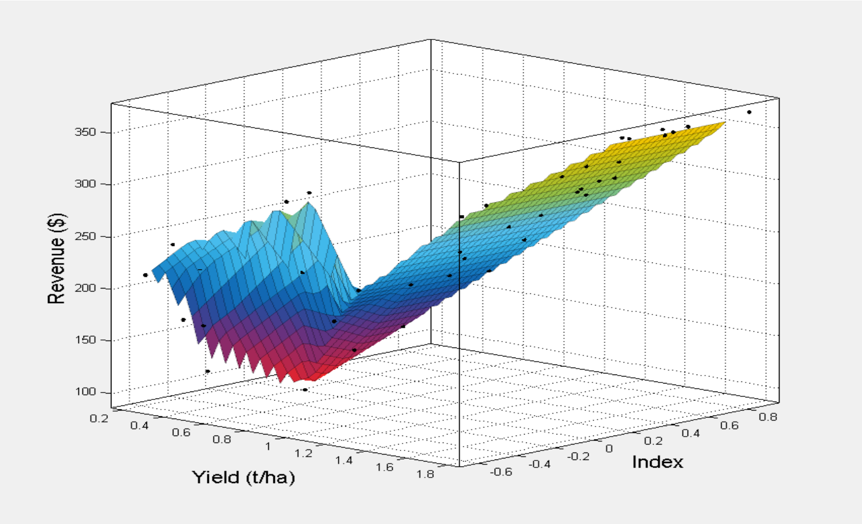

Figure 5-7: Revenue with 30th percentile insurance contract-constant price assumed

In Figure 5.12, the same illustration was made but with the assumption of a variable price. It was clear that the carpet was rougher when variable price was assumed. The roughness of the carpet showed the effect of the different price assumptions because price variability led to some undulating contours in Figures 5.12 to 5.15. The contours reveal that there were additional sources of variability in the revenue that were not explained by the index and yield which obviously showed the effect of price variation. However, the clarity of the effect of strike levels on the hedging efficiency was blurred by the contours. The effect of the insurance was therefore not very prominent across the strikes as it was under the constant price assumption.

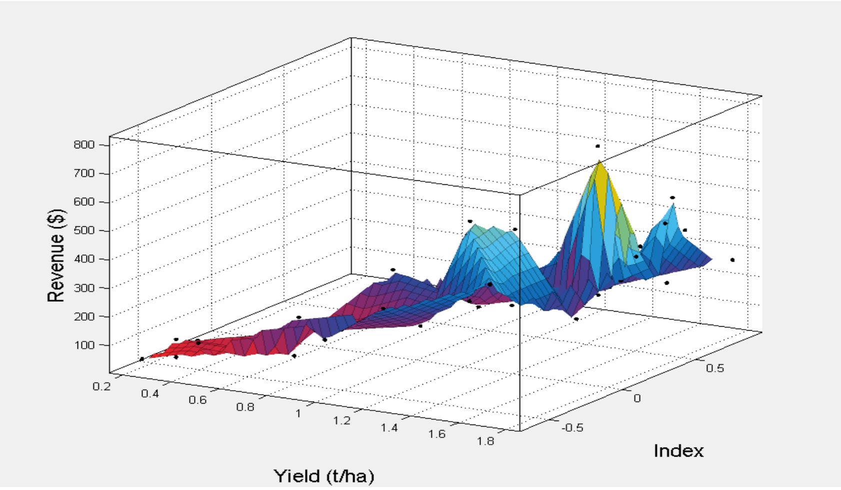

Figure 5-8: Revenue with no insurance contract - variable price assumed

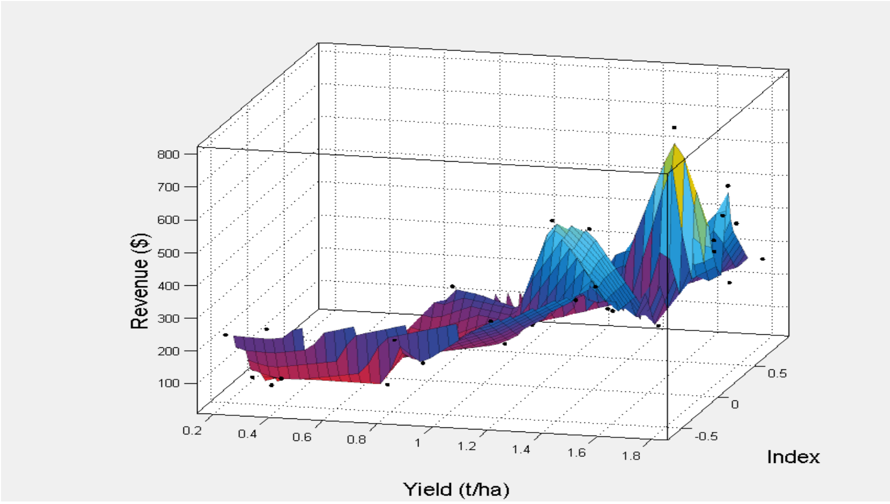

Figure 5-9: Revenue with 5th percentile insurance contract - variable price assumed

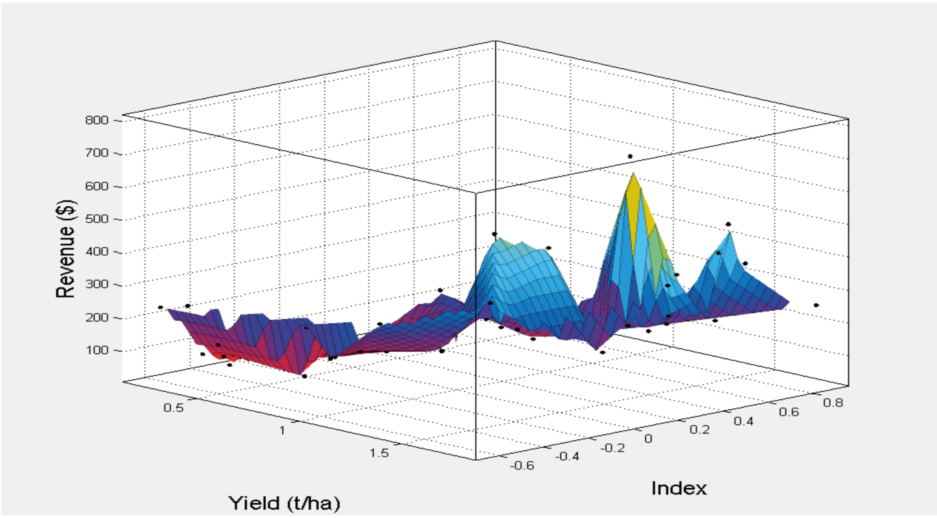

Figure 5-10: Revenue with 5th percentile insurance contract - variable price assumed

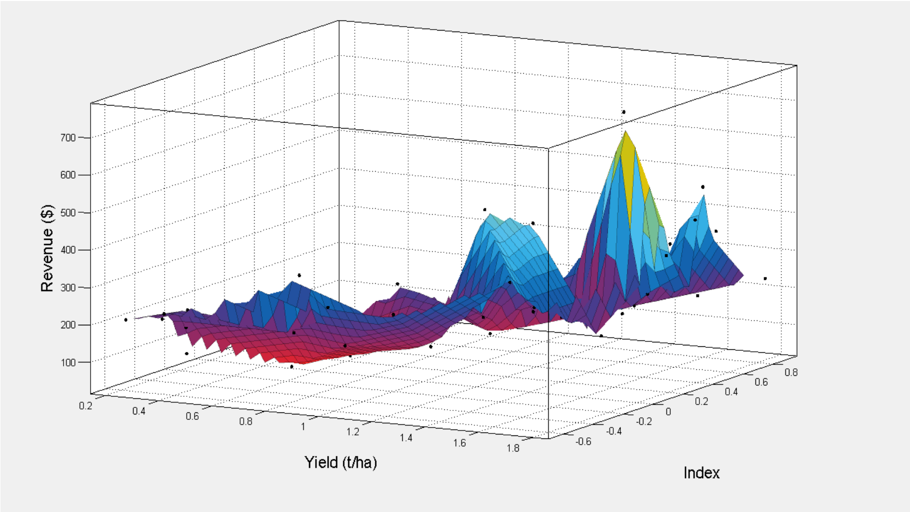

Figure 5-11: Revenue with 5th percentile insurance contract - variable price assumed

5.7 Correlation analysis of hedging efficiency with

In Chapter 4, the analysis of the relationship between yield and the index was considered. Chapter 5 features the analysis of the hedging efficiency. In this section (Section 5.7), attempt has been made to bring together the results from the two chapters with correlation analysis. The essence of the correlation analysis was to determine whether or not there is a relationship between hedging efficiency and the relationship measures. That is, if there is a relationship, then, it could be said that higher yield index relationship results in stronger hedging efficiency.

The details of the hedging efficiency results were presented in Chapter 5. Three methods were adopted namely; Conditional Tail Expectation (CTE), Mean Root Square Loss (MRSL) and Certainty Equivalence of Revenue (CER). It was expected that there will be a stronger relationship between the hedging efficiency results and the relationship measures at the 5th, 10th and 30th percentiles based on the QuantReg analysis relative to the OrdReg and QuadReg analyses.

The correlation results below show that hedging efficiency results did not in any way correlate significantly with relationship measures irrespective of the type of regression analysis conducted. The strongest relationship (-.234) was between QuadReg and MRSL at the 30th percentile strike. It was found that disaggregating the yield-index relationship did not improve the correlation results. Future studies could employ the use of larger data sets as the sample size for the QuantReg may need improvements. Furthermore, the relationship of the CTE and CER with the QuantReg results was positive but negative with MRSL as would be expected. The expectation was due to the fact that negative values of MRSL indicate downside risk reduction which creates value to the insured farmer but positive values create value in the cases of CTE and CER. The regression methods were however found to correlate with each other very strongly. Consequently, a strong yield index relationship does not necessarily lead to a strong hedging efficiency outcome.

Table 5-10: Correlation analysis of yield-index relationship and hedging efficiency

	CTE 5th	CTE 10th	CTE 30th	MRSL 5th	MRSL 10th	MRSL 30th	CER 5th	CER 10th	CER 30th	Ord Reg	Quad Reg
Quant Reg 5th	.062	-	-	-.135	-	-	.094	-	-	.725**	.777**
Quant Reg 10th	-	.120	-	-	-.064	-	-	.042	-	.859**	.849**
Quant Reg 30th	-	-	.171	-	-	-.174	-	-	.221	.951**	.866**
Ord Reg	-.069	.062	.159	.026	.014	-.197	.006	-.008	.228	1	.947**
Quad Reg	.030	.099	.116	-.067	-.044	-.234	.064	.011	.215	.947**	1

*** Significant at 99% confidence level*

[#] *QuantReg nth = Quantile Regression, QuadReg = Quadratic Regression, OrdReg = Ordinary Least Square Regression, CTE = Conditional Tail Expectation, MRSL + Mean Root Square Loss, CER = Certainty Equivalence of Revenue (Where n^{th} refers to the quantile levels in Quantile Regression or alpha levels in hedging efficiency, 5th, 10th and 30th percentiles).*

5.8 Summary of hedging efficiency results

The findings in this chapter indicated that the inverse relationship between wheat yield and price reduces the hedging efficiency of weather index insurance and this was most prominent when drought was very intense. In essence, previous studies did not sufficiently capture the cost of price stabilization that is associated with constant price assumption. These findings were based on the results derived from the analysis of the effect of hedging on the revenue of the farmer. The improvement to the revenue, downside risk minimization and willingness to pay were considered. The effect of wheat price variability was evident in all the hedging efficiency methods adopted. The analyses were further expressed using curve fittings.

Furthermore, it was found that location (state) had a prominent effect on the decision to hedge. Queensland farmers were more likely to purchase weather index insurance than their Western Australian counterparts. Also, variability in rainfall has an effect on the decision to hedge. In particular, farmers from locations with high rainfall variability were more likely to purchase insurance than those from locations with lower rainfall variability. In the previous chapter (Chapter 4), it was clear that Queensland shires were more likely to experience high rainfall variability than Western Australian shires. Therefore, the locational differences in hedging efficiency observed in this study could be due to, among other things, the differences in rainfall variability across the two states.

Similarly, it was noted that there will be differences in the weighting schemes that will be required for each shire to make weather index insurance more efficient. Finally, some differences were noted in the results of the hedging efficiency based on the methodologies adopted. Different methodologies examined different hedging objectives, the CTE measured possible increase in revenue due to insurance, and MRSL measured the downside risk reduction and the CER the willingness to pay. There were some differences in the results based on these objectives. Therefore, hedging efficiency may differ across locations depending on the objectives of drought policy. Finally, it was found that the relationship between the pseudo R^2 and hedging efficiency was not significant. In essence, a strong relationship between yield and rainfall does not necessarily lead to high hedging outcome.

6 CHAPTER SIX: RISK DIVERSIFICATION

6.1 Introduction

The previous chapter has shown that the optimized contracts performed better than the equally weighted contracts and that capping does not have very significant effect on the hedging efficiency of the contracts. Therefore, the analysis of the diversification of a portfolio of insurance contracts is based on the 60mm capped optimized contracts which was the focus of the analyses in the previous two chapters.

In this chapter the risk associated with insuring drought risk from the perspective of the insurer is examined. The risk is limited by the extent to which the insurer could diversify a pool of insurance contracts over time and space. Diversification of risk refers to the extent to which risk could be reduced by pooling contracts from different locations across time and space. It is expected that if the contracts are diversifiable, the payouts from some locations will offset the others. The extent to which this is possible is the extent to which a portfolio of insurance contracts is diversifiable. The measure of diversification is loss ratio which is the ratio of indemnity paid to the farmers and the premium collected from them. Analysis of diversification is essential in the analysis of the viability of a portfolio of weather insurance contract because the insurer will not be willing to take risks that are not diversifiable.

In this chapter, the effects of spatial and temporal risk pooling are reported. The loss ratios were calculated by dividing the payout by the premium collected such that when loss ratio is higher than one, the insurer would have paid out more than was collected in premium. When the loss ratio is close to zero, then it is considered as a profit whereas the further the loss ratio is above 1 the higher the loss to the insurer. Should the loss ratio be one, then the amount of payout was received as premium. In essence, a loss ratio of one translates to a breakeven for the insurer. In analysing the spatial effect of risk, the loss ratios were pooled over the shires in each of the states and then over all the shires in both states. The temporal effect of risk was analysed by pooling the loss ratios of shires in each of the states over time and then for both states over the same time frames. The first year considered was one year risk pooling followed by two, three, five and ten years of risk pooling.

The analyses in this chapter are based on the 60mm capped optimized insurance contracts. The trend in the other analysis is the same as the 60mm contracts but it may be cumbersome to present all information when the essence is basically the same. The results are presented in graphical form in this chapter but the actual results are presented in Appendices 15 and 16.

The graphs show the cumulative distributions of the loss ratios over time and a comparison of the graphs reveal the effect of risk pooling across the strikes as well. The cumulative distributions are represented on the y-axis as the probability of loss ratios which refers to the probability of the loss ratios been less than the value indicated. Values below 1 indicate profit that is the insurer will be having at least a sufficient amount of premium to cover the payout whereas if loss ratios are greater than 1, the converse is the case. In the next section, the effect of both spatial and temporal risk pooling is discussed based on the figures and tables in the appendices.

6.2 The effect of spatial and temporal risk pooling on a portfolio of weather index insurance contracts.

In Appendix 15, the loss ratios for the 60mm capped optimized insurance contracts were presented by strike levels and states over the forty year period. The loss ratios were based on one year risk pooling only. It would be observed that the means of the loss ratios were consistently one because the model, actuarial burns analysis assumes that what was paid out was exactly received as premium over the forty years. In Appendix 16, the loss ratios in Appendix 15 that was based on one year risk pooling and other years of risk pooling (two years, five years and ten years) were analysed based on different levels of loss ratios across the strikes between the two states. Appendix 16 was necessary because in addition to showing the spatial effect of pooling, it could unveil the effect of temporal risk pooling.

It is evident that the farmers in Queensland experienced the highest loss ratio (13.28) in 1994 when the 5th percentile insurance contracts were analysed. That is, based on the model adopted in this study, an insurer would have paid out about 13 times of the premiums collected from farmers in Queensland. The loss ratio in Western Australia for the same year indicated that the insurer would have paid approximately twice (1.99) the amount earned in premium in 1994 for the same insurance. In 2010, Western Australia experienced the highest payout because it had the highest loss ratio over the forty-year period considered. In that year Queensland farmers did not have any indemnification (payout or payment from insurance) because it had a loss ratio of zero. Both states experienced drought only four out of the forty years analysed; 1991, 1994, 2002 and 2006. At the 5th percentile strike, Queensland experienced non-zero loss ratios in 9 years. Out of these nine years (1972, 1977,1982,1991,1994 2002, 2004, 2006 and 2009), five of the years (1972, 1977, 1982, 1991, 2009) coincided with years of zero loss ratios in WA.

By implication, the insurer's burden due to the weight of payout in Western Australia in 2010 was alleviated by the fact that premiums accrued from Queensland but there was no payment to farmers in Queensland because the contract was not triggered. Ideally, farmers would not have experienced droughts in the year they had no payout. The disparity in the experiences of both states suggests that risk should be tempered when pooled over the two states in year 2010 as the loss ratio of 6.54 indicated.

For the 10th percentile strike, the trend in the analysis is the same as in the 5th percentile strike but the values of the loss ratios have reduced. For example, the highest loss ratio for Queensland reduced from 13.28 to 12.67 and from 9.66 to 7.68 for Western Australia. The trend in this decrease persisted in the analysis of the 30th percentile contract. In particular, the effect of risk pooling at the 30th percentile strike reduced loss ratio from 6.54 at the 5th percentile strike to 3.18. In essence, not only does risk pooling reduce loss ratio, it is more evident at higher strikes. It could be said that insurers will be more interested in offering products that cover milder risk across Australia than more intense drought risk over a smaller region. When risks were pooled over the two states, there were twenty one years with payments in contrast to 24 and 29 years with payments at the 10th and 30th percentile strikes respectively. However, the payments were much lower as strike level increases even though the frequency of payments increases thereby reducing the variance in payouts over the forty year period. The interest of the insurer in insuring milder risk could be further gleaned from the analysis of the standard deviations of the loss ratios found in Appendix 15.

The standard deviations show that the highest variance in loss ratio (2.80) is in Queensland which is at the 5th percentile strike. This ratio reduced to 2.57 and 1.27 at the 10th and 30th percentile strikes respectively. In comparison to the loss ratios of Queensland, the standard deviations of the loss ratios from Western Australian shires are lower across the 5th (2.16), 10th (1.91) and 30th (1.54) percentile strikes. The pooling of the risks across the two states expectedly lowers the variance further to 1.73, 1.55 and 1.08 across the 5th, 10th and 30th percentile strikes respectively.

The effect of temporal risk pooling is not captured in Appendix 15. However, Appendix 16 shows the joint effect of spatial and temporal risk pooling across the strikes. In Queensland, at the 5th percentile strike and for one year risk pool, the risk of loss ratio below one was 85%. As pooling increases over time, there was a progressive reduction in profitability from 85% to 35.5% for ten year risk pooling. For the same state (Queensland) at the 10th percentile strike, the trend remains the same as is the case for the 5th percentile contract but the differences were more conspicuous at the 30th percentile strike relative to the 5th percentile strike where the risk of a high loss ratio above one reduces to zero with ten years of risk pooling. However, the reduction came at the cost of a reduction in the prospects of loss ratios below one. In essence, the risks are clustered around one than before. It could be observed that temporal risk pooling decreases the risk of high loss ratio but also decreases the possibility of extreme profits. In essence, temporal risk pooling reduces the variance in the indemnity paid by the insurer.

A similar trend as that of Queensland could be noted for Western Australia. It seems that the risk of extreme outcomes were tempered in Western Australia than in Queensland because the probability of loss ratios below one was 75% in Western Australia in contrast to 85% in Queensland while the risk of very high loss ratio above 3 was found to be 7.5% in Western Australia but 10% in Queensland. This difference may have resulted from the fact that there were more shires in Western Australia (40 shires) than in Queensland (23 shires) in the pool. It could also be the result of higher variability in rainfall in Queensland than in Western Australia as noted in Chapter 4 or a combination of both explanations.

Analysis of both states in Panel c of Appendix 16 indicates that there was a reduction in the loss ratios at both extremes. The reductions are glaring when the 5th and 30th percentile contracts were compared. The probability of loss ratio below 0.5 reduced to 62.5% when the risks from the two states were pooled at the 5th percentile for one year whereas this value was 80% and 67.5% in Queensland and Western Australia respectively. The probability of a loss ratio below one increases at the 30th percentile strike for ten-year risk pooling for both states (74.2%) in comparison to those of Queensland (58%) and Western Australia (48.4%). Therefore, the probability of the insurer making profit increases over time and space particularly when droughts are mild.

The graphs (Figures 6.1 to 6.9) presented below show that loss ratios were higher in Queensland than in Western Australia. For example, at the 5th percentile strike, loss ratio was close to 15 in Queensland and close to 10 in Western Australia when risk was pooled for one year. The higher strikes indicated a similar trend but there was a general decrease in loss ratios towards the higher strikes based on the information earlier gleaned from Appendix 15.

A comparison of the graphs of each state (Figures 6.1 to 6.6) with those for both states (Figures 6.7 to 6.9) illustrates the effects of spatial risk pooling. It could be observed that loss ratios decreased from 15 to about 6 when the risk from Queensland was pooled with the risk of Western Australia for one year. However, when the comparison was between Western Australia and the pooled risk, the pooled risk indicated higher loss ratios because of the effect of higher risk from Queensland. Similarly, the graphs indicated that over the years and across the strikes, the effect of spatial risk pooling decreases because of the effect of temporal risk pooling. It was also evident that as the strike level rises, loss ratios decrease.

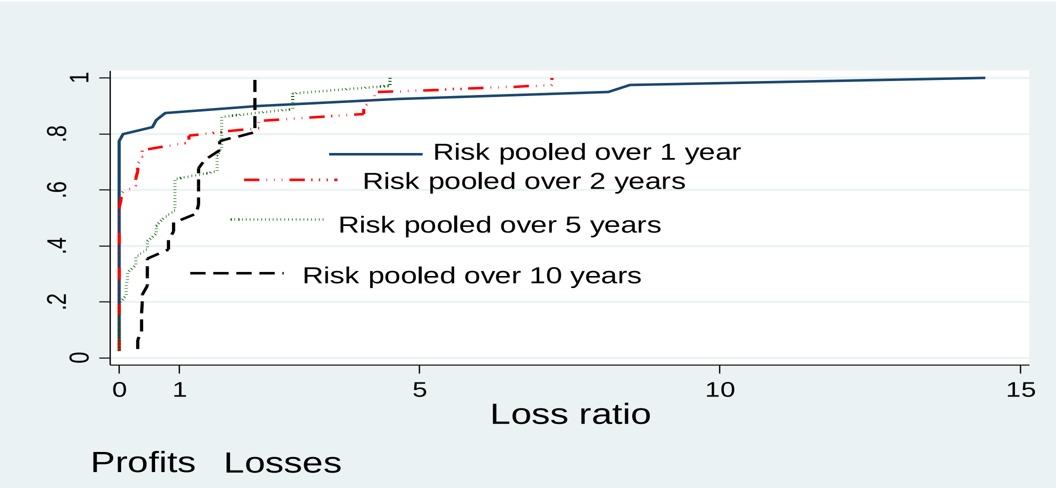

Figure 6-1: 5th percentile 60mm capped optimized contract for Queensland

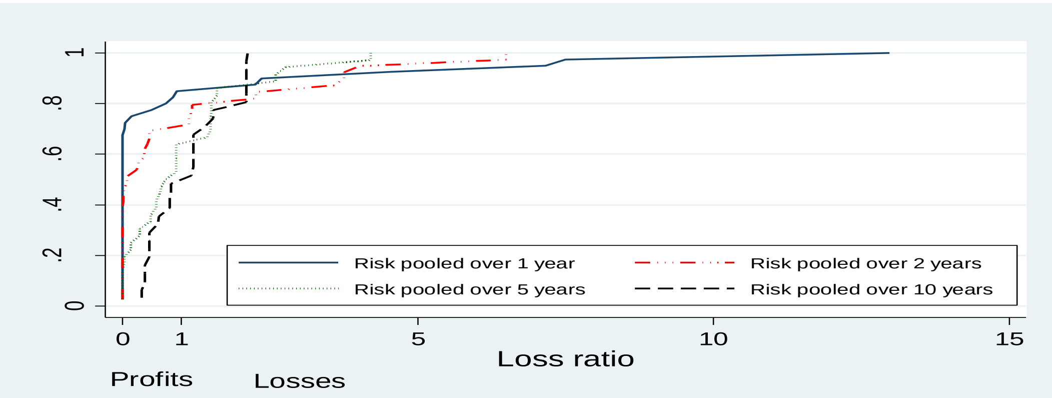

Figure 6-2: 10th percentile 60mm capped optimized contract for Queensland

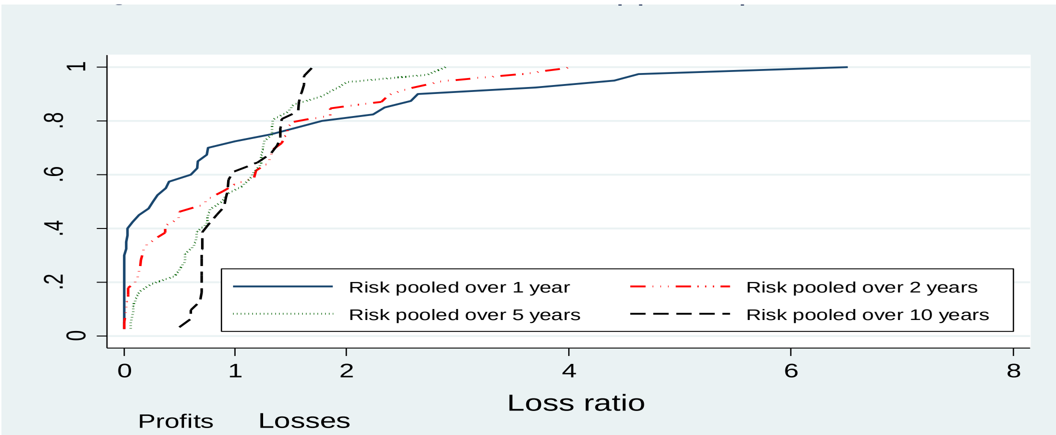

Figure 6-3: 30th percentile 60mm capped optimized contract for Queensland

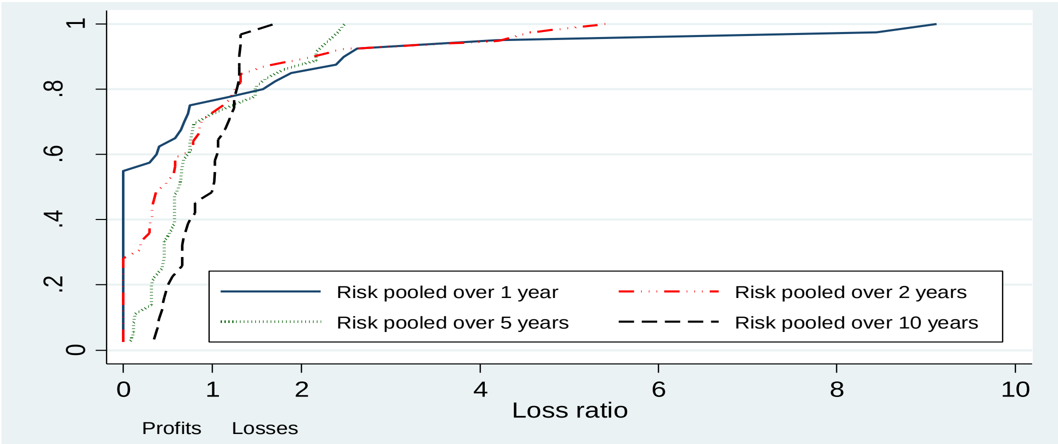

Figure 6-4: 5th percentile 60mm capped optimized contract for Western Australia

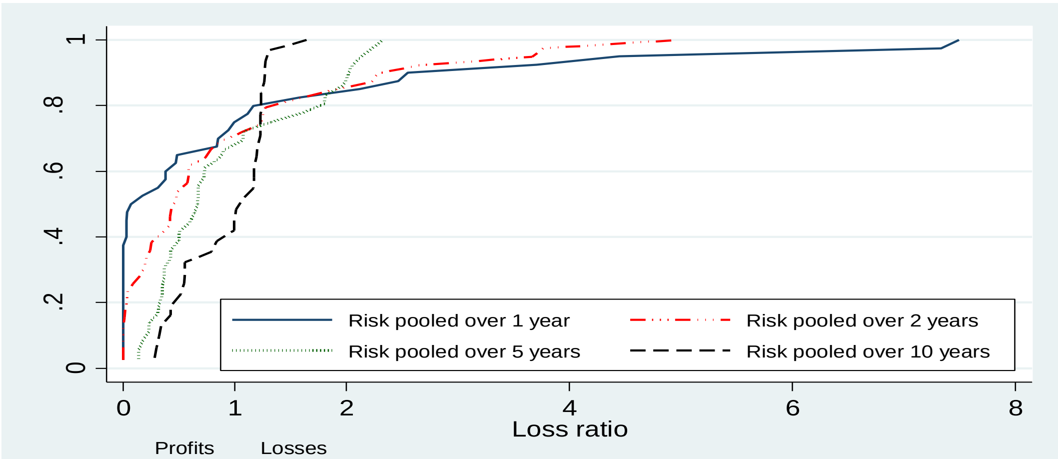

Figure 6-5: 10th percentile 60mm capped optimized contract for Western Australia

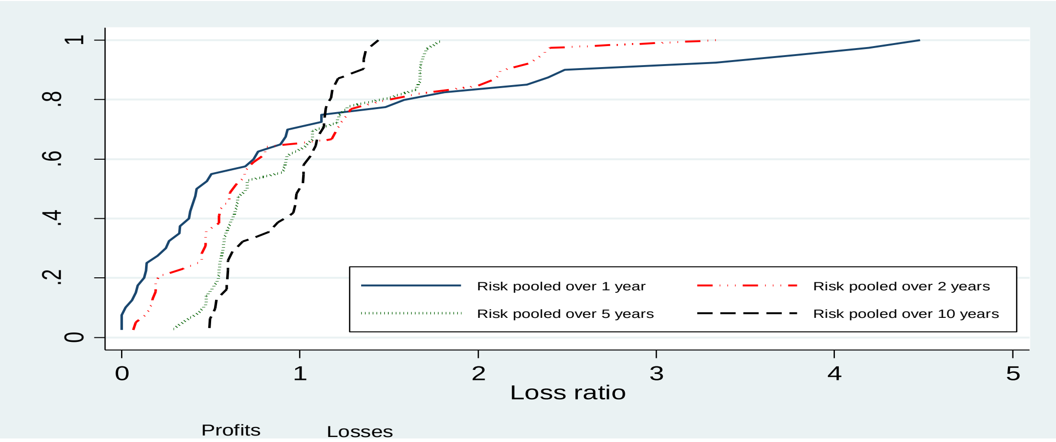

Figure 6-6: 30th percentile 60mm capped optimized contract for Western Australia

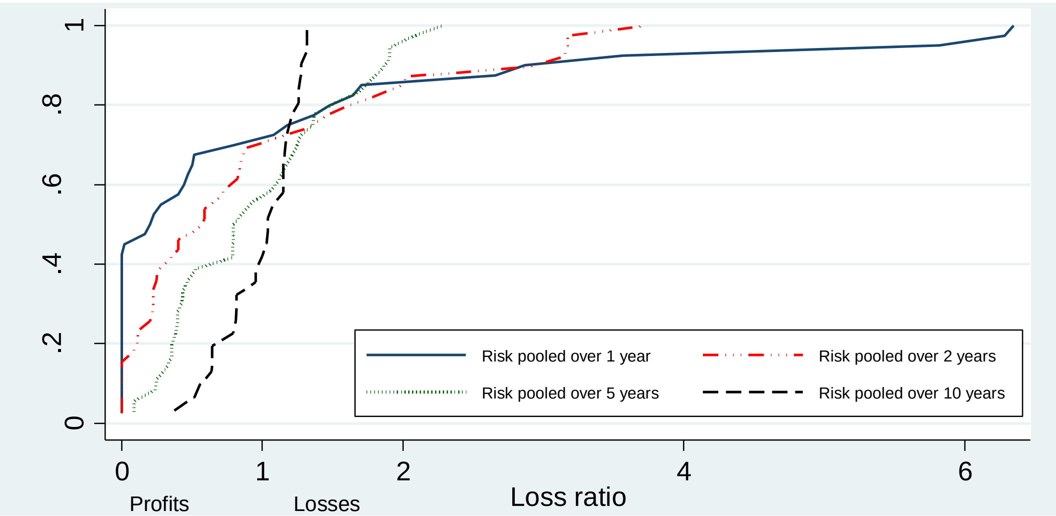

Figure 6-7: 5th percentile 60mm capped optimized contract for all shires

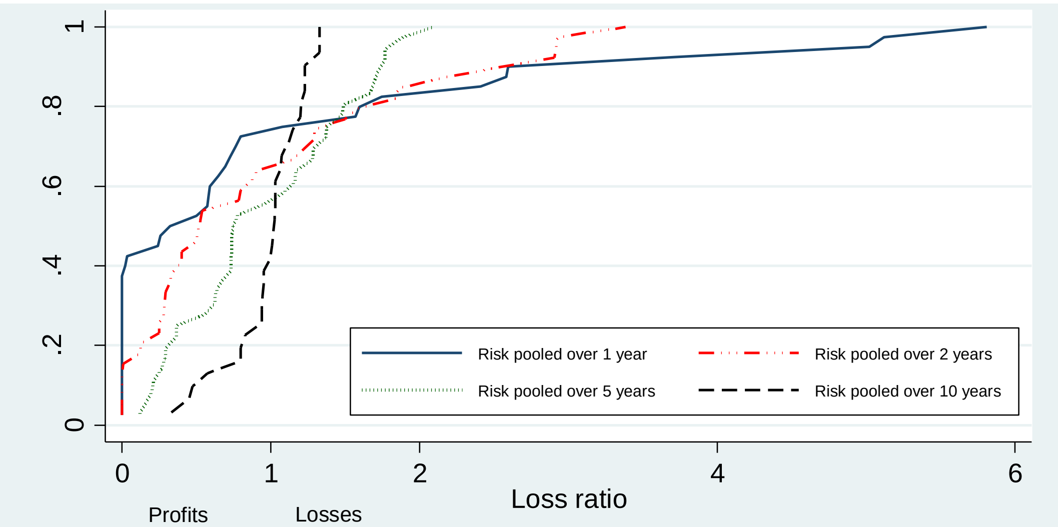

Figure 6-8: 10th percentile 60mm capped optimized contract for all shires

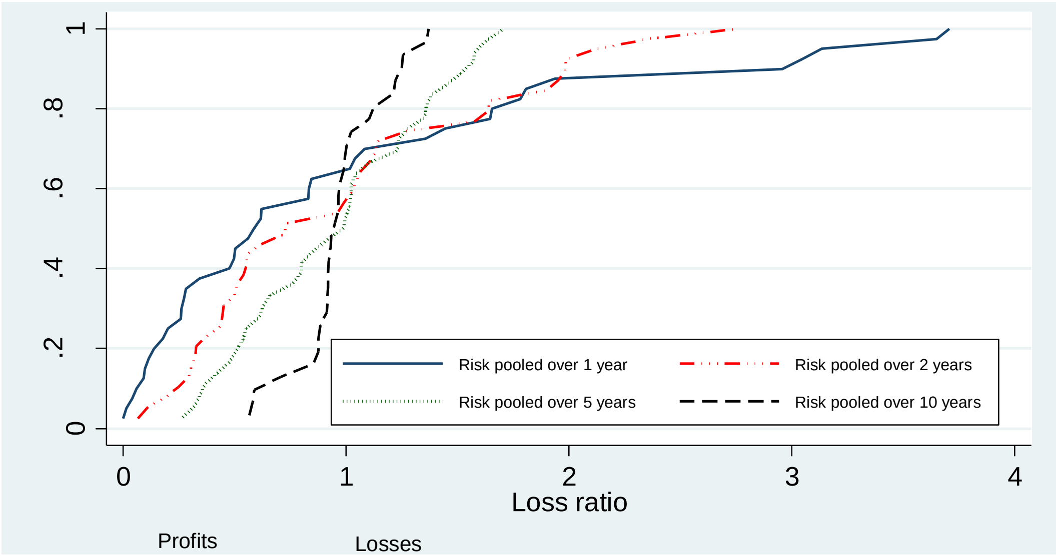

Figure 6-9: 30th percentile 60mm capped optimized contract for all shires

6.3 Summary of results

In summary, the probability of a low loss ratio, which is more profitable for the insurer, was highest for a single year pooling but this is also associated with a high probability of loss. As the risk of a high probability of loss decreases, the probability of profits also decreases. Temporal risk pooling therefore moderates the risk to the insurer particularly when this interacts with spatial risk pooling. The cost of the high probability of profit is the probability of very high loss ratio. That is to say, the probability of extreme profit is very low at the highest strike level and this probability decreases with the years of risk pooling. The interaction between temporal and spatial pooling of risk seems to reduce the probability of extremely low loss ratios but also decreased the probability of high loss ratios when risks are pooled for five years and above. In other words, as could be gleaned from the graphs, loss ratios tend to be lowered with time meaning that offering the insurance is likely to yield profit or at least the insurer will breakeven over time all other things been equal for a wider spatial coverage. In essence, the effect of temporal risk pooling is magnified when there is a very wide spatial coverage.

7 CHAPTER SEVEN: CHALLENGES AND OPPORTUNITIES OF WEATHER INDEX INSURANCE IN AUSTRALIA

7.1 Introduction

In the previous three chapters, the quantitative results from this study were presented. In this chapter, the qualitative data were analysed. The qualitative section was separated from the quantitative because it presents a unique part of the study that may be better understood if separated. Similarly, the findings in this chapter were based on research objective four that informs the research question; *what are the challenges and opportunities of weather index insurance in Australia?* The previous three research questions could not respond to the identification of the context in which the weather index insurance product will operate and the lived experiences of stakeholders as this qualitative section does.

The data in this section were generated from focus group interviews with seven participants and interviews with ten farmers, two bankers, three insurers and three other stakeholders in Australian agriculture representing and supporting rural Australia. The third stakeholder's response however showed that the issues at stake were political in nature and he therefore opted out of the study. His response was however considered useful in that other participants who declined to respond might have done so for the same reason. Therefore he was counted as one of the three stakeholders interviewed. The farmers were denoted as *FA* (*FA1 to FA10*), the bankers (*BA1 to BA 2*), insurers (*INS1 to INS3*) and the three other stakeholders as *SA1 to SA3*. Nevertheless, not all responses were stated rather the most representative expressions were included in the report and attempts were made to organize them into a coherent and logical flow of thoughts under five themes. The interview participants were labelled as shown above (*FA1* to *FA 10*, etc.) but it was difficult to label the Focus Group responses during transcription except during one of the discussions as would be seen in Section 7.3.2 of the analysis where three participants were exchanging views on their awareness of some government-based risk management options for graziers. The venue and other characteristics of the participants were documented in Chapter 3. Although, the participants in this study could not be said to be representative of the various stakeholder groups, their responses shed some lights on some of the issues at stake in Australian agriculture.

The purpose of this qualitative section is to take a broad look at the context in which weather-based insurance is situated relative to competing alternatives and its costs and benefits in the specific context of Australia. Three major findings were eminent in the quantitative chapters. The first is that the natural price hedge will reduce the willingness to pay for weather insurance. Secondly, there are locational disparities in the efficiency of weather index insurance. Consequently, a regionally-based insurance may not be sufficiently patronised because of basis risk and other characteristics unique to the locations. It was also found that an insurer could only make profit from a portfolio of weather contracts in the long-term and they will be willing offer insurance for milder risks.

In this chapter attempt is made to extract other issues relevant to the adoption of weather index insurance in Australia particularly in terms of policy evolution, competing alternatives that are available and those that are anticipated. In essence, the chapter facilitates the understanding of some issues in Australian agro-risk management landscape from the perspectives of the farmers and other industry participants. These issues could not be captured in the quantitative chapters but are relevant to discussions and recommendations on weather index insurance. The issues discussed in this chapter were generated from relevant literature and current affairs in Australia as documented in the literature review chapter. Therefore, the research proposition focuses on achieving an in-depth understanding of stakeholder perception of issues related to agricultural insurance in Australia. Similarly, it serves to triangulate some of the quantitative findings and relate stakeholders' experiences with the broad context in which the literature was reviewed and bringing the issues down to the specific context of contemporary practices in the Australian agricultural industry.

The chapter is divided into seven sections. In the first section (this section), the chapter is introduced. The next five sections feature five different relevant themes derived from literature that were considered relevant to the discussion of the issues at stake. The first of these themes is a discussion on risk and risk management in Australian agriculture that focuses on the different types of risks Australian agriculture is prone to and how they are managed. Emphasis is placed on drought risk and the policy evolution for managing it. The second theme, the need for policy change, addresses the necessity for a change in policy. The policy evolution section discusses market-based options in the form of insurance options which is emphasized under the third theme. The insurance mechanism was linked to the current state of debt and attrition in Australian agriculture under the fourth theme and finally suggestions gleaned from the respondents were documented in the fifth theme. The chapter ends with the summary of the findings from this chapter.

Under each of the five themes, the interviews were discussed followed by the Focus Group interviews relevant to the theme. At the end of each theme, a short summary of the theme was presented. In the following chapter, the findings from both quantitative and qualitative analyses were discussed with respect to the literature.

7.2 Australian agriculture and risk exposure.

In this section, the risks that Australian farmers were exposed to were identified. The risks identified were particularly, yield, price, input and political risks. These are related to the weather and the nature of the Australian economy. Some responses from which these risks were gleaned were highlighted.

7.2.1 Analysis of Australian agriculture and risk exposure - interviews

The farmers expressed their concern about drought risk than any other risks by saying that they will be more interested in buying rainfall certificates based on drought rather than any combination of weather variables. It seems that since extreme drought will affect all crops and even hay for livestock, there is a prospect for weather insurance for Australian farmers particularly given its systemic nature but for its future intensity and coverage that is difficult to model.

A few others (2 farmers) were of the view that a combination of both drought and flood may be useful. Their responses suggest that all of the farmers are prone to drought. Similarly some of the farmers were of the view that temperature certificate is of no use except when combined with rainfall certificate to make a double trigger index insurance.

The farmers tended towards rating yield risk as the risk they are most exposed to (very large extent) followed by price and then input costs rated as (large extent). It seems that input is becoming a rising concern more than ever before; '(Input) costs *is a trouble now'* (*FA4*).

The analysis suggests possibility of diversity in the perception of risk exposure due to economy of scale, natural hedge and spatial diversification. In managing their price risks, *FA8* and *FA9* were adopting long term storage in addition to forward selling as the other farmers do. Some farmers seem to adopt the services of consultants in deciding on how to hedge their price risk.

In the case of yield risk, Australian farmers seem to depend on traditional risk management techniques rather than insurance as noted by *SA2*; that most farmers manage the risks themselves. Those who take insurance took hail and fire insurance:

> *The only thing we do is to insure for hail and fire (FA1).*
>
> *You cannot insure for yield, mainly through fallow. Increase the soil moisture. Most yield risk is due to lack of rain (FA4).*

The above responses suggest that farmers tend to self-insure and could possibly prefer that other options were available to manage their exposure to *lack of rain*. In the case of input risk, family labour was a major means of managing the cost of input along with contracting. Participating farmers were given the opportunity to mention any other risk they were prone to. A particular respondent (*FA8) was of the view that; Political interference, red tape and activist minority are some of the* risks Australian agriculture is exposed to. *FA8* also mentioned that mining industry and increased cost of everything are risks the agricultural sector faces. This particular farmer sees union activism as a means of managing the risk of political interference and the activist minority. This opinion suggests that notwithstanding the outcome of any study on what creates net welfare benefits to Australia, any policy that would deliver more of government fiscal budget towards farmers will require some economics of politics.

In the response of *FA 10* to the reason why adequate support has been lacking for Australian farmers, the Australian trade flow was found to be an issue of concern; *Lack of appreciation of grains industry production. Trade imbalance – too many imports.* In essence, the fact that Australia's outputs are largely exported and the inputs are largely imported puts the farmers at a dual disadvantage. The trade imbalance is skewed against Australian farmers and this was well noted in the response of *SA2* who affirmed the lean domestic market for Australian products.

The participants were asked about their level of awareness of risk management options. None of the farmers was aware of weather risk hedging (YieldShield by Primacy Underwriters and Full Season Weather Certificate by CelsiusPro). Revenue insurance seems to have gained more grounds among farmers though it only emerged about a year prior to the compilation of this report. Named-peril crop insurance (against hail and fire) was absolutely popular among them.

Two of the three insurers were of the view that farmers have the named-peril crop insurance but the insurance is not what they needed because it insures hail and fire which are much rarer events than drought that poses the main challenge:

Hail insurance is available for some crops like cotton as far as I know but there is nothing like lack of rain insurance (BA1).

At the moment, 85% of Australian farmers are already buying hail and fire insurance. So, 85% of farmers are buying the wrong insurance because they have no option (INS1).

The yield that we are looking at is affected by weather. If we can control the weather we can control the yield. They pay for an event that is once in a 100 and pay 2 to 3% for it, whereas an event that is once in 10 that is 7%, they will not pay for it and they take machinery insurance at the same premium and the asset depreciates (INS3).

The farmers attested to the fact that the hail and fire insurance is not meeting their needs in that they don't get very much hail so they rarely insure for hail. The responses of farmers suggest that they will be interested in other forms of insurance particularly weather insurance and revenue-based MPCI:

I'll probably have a go (on weather insurance) (FA4).

I think it will be good to have weather index insurance option but drought is more frequent (FA2).

I have not thought about that (revenue-based MPCI) but is important to have that ability (FA1).

Revenue-based MPCI is better because it insures both risks, it addresses some of the other risks we have (FA 2).

I prefer it to be based on revenue because it is yield and price

I will be willing to pay $20 (out of $100 for weather insurance) if prices are going down. It depends, if you know what I mean. The variation in our income can be six fold from $200,000 to $1.2 million gross income (FA1).

The final response above shows that the uptake of weather insurance might have been influenced by other factors beyond weather itself and explains the reason why the nature price variability may reduce the incentives of farmers to insure. Insurers confirmed this possibility of extreme variation in farmers' revenue and the need for alternative models of agricultural insurance:

It depends on the season they are having. If they have good crop and low prices, they might, low yield and high prices they won't, low yield and low prices they will (buy weather insurance) (INS3).

Australian agriculture is so exposed that people can lose 60 to 70 % of their net worth in one season that is why insurance is the only way to deal with it (INS1).

There is a fundamental flaw in the fact that it is always yield based. Yield does not lock your price in. An example; 3 t/ha at $150/t = $450/ha, 1.5t/ha at $300 = $450/ha, but if you grow 2t/ha at $100/ha = $200/ha. You need insurance when you have 2t/ha because of the price. The issue is not how much yield you've got, is how much money you have in your bank accounts.

> *That is the fundamental truth. All the other policies have failed because of this. They have never really answered the question (INS 1).*

The opinion that insurance is the only way to deal with it may however be biased. The tendency to be biased was also emphasized in another response meaning that every rational being is a self-interest maximizer as noted in the literature review:

> *… if government subsidizes agricultural insurance is actually lot cheaper than if government just gives payout. There was a severe drought a couple of years ago in Australia. That affected a lot of farmers. The government ended up having to pay like relief efforts to those farmers (INS 2).*

When the argument of the government that insurance will not stop disaster payment was presented to the respondent above, he affirmed the position of the government and emphasized that different stakeholders tend to look at the issue from different perspectives. However, other insurers seemed agree with him on preference for tax incentives on insurance premium because they opined that everyone will attempt to pay the government less.

Further analysis of the responses also indicated that the willingness to pay may be influenced by the location in that the type of weather certificates demanded depends on the location of the farmer. The response of *FA 10* indicates that there are regional differences in rainfall distribution in Australia and that has an impact on profitability of their ventures:

> *We have just sold our farm, and moved to higher rainfall area – from 250mm average to 450mm average annual rainfall (FA10).*

It is evident that there are differences in risk exposure, insurance preferences and supports, therefore whatever form of intervention should take cognisance of these differences.

One other risk management strategy is increasing the water holding capacity of the soil through liming as noted by *FA 1*. *FA 1* further attested to the use of radiometric survey as a way of working out the most profitable paddocks in an effort to enhance decision making. This type of decision making seems to involve playing the season as indicated by *FA 7*. *FA 7* indicated that *'playing the season and not putting in as much crop if conditions are unfavourable'* has been his own way of managing risks. This response suggests that in the presence of a purely yield-based insurance, farmers would play the season in such a way that maximizes their utility. Playing the season is the bane of yield-based insurance. Another interesting note from *FA7* was that to improve drought risk management in Australia, *'Reduced interest will be beneficial. Reduced tax as the 20% of good years we have to pay provisional tax in poor years – borrowing money to pay tax'.* The interest rate risk was affirmed by *FA4* who valued the Exceptional Circumstance Interest Rate Subsidy (ECIRS) to a very large extent because interest rate is a fairly large component of farming operations. These responses suggest that farmers are exposed to interest rate risk. It could be further gleaned from *FA7* that they would possibly appreciate a review of their taxation.

An interesting trend was however noted by an insurer who was of the view that farmers' verbal demand for insurance does not necessarily translate into active demand when the products become available. It may not be that these farmers do not want to take insurance but may not have access to the type of insurance that is most appropriate for them in that they believe that insurance in Australia is inadequate as observed from their responses. Besides, they do not seem to have sufficient information about these options because they are often dependent on the advice of their consultants. The analysis of the responses related to risk and risk management options for Australian farmers shows that they are likely going to consider insurance as a viable option. However, given previous experience, verbal demand does not always translate into actual demand. It seems that agricultural insurance that will be really useful for farmers cannot be offered at a commercially viable premium and would therefore require some subsidies. Two possibilities were examined in the IAC (1986). These are payment of subsidies to insurers and provision of reinsurance by government. Whatever the role of government will be, it must involve the provision of appropriate infrastructure needed for premium rating.

Weather insurance would be challenged by the revenue-based MPCI because it does not capture the price variability in its modelling. The cost of offering the insurance may however be cheaper because it may be easy to diversify the portfolio risk within Australia and with other offerings for other industries. This diversification is possible because there are market participants who will be ready to take every position required to hedge existing exposure of the insurer. The prospect of the insurance option is at least one step brighter with the recent changes to policy on drought risk.

7.2.2 Analysis of Australian agriculture and risk exposure - focus group interview

The farmers during the focus group said that the major problem they have is the fluctuations in the seasonal weather; *risk factors beyond your control, weather is at the top of the list.* Another point they made that could be worth documenting is that weather risk affects their yield up to a point. Other risks including input risk were also related with the weather because they can spend so much money on input but the weather conditions could nullify all their investment. In essence, they are not intimidated by input price as much as they were of getting no returns for the input. They also compared their experiences with their counterparts in the US; *I think a big percentage of Australia will experience some failure every year in comparison to US cropping. Their corn crop can come through and 95% could be from good to excellent. They just don't technically have a failure.* The responses of the farmers suggest that they are facing a much tougher seasonal condition than other countries of the world particularly US which they envy the most for getting so much supports even when their risk exposure is not as frequent and intense as Australia's.

An important comment from a participant revealed that Australia's exposure to price risk through input import and output export is a major source of risk: *Because we have become a world economy, we are also exposed to demand and supply more and external factors than we ever have been before. We sell wheat based on export market, but the imports are not like what obtains in America.*

In essence, the comparison with the farmer's condition in US shows that the prices that US farmers take for their outputs and those they pay for their inputs are not significantly influenced by external factors unlike the case is in Australia. This risk therefore puts the Australian farmers at an additional disadvantage as would be noted in a response by *SA2* under the insurance options and associated challenges in Section 7.4 below.

On their risk management strategies, they believed that risk management is about making daily decisions appropriately. They said that a farmer should; (*you) manage with good farming practices. I suppose is a very simple answer but there are so many variables involved in what you do but is a day-by-day choices you make when you manage. For me is not a particularly set plan, is just a case of looking at what you are doing as the years go by.*

They were interrogated on the types of market-based options they adopt in managing their risks. It was noted that the level of awareness of the respondents were low in terms of current menu of insurance options available in the Australian market but they were unanimously aware of the named-peril crop insurance. The participants in the focus group seem to suggest that they were exposed to political risks because of the small size of the rural population in Australia. They also attributed the risk to the valuation of agriculture by Australians which they traced to history in comparison to Europe:

> *A couple of other things; Europeans actually value farming because of hangover from World War II and in America farmers hold sway, they 've actually got some power whereas we, we are a smaller percentage of the total economy.*

In summary, the above analyses have shown that farmers are primarily exposed to weather risk which influences their yield. However, other risks are not unrelated to the impact of the weather particularly input and price risks. The next forms of risks are related to international trade as input costs and output price are both dependent on foreign import and export respectively. These risks further expose Australian farmers to foreign exchange risks. Finally, political risk is another prominent feature of both forms of interviews. The risk emanates from the fact that Australians do not have much regard for agriculture and the farmers are not sufficiently powerful to influence decisions.

These risks that farmers have been exposed to necessitated different policy responses from the government of Australia. Consequently, there have been changes to policies and these changes were necessary because of inequity and inefficiency in previous policies as would be noted in the next section.

7.3 The need for policy change

The policy landscape of Australian agriculture has been dynamic over the years. The changes have been necessitated by the need to find the most appropriate policy response that is equitable and efficient. Equity and efficiency have however been elusive in agro-risk management around the world, Australia inclusive as shown in the literature review. In this section, the responses of the participants were collated and related to their satisfaction with the policies in the context of equity and efficiency.

7.3.1 Analysis of the need for policy change – interviews

Respondents were asked whether they, or anyone they knew, had benefited from the Exceptional Circumstance (EC) declarations in times past. It seems that they have all benefited one way or the other:

Actually, we had EC long time ago (FA 4).

Got Centrelink in 2002 about $300 per fortnight (FA 2).

The responses of the participants however indicated that they were discontented with the programme and that the programme seems to be favouring livestock farmers more than broad acre farmers. One of the farmers said that EC was '*not very nice! We don't qualify, livestock farmers are given priorities'. Another respondent rejected the programme vehemently 'Not really, no. EC – No!'.* It seems that farmers did not *'(I don't) really like the pay out even though it was necessary'.* This response confirms that the EC was much-maligned as rightly noted in the National Farmers' Federation publication (NFF 2011). Welfare payment will be similar to EC payout and would be loathed by farmers because it does not empower them to hedge their risk. If farmers were said to be demanding higher prices for their assets because of EC, then a welfare package may not be different.

The Farm Management Deposit (FMD) was popular among farmers as all of them were aware of it. However, they were concerned that it; *'only works if profitable' (FA8)*. Similarly, they expressed concerns that FMD limits are too low for a grain business.

It is evident that Australian farmers are managing their risk their own way and their counterparts in other countries may make sub-optimal decisions because of the incentives they have. Similarly, there may be a shift of production capacity towards livestock farming as a way of diversifying and qualifying for assistance:

I think what happens in Australia is that farmers have in some ways taken out their own insurance by adopting minimum tillage, by adopting variable rate technology and also by significantly increasing their yield per millimetre of dry season rainfall. So, farmers are trying to adapt to the risk by changing their productions rather than looking to a financial instrument to provide that insurance. So, what I see happening is farmers for example not planting their crop until they know whether they have the available rainfall or in cases when they planted their crop in the absence of rainfall delaying putting on any extra input like fertilizer until they know how much rainfall they have using variable technology to manage the crop that way so that they don't have so much risk exposure in times they terms of what they put in the ground hoping they will recover when they have the crop. That is leading farmers not all farmers are doing that. And then the other pattern which is more evident in Australia than in the US in particular is the integration of livestock and crop production on one farm (SA2).

It is evident that farmers are diversifying into livestock production. The diversification may nonetheless be due to attempts to capture some benefits that are given to livestock farmers that are not for broad acre farmers because of the sympathy that follows livestock stress during famine. Another fact that is prominent in the above quote is that not all farmers are adopting best practices. The implication is that a premium based on regional averages penalizes diligent farmers. The stakeholder who volunteered the above response noted further that:

I think Australian farmers are keen to manage their risks in those ways rather than rely on financial instruments to manage them. Whether that is sufficient *for them to remain competitive or not, given the US has just announced its new farm bill that is actually increasing their protection on crop insurance, I think it will be interesting to see (SA2).*

The additional quote above suggests that the state of risk management in Australia is based more on traditional practices rather than market-based mechanism despite the availability of hail and fire insurance, weather insurance and the recent entry of revenue-based MPCI. On one hand, the lack of supports for Australian farmers constitutes exogenous inequity particularly because Australian farmers are more exposed to weather, price and input risk than others who are getting much more supports. On the other hand, these other countries are known to engage in farming practices that promote risks.

A response suggests that the banks are actually compelling farmers to take hail and fire insurance as could be seen below. The response also affirms the role insurance plays in facilitating credit:

Is usually the banks that are forcing the farmers to take insurance. The banks are trying to protect their loans, if the farmer has a bad year they cannot pay the loans. So in this case, the banks want the farmers to take insurance if there is a storm that destroys all their crops, at least they will get some money from the insurance (INS 2).

Only one farmer held a dissenting view on subsidies as he did not appreciate any form of subsidy in whatsoever form because it gives incentives to unproductive farmers to stay in business thereby unnecessarily increasing the value of land to those who are capable of buying them over for efficient use:

You support the bad inefficient farmers. I don't think there should be any subsidy; you just let the market map it out (FA 6).

This farmer is of the view that inefficient farmers should be allowed to get out and those that are efficient should take over their properties. The establishment of a welfare system for farmers may however be a stumbling block to the exit of such farmers. He is also interested in making farmers pay more for research and development.

In another response, it could be said that the remaining farmers in Australian agriculture are the viable ones:

Too costly (insurance).The problem with most support is it's geared to examining the business and gets gobbled up by consultants. Sounds like the government is helping in the media but very little hits the ground. All the unviable or inefficient farms are gone and more analysis is not required in times of drought but financial help (FA7).

The tone of the above response confirms that most farmers did not actually get any form of support as noted by Kimura and Anton (2011) and those who got only had little. In contrast to the suggestion by *FA6* that inefficient farmers should not be supported, *FA7* believes that those farmers that are inefficient are gone and that those who are left should be aided in such a way that will make them return to profitability. This opinion could be true in that the rate of attrition from the agricultural sector has been very high as noted in the literature review.

Farmers tended to rate the interest rate rebate triggered by EC (ECIRS) as being helpful to a very large extent. This is '*because interest rate is a fairly large component of our (their) business'* (*FA4*) a notion well supported by *FA 7* and *FA 10* whose responses suggest that policy responses should target interest rates. The response of *FA 7* is as found below; *'reduced interest would be beneficial. Reduced tax as the 20% of good years we have to pay provisional tax in poor years – borrowing money to pay tax' (FA7).*

Inability to manage this rate is the cause of growth in the debt of farmers without a commensurate growth in productivity. The ECRP and ECEP were valued to a much lower extent. In all, exit package was the least rated as helpful by all farmers. The deregulation measures of the Australian government were considered as the major reason for the decision by government not to subsidize. The aim of the deregulation was market competition. The competition has led to the takeover of farms by large corporations to the extent that some farms are bigger than some European cities. The response of one of the participants captured the issues related to competition:

> *If you look at the landscape of Australian agriculture in terms of rural industry in the last 30 years, there is a lot of heavy deregulation that is why the government does not want to subsidize insurance. Less subsidization, more competition. Now at the point where Australian farms are run by large corporations (INS 2).*

The response of *INS 2* further acknowledged the increasing size of Australian farms and a reduction in their number as noted in ABS (2013) and Hunter and Biddle (2011).

It is evident that the reason for deregulation was competition. However, should subsidies be allowed in whatever form, as long as it does not distort the market through anti-competitive behaviours such as detrimental collusion and rent-seeking, the policy may lead to a pareto- improvement in the economy of the Commonwealth. It is evident that the EC is *much–maligned* and other supports may not help farmers to plan. In order for farmers to be independent and to take responsibility for their own risk, there has to be some forms of comprehensive interest rate risk management in such a way that facilitates the reciprocity and mutual obligation expected by the Australian government. The next section examines the challenges associated with the insurance route to risk management in Australia. It seems that the system has enriched some farmers at the expense of the others who were in genuine need of supports but could not get (USEPA 2013; Freebairn 1983; Kimura & Antón 2011).

7.3.2 Analysis of the need for policy change - focus group interview

The results from the focus group interview shows that the participating farmers were also very much aware of government's interventions like the Exceptional Circumstance (EC) as a form of risk management option. Discussion with them however shows that the Exceptional Circumstance actually favoured cattle farmers than the broad acre farmers. A discussion ensued among the seven Focus Group (FG) participants to which three of them responded as follows:

> *FG1: It's more for grazers. It helps them move stock and fodders around between properties.*

FG2: I can tell you, if you go out west, some people get as much as $50,000 to $70,000. If you talk to other growers out there they will say the only reason we survive is that we have this system in place.

FG3: I thought it was just fret.

FG2: It's not just fret! It was put out as just fret. I can nominate several growers who rob their hands with this scheme. There is a lot of business there.

The discussion above shows that the levels of awareness of farmers differ greatly. Secondly, the attempt by farmers to diversify into livestock farming may be to *rob their hands* with the proceeds from the existing scheme that allows livestock farmers to get as much as $70,000 of tax payers' money at the slightest opportunity. The trend in sympathy for livestock farmers is also evident in other parts of the world (USEPA 2013).

The other risk management option that the farmers made mention of was the Farm Management Deposit (FMD). They acknowledged that; *like everything people will explore the benefits somewhere.* The mode of exploration of the FMD seems to suggest that the policy is not necessarily achieving the desired effect. The discussions suggest that farmers are actually engaged in FMD more in the years when they should be pulling out of it. The FMD was meant to give incentives to help farmers save in times of abundance by ensuring that their tax obligations are reduced and then pull out their savings in years of low profit. Experience however has shown that the converse is the case as farmers tend to save more in years when they are getting drought supports. After some explanations of this contradiction, it was reiterated that:

You find in the highest drought payment (2006/8) it was the highest period of FMD. You will think FMD is to be pulled back in bad years.

However, farmers really wanted the tax benefits of this programme to continue because of the perceived pressure by treasury to phase the programme out. They also wish that it could be extended to other industries:

I will hate to think they should withdraw that (FMD), what they should actually be doing is expanding it to other industries like the supply industry even though they are not farmers. … If you have insurance you are not going to cover that one.

The response was further emphasized in the cause of the discussion:

The other thing that needs to be included in this is that FMD needs to be expanded to the secondary industries like the providers to farms.

The major benefit of FMD is that it gives tax benefits to farmers and therefore tax incentives were well discussed in the group interview. It was observed that farmers tend to support any policy that confers tax advantages on them.

Firstly, I like tax incentives because it encourages people to become profitable. If everyone is profitable it solves everyone's problems. It is a disincentive to be taxed hard when you had a bad year. There is no incentive to declare taxes?

It was evident from the discussions that farmers tend to structure their finances in such a way that maximizes their tax advantages. However, the structure is not necessarily the most efficient in that they may engage in sub-optimal asset purchases that does not maximize the value of their investments. (If a farmer declares profits in such a way as to pay $30 on $100 and he has the option of declaring profits in such a way as to pay $20 on 100 by purchasing some assets, he would do so. However, the asset could have been leased rather than purchased. The $10 difference in tax benefit may not be worth the investment). They expressed their tendency to make sub-optimal decisions in the absence of tax benefits as follows:

> *A lot of farmers are guilty of having a good year and buying tractor and a harvester. … You spend a dollar to save 30 cents.*

In view of the above discussions and survey of relevant literature, insurance has been considered as an alternative that could be beneficial but it may require some forms of government support to keep it running. It is evident that hitherto, farmers have not been satisfied with agro-risk management policies in Australia. Consequently, the insurance options and challenges were discussed in the next section.

7.4 Insurance options and associated challenges

7.4.1 Analysis of insurance options and associated challenges – interviews

The major options advocated which is the market options were explored under this theme alongside its associated challenges and competing alternatives. Issues related to pricing, technology, subsidies and the experiences of other countries are analysed under this theme. The comparison between the Australian agro-risk management and that of the US was very prominent.

One of the challenges of insurance in Australia was that it will be very expensive because of the current frequency and intensity of weather variability:

> *Basically it boils down to price variability and seasonal variability. It seems that price is more variable for grain production in Australia. That's probably because we don't have a large domestic market or biofuel market as the US does. Secondly, the seasonal climatic variation appears to be much greater because the yields and the outputs per farm vary by lot more than is the case for US. The sum of those two appears to be that the value of crop production per farm in Australia is much more volatile than most overseas location. When you compare the volatility of the cropping sector in Australia in terms of how much the total value of annual production changes each year, when you compare that with the volatility of the cropping sector in overseas locations, it's much greater in Australia by a fairly large factor. So, that means the potential underwriting risk for an insurer in Australia is probably greater than is certainly the case in the USA (SA 2).*

Beside the fact that Australia is prone to both price and yield variability beyond their counterparts in other countries, their counterparts from these countries are heavily subsidized:

> *In the USA, the federal government subsidizes insurance premiums paid by farmers by about 65% and also subsidizes the administration of the*

programme by the underwriters (the insurance companies) and also collect the data that is used as part of the administration of the US system. By the time you add the total cost together, the US government probably subsidizes the cost of the US cropping insurance programme by about 80% or more. So, farmers are only paying around 20 – 30 % of the insurance in the US. If you compare that to Australia which has a more volatile cropping sector, I think that would mean the cost of insurance would likely be higher in Australia unless the government is ready to subsidize it to a very high level, it's hard to say that producers will be prepared to pay the premium necessary to cover their insurance cost and get that programme up especially when you look at the example of CBH in WA. I think the premium there was about 10 -15% of the insured value of the crop which is quite high. For example between $20 and $30 a tonne to the cost of growing the crop which I think most farmers will say from their perspective will manage the risks themselves in a number of different ways without paying that much premium (SA 2).

Based on the responses of the stakeholder above, it was not surprising that Australian farmers are not taking up insurance. The reasons attributed to this poor uptake are evident in the quote below:

Farmers are not picking the product up due to lack of support and understanding (INS 3).

Another reason adduced to the poor uptake of weather and crop insurance is that the farmers invest on the wrong things or the wrong products in the view of the two insurance providers that are active in the market. The interview sessions with the farmers however suggests that there is a low level of awareness of weather insurance probably because most farmers adopt the services of consultants and do not know so much about the options themselves. Extension work may therefore be needed in this regard. The wrong things could also include wrong insurance as noted earlier in the risk and risk management in Australia section. It could be noted that previous yield-based MPCI '(*It) died off because the premiums were too high. It's always been at operating loss (INS 2).*

In the particular case of weather insurance, the difficulty of offering products that are based on non-observable weather variables at the time of impact was well articulated by a participant. It seems that this participant was attempting to capture the impact of structural basis risk. Structural basis risk refers to a situation where weather insurance is taken and there is a yield shortfall due to other factors or variables beside the parameter underlying the index when the insurance is not triggered. If the index is not triggered then, there could be concerns on the efficiency of the insurance product. It is more likely that insurance will be triggered if it targets the most extreme drought. A particularly interesting point was that some variables including management practices could impact on productivity which implies that yield-based insurance products could be affected by the management practices of the farmer thereby leading to moral hazard:

It is very difficult to say this product does not have enough water if the farmer has not been putting water on the crop is it due to temperature, is it due to weather or management practices (INS 2).

This insurer nonetheless believes that insurance may be cheaper than government payout because; *a lot of people saying that if government subsidizes agricultural insurance is actually lot cheaper than if government just gives payout.*

Similarly, despite the challenge of structural basis risk, one of the insurers (*INS 3*) observed that the government actually likes their products which they cannot offer without some forms of government aids. The insurer also observed that the product, weather insurance, puts less pressure on the government in terms of disaster aids but when it comes to offering supports, the government declines on the ground that they cannot support individual industries.

Geographic basis risk has always been a major challenge to the offering of weather index insurance. However an insurer was of the view that:

> *The basis risk does not exist anymore. ... We price the derivatives on an algorithmic weather station through grid reference (INS 3).*

The inexistence of basis risk may be a difficult pill for some farmers to swallow in that their farms are farther away from the closest weather stations than they would want if they were to take insurance. For example a farmer (*FA8*) wants the weather station on which their contract will be based to be 5km from the farm whereas the closest station is 140km away. For others they want a radius of 5km but the station is about 20 km away (*FA1*). The 5km proximity was the dominant preference because their farms could be as long as 16km. The farmer (*FA9*) with the closest weather station which was 6km away from his farm would prefer the station to be only 4km away. On average, farmers want their weather station to be 17.6km away from their farms but their closest weather stations were on average 64.8km away.

Weather index insurance requires specific tailor-made indices without which there could be basis risk (geographic or structural). The analysis of the responses of two of the three insurance firms offering weather-related hedges indicated that farm-specific parameters were used in the design of the products. It seems that weather index insurance has an advantage in that it gives a lot of the choice of parameters to the farmer and those few farmers who have been using the products are satisfied with it inspite of all odds:

> *Most farmers who use it like it. About 35 to 50 farmers use it. It depends on what they want to hedge and we build the index around the weather station and the farmers choose. This is a parametric index. The farmers choose the parameters and we build the index (INS 3).*

The nature of individual farmer's risk is a determinant of the choices they make in terms of parameter choices. This diversity among the farmers in terms of location and other inputs makes pricing of insurance contracts complex. It therefore requires farm-level pricing of insurance contracts as could be further gleaned from the response below:

> *It is (a) hard one and very complex, I suppose every area is different. It has to be a local one and based on individual farms. Everyone does it differently. Some people do it differently by trying harder to make their farms more viable than others (FA 4).*

Lack of technological capabilities was also cited as a major issue impeding insurance in Australia. Presently, Australia seems to be lagging behind in the pace of technological innovations necessary for the industry:

> *They provide a top-down image of the actual farm itself and load that into a database. You can take that image and you can keep it up to date every year when subsidies are given out. In Australia we don't have that type of technology because it is so expensive to implement (INS 2).*

7.4.2 Insurance options and associated challenges - focus group interview

Among all the options, farmers seem to be against welfare benefits for farmers rather any policy that would advance their tax advantages is preferred:

> *Am not a big fan of welfare for farmers. Taxation helps farmers to move forward.*

It is evident from the responses of the participants that they are taking hail and fire insurance because they do not seem to have sufficiently wide range of options to choose from. The choice of hail and fire insurance is actually necessitated by the fact that banks request for the cover before advancing loans to them. From the interaction with the farmers, it could be gleaned that, the insurance is only considered because it is viable in terms of the premium. They did not seem to be buying it because of its usefulness but because they must respond to the bank's conditions for loans:

> *In regards to insurance, the banks need some insurance before supporting the loan.*
>
> *It would be a much simpler system insuring yield. I presume that is the US systems even though I don't really know. If you insure against yield you've got a basic number and if you don't make it you get paid the difference.*

In the case of weather insurance, they were concerned about the definition of drought and basis risk:

> *There is no actual definition of drought. Is just subjective to the nth degree. Is not like one in 25 years or …*
>
> *Those around here may not mind to take insurance based on the weather station close (the one close to the venue of the Focus Group), they measured 30mm of rain yesterday, and we had 1.5mm.*

The farmer who obtained 1.5 mm of rain was only about fifteen minutes' drive away from the venue. Furthermore they voiced out other concerns:

> *Actually, the thing it does not cover you for is the reason why is not so good. You pay for hail and fire and then you get flooded. Something that is yield based at a reasonable premium. Especially if it gets wider spread and subsidized by government that possibly would work.*

The above expression suggests that farmers are anticipating government's support to make insurance options beside hail and fire workable in Australia. Secondly, they expect that the insurance should be wide spread for it to work. Perhaps, they are thinking of diversification benefit to the insurer. They seem to like the concept of revenue insurance because; *Revenue insurance is what will save you from disaster if all goes wrong. Yield and price equals revenue. How does that work? Another farmer tries to explain.* They however expressed concern about the election of the price and yield thresholds.

One of the participants however had concern about the selection of the price and yield; *it's like picking a yield and a price and averaging it across the country, I think that is what the US does, and come up with an insurance guarantee price.* They however acknowledged that the insurance is not meant to make them richer but to get them through the hard times and they would be interested if the premium is low enough.

> *There are other issues which could help the industry is the availability of low interest rate loans at drought times.*

Notwithstanding these challenges, which are also prevalent in other countries (Smith & Goodwin 1996; Stoppa & Hess 2003), an improvement in agricultural insurance in Australia could be useful in aiding farmers' credit worth (Skees & Barnett 2006; Nieto et al. 2012) without which credit could be more risky to the banks. Consequently, insurance option is considered as a formidable tool in tempering rural debt.

7.5 Debts, lending and attrition from the agricultural sector

Given the rate of growth in rural debts as discussed in the literature review (Chapter 2), attention was paid to prompting questions related to growth in rural debt from the participants and the possible role of insurance in tempering the growth. Their views are reported below.

7.5.1 Debts, lending and attrition from the agricultural sector - interviews

The role of insurance in enhancing finance and curtailing debts and attrition is analysed under this theme. A banker affirmed that insurance could have an impact on the assessment of farmers when they are demanding for loans:

> *It (insurance) does because we access loan on viability of operations and getting the cash in. If no insurance, there is risk. Favourable not lower interest more of a chance of getting finance (BA1).*

Although, it is obvious that insurance could have improved the chances of getting loans for farmers, it seems that it does not affect the cost of capital. However, the chance that the insurance adopted would be triggered was very slim in that they mostly adopted an insurance that may not be triggered but once in several decades.

In another interview, a banker was of the opinion that farmers are having issues with managing their debt because their lending is not focused on investment rather on cash flow supports:

> *There's a lot more lending in regards to helping people with their cash flow. Given the drought and all sort of things, the cash flow they are working with in relation to funding to help sustain their operations until seasonal*

conditions change around. We see a lot of that relative to other industries (BA2).

This trend shows that farmers are somewhat in a liquidity squeeze. The lack of profitability was affirmed by the farmers. This lack of profitability has led to the acquisition of smaller farms by larger farms in an attempt to gain efficiency. These bigger farms are usually multinational/corporate farms:

The current structure of the agricultural market changes from the hands of individual farmers to the hands of the corporate (INS3).

7.5.2 Analysis of debts, lending and attrition from the agricultural sector - focus group interview

On the issue of debt, the farmers were of the view that the current debt situation arose from the re-evaluation of the farmers' properties. In essence, it is not the debt itself that is the issue rather, the relative position of the debt to the equity of the farmers:

I don't know whether it is a debt crisis or an equity crisis. The debts only look big because the banks are revaluing.

The revaluation occurred in a time of drought thereby increasing the debt to equity ratio. The farmers noted that Australian farm equity is sliding at an historical rate. One could then conclude that the evaluation of Australian farm assets is getting downgraded and there have been concerns about takeover by corporate farms particularly multinationals as shown in the literature. The researcher probed into the concern that Australian farms could become more corporate than family owned.

There is no abandoned land someone will pick it up, there will be some personal pain but in the next ten years' time the industry will probably be in a better place. It's a pretty cruel way to look at it. Someone will take it up for a price, but someone will probably hurt.

It was not important who picks the farms up, a neighbouring family farmer or corporate farmer; the above response indicated that the current situation will adjust itself. However, the farmers; *'don't think the multinationals are good enough at farming. Their cost structure is too high. They are not making returns that people in this room will be making either per hectare or percentage-wise'.*

They affirmed that; *'Family farming, especially from the cropping point of view, is probably the most efficient model in that when there is a trough, they all pull in and it rises whatever you have to do. If you have a corporate structure they buy company cars and they do not pick the troughs up and they do not have the incentives to do so.*

In essence, corporate farms are not as resilient as family farms. The experience of a farmer confirmed the lack of incentives to be as efficient as family farms by their corporate counterparts. The farmer visited a farm where the crops were looking pretty good but the officer in charge informed him that he would not get any bonus for his efforts.

From the discussions, it could be gleaned that the major concern of the farmers about corporate farming is that the corporates have a high labour cost and they obviously spend on luxuries particularly for the top officers than those who are actually on the job. In the discussion, the labour cost structure of family farm allows the farmer to multi-task. That is, the family head could be the mechanic, electrician, financial manager and would be putting in more hours of efforts on his farm. These labours would have to be hired separately on corporate farms thereby increasing their costs. Similarly, in commenting on the decision making of the corporates;

> *I wouldn't say the management is not good enough but their decision making is too slow. Their risk management too won't be as good.*

Furthermore, the farmers talked about segmenting the market before making certain conclusions on Australian agriculture as evident in literature (Wittmaack 2006). The need for market segmentation resulted from the discussion on the consequences of policy shifts that have possibly brought Australian agriculture to the current state of debt.

The two major segments noted in the discussions were the cattle and grain farming. In their comparison of the two segments of Australian agriculture they noted that:

> *Whereas in the grain farming sector people wanted to expand but the impact of the weather has possibly had a bigger effect whether is flood or dry times. And the impact of 1 year or 18 months of dry is a very long time for people to go for. The cost of living has been going up and the cost of production has been going up that becomes a big hump for people to get over.*

The expectation of the government is that welfare payments will help farmers get over the humps but the payment gives additional incentives to farmers to be unprofitable. In contrast to expectations that the policy will make unprofitable farmers to leave the scene, the welfare benefits will actually be an incentive for them to hang on to their assets and demand a higher price.

Besides further ascertaining the impact of weather risk, the increase in production cost (input risk) and cost of living were also noted but in the particular context of grain cropping relative to livestock farming. Generalizing the debt situation without segmenting the markets could pose a challenge for policy makers.

It is evident from the discussions so far that livestock farmers are having an advantage over their broad acre counterparts in terms of the empathy they evoke in times of drought (Keogh & Potard 2014). Besides this advantage, farmers could readily run livestock intensively whereas; the case of broad acre farming is somewhat different.

The implications of this market segmentation is that attempts to consider a corporate farming system may benefit livestock farmers more than the broad acre farmers who are largely susceptible to weather conditions. Also, the livestock farmers have advantage of technological facilities that enhance production and economy of scale than the broad acre farmers. Consequently, policies may have to consider this diversity in such a way that will not cause a sub-optimal shift of productive capacity to any market segment. The researcher prompted some suggestions for the improvement of agro-risk management in Australia from the farmers as could be found in the next section.

7.6 Policy suggestions

Under this theme, the suggestions emanating from the analyses were highlighted. Based on the observations and insights from all participants, some ideas that may be useful for policy recommendations were identified.

7.6.1 Policy suggestions – interviews

The opinions on the way forward were analysed under this theme. Some of the major suggestions that came up in the interview to aid agro-risk management in Australia were related to technological improvements, improving uptake of insurance, government supports and awareness. Sample responses are as follows:

> *I think if there is better technology being utilized, that will help everybody. … An ability to improve your management based on technology will help out. … People come in they offered MPCI and then a year or two later they leave. It died off because there are no enough uptakes or the premium is high (INS2)..*

The major causes of the failure of previous efforts to offer yield-based MPCI were adverse selection and moral hazard as discussed in the literature review. Weather index insurance seems to be a major possibility that could be adopted to contain these impediments. The major suggestions offered are around the issue of subsidies. It seems evident that a more viable insurance than the named-peril crop insurance may not operate in Australia without subsidies. First, it has to be noted that the EC and FMD are all forms of subsidies and if insurance is subsidized it may be more profitable in that it helps farmers to plan. The form the subsidy should take is a major concern. Suggestions could be clearly categorized into two namely; tax incentives and subsidy payments to the insurers.

> *I think there is some opportunity for tax incentives associated with preparation for drought. Whether that is taking insurance or FMD, or other instruments but I think it's probably more likely that the government will move towards some forms of improved tax incentives for those instruments rather than paying out actual subsidies (SA2).*

Nevertheless, it seems that there are barriers towards this move:

> *Farmers will argue against that (Tax incentive) because they will say look there is no advantage because we won't pay tax anyway we are not making profit. I think Australian governments are unlikely to go too far down the track of paying subsidies (SA2).*

Two of the farmers (*FA2* and *FA6*) affirmed this position while F6 opined that the subsidies could be paid to the insurers but it should be transparent. It is evident that there are concerns about paying subsidies directly to insurers. The alternative which involves tax incentives is however not profitable for unprofitable farmers. These farmers could however be entitled to some forms of social welfare benefits while those who are profitable benefit from the tax incentives on insurance as the current policy allows for welfare benefits to all farmers in distress. The challenge with the welfare payout is that it takes the farmers back to a form of EC payouts only that more farmers will be entitled to the pay since it covers all forms of sources of income shortfalls. The implication could be that farmers would still hold on to their assets and demand higher prices as they were alleged to do under the EC. It should be expected that government expenditure on such welfare benefit will be much higher than under the EC and equally inefficient. This waiver of asset test to qualify farmers for the welfare benefits may be equitable but it will be inefficient without some incentives to make farmers manage their own risk ex ante.

The FMD was considered by farmers as a viable option but for the fact that; *'it only works if profitable*'. Similarity between the insurance option and FMD is that farmers have to be profitable, but insurance is an ex-ante arrangement that also alleviates the cost of debt though it comes at the cost of dividends to shareholders. This same farmer suggested that if government supports were to be available to farmers in Australia it should take the form of tax incentives and that an increment should be made on the limit placed on FMD because: *FMD limits are too low for a grain business.* In another response, *FA6* suggested that *'the FMD should be more flexible'.*

The insurers drew parallels between their products and other insurance products to justify the needs for incentives:

> *Within this industry there is about four or five insurers so is a small market unlike housing and car insurance with competition (INS2).*

> *The way it works is that when you get medical insurance, you go for blood test, cholesterol. We do the same, we have to analyse your financials for the last five years. That costs $5000. Give them $5000 rebate, to do their health check (SA1).*

Concerns were however, rife about the viability of both weather and revenue insurance:

> *There are a number of commercial organizations trying to establish crop revenue insurance products. The latest one is trying to be very selective about whom to include. So you have to go through a fairly detailed registration process and pay, I think is $5,000, before they even consider whether they might accept you. So what they are trying to do is to use that to select the population so that they can avoid some of those risks associated with insurance programmes. I genuinely doubt whether that will be successful (SA2).*

This and other concerns about data management and legal requisitions were also expressed in a meeting with some stakeholders (MPCIC 2014). A stakeholder (*SA1*) attested to the need for the government to; *'invest(ment) in infrastructure which will underpin the development of the products like government investing in weather stations, farm data which will support the development of such products. They don't only help in product development but will also help farmers' information.*

The response of this stakeholder suggests that the necessary infrastructure is the responsibility of the government (Freebairn 1983; Kimura & Antón 2011). It is unrealistic to expect that a commercial organization will pay for such public goods and services since they are offering the services for their own returns. Should a private organization provide such information and infrastructure, they will still need some forms of legal and regulatory assurance from the government about their usage. Currently, the weather hedge provided by the active provider of weather hedge in Australia is in the form of derivatives. If farmers will be getting incentives on the premium they pay to hedge their risks, the hedge may retain its structural and functional forms but may have to metamorphose into insurance so that farmers will not turn to gamblers.

In the case of a model of weather insurance once offered, it was noted that the provider does not offer the product anymore because the uptake was poor and; *No one took it to be honest. When we introduced the product there was a lot of rainfall as well (INS2).* It is evident from the quote above that the timing of product launch was also crucial. The expectations about seasonal conditions would go a long way in impacting on the viability of weather index insurance. The recent formula of weather index insurance, the Full Season Weather Certificate, however captures every form of weather related exposure including floods and may not allow for inter-temporal adverse selection. The attempt to discriminate the farmers to insure in the case of revenue-based insurance suggests that only farmers who are 'healthy' will be selected. The cost of this 'medical check' remains an issue in the industry in regards to who bears it and how the information generated from the medical check will be used.

A farmer (*FA1*) interestingly noted that; '*the government is being very cautious (about supports to farmers) which is very sensible. It is not so much that they are not doing enough is just that more needs to be done to get to where we need to get'.* It seems that some farmers appreciate the effort of the government but would wish that efforts are bolstered towards delivering more rewards to farmers. A similar response was that; *it is hard to say whether or not government programme is not worthwhile (FA2).*

7.6.2 Policy suggestions – focus group interview

Some comments were worth noting in the group interview. The prime note is that farmers would do everything they can not to pay taxes. This was clearly noted when a participant said that; '*…it's against their DNA to pay tax',* referring to Australian farmers. It seems that tax-based policies are strongly preferred by Australian farmers whatever form it will take and they are exceptionally very skilled at optimizing their tax benefits. Even if they are at risk of an eventual loss, they would rather *'spend a dollar to save 30 cents'.*

It was also observed that; *the banks if they knew that production insurance is available, they will ask for it. If there was they will think is a good thing.* This suggests that appropriate insurance if available would be preferred by the credit providers beside the hail and fire insurance that are not having significant impact on their risk management. One would therefore expect that the availability of effective insurance will temper the debt growth and also improve the productivity of farmers if they are incentivised to do so.

The FMD gives farmers tax advantages but it was noted that it is not serving its primary purpose. Instead of farmers pulling out money in bad years, they are actually saving more in bad years because of the payouts they derive from government supports. Similarly, the FMD is an ex-post mechanism rather than an ex-ante mechanism that allows production planning and is only beneficial for those farmers who are profitable at the end of the season. Although farmers want the FMD to be retained and extended to allied industries like their suppliers, they value the provision of insurance. The discussion with the farmers suggests that they will really value the Full Season Weather Certificate. Their perception of weather insurance seems to be too simplistic than what the product offers. In the case of revenue insurance, their attraction to the product stems from the fact that it captures both yield and price risks. They however expressed concerns about costs and the need for government supports on insurance generally and expressed the need for *mutual responsibility*:

> *The insurance system government backed if it could be made affordable for the government and for farmers it's easy to manage and less likely to be hoarded.*

The diversity in the management practices and efforts invested by farmers was also noted. Policies that will deter bad farming practices were the essence of the quote below:

> *I know I can get stoned for this, …. In the bank what you find is that you get a useless farmer getting all the stuff, and a good farmer who has other investments and could not get it, it squeezes the market. Others can't buy the farms. You keep promoting the bad farmers. Some farmers will be successful no matter what you give them.*

Index-Based Risk Transfer Products (IBRTP) and FSWC in particular have the advantage of being exogenously determined and may therefore disallow bad farming practices. The next concern will be about the security of the weather stations but discussions with the industry shows that the data used are generated in real time from the Bureau of Meteorology and the payments are also swift in comparison to any other form of insurance therefore the time-lag between the event and payout is short more. The revenue insurance was also considered as a training tool to aid good farming practices as noted in a discussion with an insurer. It seems that the best way forward is to institute polices that will allow competition. The competition will lead to innovations rather than giving a hedge to any insurance provider as the future of Australian agro-risk management unfolds.

7.7 Summary and recommendations from qualitative results

The chapter examined research question four that focuses on the challenges and opportunities for agricultural insurance in Australia. Five major themes were extracted from literature and the analyses were conducted according to the themes although there were overlaps. The themes were: risk and risk management in Australian agriculture, the need for policy change, insurance options and associated challenges, debts, lending and attrition from the agricultural sector and finally suggestions and recommendations. Some of the issues brought to light in the qualitative chapter were also evident in the quantitative analysis particularly the issues related to the pricing of insurance as it relates to variability of commodity prices and geographical differences.

Findings from the first theme suggest that the available insurance in the market until lately has been mainly hail and fire insurance that have not been very useful for farmers. Although, new models of insurance are emerging in the Australian agro-insurance market, patronage has been very low partly because of low awareness. Under the second theme it was emphasized that there was a need for policy change in that the Exceptional Circumstance (EC) was not addressing the objectives of the Australian Drought Policy (ADP). Although, there has been a recent move to address some of the challenges of EC, it was noted the policy change may not advance the tenets of mutual obligation, self-reliance and reciprocity intended by the Australian government.

Consequently, the third theme focused on the insurance option as a more appropriate model for managing agricultural risk in Australia. However, it will require some incentives. The discussions with the participants suggest that tax incentives would be an appropriate way to inducing the tenets of mutual obligation, self-reliance and reciprocity intended by the government of Australia. In the fourth theme on debts, lending and attrition, it was found that the insurance option may improve the credit worth of Australian farmers. Issues on the debate between the corporate and family farm models were also examined. It was believed that family farms are more sustainable than corporate farms therefore polices should be directed to building the family farm model. The final theme documented some suggestions. It was concluded that the government will not likely pay direct subsidies rather improve the tax incentives system for farmers. However, the tax incentives may not benefit some farmers.

8 CHAPTER EIGHT: DISCUSSION, CONCLUSION AND RECOMMENDATIONS

8.1 Introduction

There are six sections in this final chapter. In this section (Section 8.1), the chapter is introduced. In Section 8.2, each of the four research objectives is stated and the result from the analyses related to each one of them discussed in the context of relevant literature. The third section (Section 8.3) features the contributions of the study while recommendations are made in Section 8.4. The limitations and conclusion are contained in Section 8.5 and Section 8.6 respectively.

8.2 Summary of findings

This section addresses the four research objectives. The objectives are stated in the form of research questions. The fourth objective was addressed using qualitative methods while the first three were addressed using quantitative techniques. Some of the findings in research objectives one to three are also prominent in the fourth objective. The qualitative analysis therefore serves to triangulate the quantitative analyses and helped in gaining insights from the experiences of the farmers.

8.2.1 Research question one

What is the relationship between rainfall index insurance and wheat yield across the shire of Queensland and Western Australia?

The first research objective explored the relationship between yield and weather index. In this thesis, the Cumulative Standardized Precipitation Index was used as a proxy for the insurable interest which in this case is revenue from the sale of wheat. As in previous studies, the relationship observed between yield and index varied widely with location (Vedenov & Barnett 2004; Turvey & McLaurin 2012; Leblois & Quiron 2013). However, in some locations, the relationship was sufficiently strong to permit the index to be used as a proxy. The study by Vedenov and Barnett (2004) and Turvey and McLaurin (2012) emphasized this possibility of wide variance in the relationship between yield and index by location. In particular, Turvey and McLaurin (2012) issued caveats on the adoption of weather index insurance strictly on the basis of the relationship and that such relationship should not be generalized to imply that weather proxies will make a good basis for calculating premium across all locations.

The first method for assessing the relationship was the Ordinary Least Square Regression (OrdReg). However, the results from OrdReg delivers only one slope for each of the sixty three locations considered. The results from the OrdReg indicated that the strength of the relationship varied across the shires ranging from R^2 adjusted of 2.32% to 90.26%. The second method was the Quadratic Regression (QuadReg) and the results (R^2) range from 0.76% to 91.78%.

Although, the relationship measure adopted in Vedenov and Barnett (2004) and Turvey and McLaurin (2012) was Quadratic Regression (QuadReg), it is similar to the OrdReg in that the relationship was assumed to be the same across the whole relationship continuum. Although, QuadReg, the second regression method adopted, was expected to be more ideal, results indicated that this is not always the case. The assumption of a uniform slope limits the interpretations of both OrdReg and

QuadReg in the context of yield-index relationship for the purposes considered in this study.

Consequently a third method, Quantile Regression (QuantReg) was also adopted to break down the slope across the quantiles. The quantiles of particular relevance are the 5th, 10th and 30th percentiles that were related to the hedging efficiency results from research objective 2. This method is an improvement over the QuadReg and OrdReg in that it allows the researcher to note the relationship at the corresponding tails to the efficiency levels rather than across the whole continuum. In this study, it was observed that wheat yield – weather index relationship varies across the continuum from shire to shire. The pattern ranged from left skewed to almost normal to right skewed results in that the strength of the relationship is stronger at one tail than the other in some shires while it is almost the same across the continuum in others. The results suggest that most (80%) of the relationship was strongest towards the lower tail implying exposure of most locations to drought than flood. The responses from the interviews indicated that farmers were actually more interested in drought cover than flood cover.

When the results of the disaggregated relationship were correlated with the efficiency results, it was observed that the correlation was stronger when the efficiency is related with the tail relationship than with the whole relationship. When the results from the QuantReg for the 5th, 10th and 30th percentiles were related with the hedging efficiency results at the 5th 10th and 30th, the relationship (correlations) was found to be stronger than with the OrdReg. However, as in previous results by Vedenov and Barnett (2004), it was noted that the most efficient shire does not necessarily have the highest yield-index relationship although this tends to improve when the results of the relationship at the tail is compared with efficiency.

These results affirm the convexity in the relationship between index and the object of insurance as noted in Chantarat (2009). Although, the study by Chantarat (2009) related famine index weather derivatives based on Normalized Difference Vegetative Index (NDVI) with child malnutrition, the essence of the two studies are the same – a non-linear relationship between the index and the outcomes. In a more closely related study, Kapphan (2012) observed that the index that accounted for the non-linear relationship between yield and index was the strongest. Hence, the superiority of the QuantReg over the OrdReg.

The third method utilizing the Panel Regression (PanReg) analysis shows that, overall, the relationship between yield and weather is strong enough to allow weather indices to be used as a proxy for yield in the calculation of payouts. The PanReg further shows that there may be need for location-specific indices to be designed for the index insurance to be effective as noted above and in previous studies. Shire-level weather index insurance may be easier to design than a farm-level design in that one design will be used by all farmers in the shire. Similarly, all farmers in the shire may not be planting the same crop or the same variety of the same crop hence a limitation of this study. Besides, the soil characteristics may differ from farm to farm within the shire.

It was found that the relationship between yield and index is not consistent across the locations and the relationship between the regression results and hedging efficiency is not significant. As in Turvey and McLaurin (2012), the major essence of this study is the hedging efficiency of weather insurance. That is, the researcher attempts to know whether or not the insurance is capable of delivering an increase in revenue and reduction in down side risk which should translate into willingness to pay for the insurance contract. This essence is captured in the next sub-section below.

8.2.2 Research question two

Can weather index insurance help farmers to hedge the exposure of their revenue to drought risk?

Three methods were adopted in the evaluation of the hedging efficiency of the weather index insurance contracts. The first method, Conditional Tail Expectation (CTE) was based on the assumption that if insurance is triggered in years with the poorest rainfall and rainfall is related to yield, then, the revenue of the farmer should increase in years with low readings of the index. The second method based on the Mean Root Square Loss (MRSL) measures the extent to which the downside risk is minimized by the insurance. Finally, the third method uses the Certainty Equivalence of Revenue (CER) which is a measure of the willingness to pay for the insurance. For each of these three methodologies, efficiency was considered at three levels. The levels are the 5th, 10th and 30th percentile strikes which assume that insurance is triggered in two, four and twelve years during a forty-year period. Similarly, the analyses were conducted under two price assumptions – constant and variable price assumptions.

Based on the CTE results, Queensland farmers experienced improvement in revenue resulting from the insurance than their Western Australian counterparts particularly at the 5th percentile (See Figure 5.1). The assumption that wheat prices varied over the forty-year period decreased the revenue stream of the farmer across all strikes for Western Australian farmers but Queensland farmers experienced increase in revenue for moderate drought at the 30th percentile strike. The results were further alluded to in the categorical analysis of the data in that the proportion of shires experiencing increase in revenue due to insurance decreased when variable price was assumed except at the 30th percentile where drought was only moderate.

The results from the MRSL were expected to decrease if downside risk was minimized with the insurance contract. There was a decrease in downside risk when constant price of wheat was assumed for Queensland farmers but the contracts did not reduce the risk for Western Australia. However, when price was assumed to vary, the downside risk in Western Australia reduced relative to the constant price but was still higher with insurance. The downside risk in Queensland however increased at the 5th and 10th percentile contracts but marginally decreased at the 30th percentile.

The CER analysis reveals the contrasts observed in the hedging efficiency results by location, price and strike levels more appropriately (See Figure 5.3). The figure shows that while the willingness of farmers to pay for the insurance increased in Queensland across the strikes, it decreased in Western Australia when constant price was assumed. The same trend could be observed when prices were assumed to vary but the benefits of insurance reduced in that willingness to insure decreased for both states at all strikes relative to when price was assumed to be constant.

One very interesting result was that the trend in the benefits of insurance increased across the strike levels for Queensland when the willingness of farmers to insure was calculated based on CER. The results suggest that farmers were generally willing to pay for insurance in Queensland but their willingness to pay for the most extreme drought is lower than the other levels of drought. The explanation for this is that yield and yield risk were higher in Queensland than in Western Australia. Therefore, the willingness to pay is higher in Queensland but relatively low when drought is very intense unlike the case of Western Australia. Since the cost of insurance will be higher in Queensland because of the higher risk and the revenue is lower because of lower yield (See Section 4.2), the willingness of farmers to pay for insurance is generally high but at an increasing rate towards the higher strikes. This finding is in congruence with Liesivaara and Myyra (2014, p. 551) that willingness to pay for insurance is anchored on premium. Furthermore, the disparity in the results between the two states suggests that there may be differences in the risk aversion of Queensland and Western Australian farmers. On disaggregating the farms within each shire, it would be expected that the initial wealth and the existing portfolio of farmers' assets will further exacerbate the divergence in willingness to pay for insurance.

It was observed that the CTE results varied by price assumption and level of drought. Previous analyses by Vedenov and Barnett (2004), Chantarat (2009), Kapphan (2012) and Leblois (2013) assumed that prices were constant across the periods under review. In this analysis, a comparison of a variable and constant price assumption was made. It is evident that the implication of price variability in pricing insurance cannot be ignored in the pricing of insurance contracts.

Overall, the findings were not different from those of Vedenov and Barnett (2004) in that the results vary by location and the strength of the relationship is not necessarily an absolute determinant of efficiency. Although, the findings of the hedging efficiency results from this study were similar to those from Vedenov and Barnett (2004), further analyses were conducted on the hedging efficiency results since there were sufficient results for further statistical analysis.

Generally, the results from all three measures of efficiency (CTE, MRSL and CER) indicated that under constant price assumptions, weather insurance is more profitable than when the variable price was assumed. It was evident that the assumption of a constant price inflated the extent to which the insurance was evaluated as efficient. In essence, the revenue of the farmer increased much more in years of drought under constant pricing than under variable pricing particularly at the 5th and 10th percentile strikes in comparison to the variable price under the CTE and the variance reduction was more prominent under the same assumption. The results were however more evident when the CER was considered in that farmers were more willing to pay for the insurance when the constant price was assumed.

In the specific context of CTE analysis, it was noted that for the 60mm Capped Optimized Contract, the insurance was not profitable under variable pricing but this is less so at the 30th percentile whereas the insurance was decreasing in profitability towards the 30th percentile when constant price was assumed. It could be garnered that the results tended to move in opposite directions across the strikes under the two price assumptions. Should the researcher be content with the usual assumption of a constant price, the conclusions could have been different from the reality that obtains in a world of variable price. This comparison is conspicuously missing in previous studies (Turvey 2001; Leblois & Quirion 2011; Kapphan 2012).

Furthermore, the observations made in Turvey (2001) and Turvey and McLaurin (2012) that event specific insurance like weather insurance should be location-specific was affirmed in this study. Consequently, results based on the analysis of only one location may not be generalizable to other locations without a specific analysis of such locations and the characteristics of the farmers. In the particular context of this study, the CTE, MRSL and consequently the CER results indicated that overall, the insurance was relatively more profitable for farmers in Queensland than those in Western Australia.

Although, 40 shires in Western Australia and 23 in Queensland were analysed, a breakdown of the states revealed diversity in the profitability of the contracts within each state. This diversity could be extended to the shire-wide aggregation by concluding that results will differ among the farms in each shire particularly when other factors like farm gate prices of commodities are considered. Most previous analysis have also adopted aggregate data because of the lack of individualized historical farm yields (Just, Calvin & Quiggin 1999; Hatt, Heyhoe & Whittle 2012). The work of Leblois and Quirion (2011) affirmed the need for plot-level data in the design of weather index insurance based on the analysis of millet farms in South Western Niger.

The analysis in this thesis assumes that the national domestic price is taken by all farmers. This assumption is however far from reality in that farm gate prices differ markedly between farms and therefore a limitation of this study as is the case for previous studies because of lack of appropriate data.

Another noteworthy result is the impact of the variability per unit of rainfall measured as Coefficient of Variation (CV) on the efficiency of the contract. The CV was divided into low, moderate and high variability and only the more realistic price assumption, variable price, was assumed. The categorization of CV was based on the division of the CV into the bottom third, middle third and the upper third. The profitability or efficiency of the contracts were analysed with respect to this benchmark. It was noted that when the variability benchmark based on Capped and Uncapped rainfall were adopted in the analysis, there was significance in that high variability tended towards producing efficient results particularly at the 30th percentile. It could then be said that weather insurance will be profitable for farmers in locations that are experiencing very high seasonal variability of rainfall. However, when drought is very intense, the gap in the extent of efficiency closes between constant and variable price models.

Although, drought is hard to define, its benchmarking would be essential in the design of appropriate insurance and government supports. The once in 20-25 year event may not be appropriate rather once in ten years (Kimura & Antón 2011). It was also observed that the optimization of the decadal weights added value to the efficiency of the contracts. Therefore, in line with intuition and previous researchers' models (Leblois & Quirion 2011; Nieto et al. 2012), the indices that capture the phases of the crop growth cycle would be preferred by farmers as it increases their utility, decreases their down-side risk and increases their willingness to pay.

The failure of the CTE and MRSL to capture the significant effect of annual rainfall on the willingness of farmers to pay as measured by CER indicates possible differences in the results with respect to the methodology adopted. The work of Vedenov and Barnett (2004) showed this difference in methodology but did not have a sufficient sample for statistical analysis of the effect of methodology on the results. This study bridged this gap by concluding that there is a statistically significant difference in the conclusions that could be derived from different methodologies. Although the results were essentially the same at aggregate level, there were differences in the relative extent of the efficiency across the locations and strike levels. By implications the risk management objectives of farmers may differ by locations for every level of drought.

Overall, the findings of this study concur with those of Leblois and Quiron (2011) that the gains from implementing weather insurance only slightly exceed the cost of implementation. In essence, the benefits of weather insurance as modelled in this research are marginal and are location-specific. However, it is expected that location–specific pricing of the insurance would improve the benefits of hedging to the farmer as is currently done by CelsiusPro (CelsiusPro 2013). Nevertheless, scholars (Freebairn 1983; Quiggin 1986; Quiggin, Karagiannis & Stanton 1994; Turvey 2001; Quiggin & Chambers 2004; Chantarat et al. 2008;) are of the view that the gains could be much better than a system of drought assistance. In particular, Quiggin, Karagiannis and Stanton (1994) were of the view that if subsidies are to be paid to farmers in times of drought, rainfall insurance is one of the most cost effective means of doing so. Freebairn (1983) suggested that new initiatives were required to provide an income safety net for self-employed persons. Although, the current waiver of asset seems to provide such a safety net, in the view of the researcher, the policy will not lead to a pareto-improvement of Australia's welfare. Another benefit of insurance that should be factored into its valuation is that it tempers the risk of risk-increasing inputs like fertilizer and improved cultivars (Leblois & Quiron 2013).

8.2.3 Research question three

What is the dependence structure of rainfall index insurance at different triggers in Queensland and Western Australia?

The findings based on the analysis of Loss Ratio shows that an insurer offering weather index insurance could take advantage of temporal and spatial diversification to temper extreme payouts. Also, it was found that insurers will prefer to offer insurance for milder risks and would only make profits in the long term.

The analysis of the dependence structure, or diversification prospects, of the portfolio of insurance contract was examined using Loss Ratio (LR) analysis. The LR calculates the ratio of indemnity to the premium and when loss ratio is higher than unity (1) then the premium would not have covered the payouts for that year. The researcher pooled the contracts over space and time. The LR for Queensland and Western Australia were calculated separately and then jointly for one year, two years, five years and ten years for each type of contract.

Similarly, reinsurance is readily possible for index insurance unlike yield-based and revenue insurance (NRAC 2012). These advantages will tend to have positive cost implications more so that weather index insurance is patronized by other clients who intend to hedge their weather exposures thereby giving the product a broader basis for risk pooling than modelled in this study. Besides the reinsurance possibility, Turvey (2001) suggested that weather data could be triangulated by weighing two or three weather stations based on proximity to the farm for which a hedge is to be provided. This triangulation is not possible with Multi-Peril Cop Insurance besides its limited prospects of reinsurance. The results above are also in tandem with the findings of Chantarat (2009) that diversification prospects is a key benefit of index insurance.

On the side of the farmers, it was assumed that all farmers in the shires were equally insured and that they have an equal level of insurable interest. The reality is that the purchase of insurance is a function of risk aversion which may depend on initial wealth, existing portfolio of assets and risk attitude (Lence 1996; Deane & Malcolm 2006; Musshoff, Hirschauer & Odening 2008). Larger farms may devote less proportion of their wealth to hedging because they have the capacity to bear the shock and they have a natural hedge that increases with farm size (Coble et al. 1996; Finger 2012). The reality may therefore be somewhat different from what has been modelled to a varying degree depending on the expectations of farmers in terms of price and other variables (Barrett 1996). The possibility of obtaining mixed results in the analysis of insurance market operations has been well attested to (Eisenhauer 2004).

Furthermore, it was found that the offering of insurance is more risky to the insurer at the lower percentiles. However, the farmers are more likely to be interested in hedging at the percentiles that is most risky to the insurer as the standard deviations of the loss ratios show. Furthermore, the analysis of the willingness of farmers to pay for insurance suggests that they will be more interested in insuring the most extreme droughts when the shires from both states were aggregated. Disagregating the results by state yielded a mixed result.

The results affirm the need for differentiated policy response as noted in Kimura and Anton (2011). In essence, the insurer is most likely to be willing to offer insurance to cover mid-layer risks while the catastrophic risk layer requires some government intervention. Some policy adjustments may be required to match the willingness of both farmers and insurers to establish an appropriate risk management market in Australia. Although, assistance is available in the form of welfare benefits, it may not lead to a pareto-optimal improvement if it is not aimed at productivity. Also, the loss ratio analysis indicated that offering weather insurance could only be profitable in the long-run. Investment in such a venture will require patient capitalism (Della Sala 2004) which could only be fostered by a stable regulatory environment particularly in the context of competition and data usage. Overall, it was noted that a pool of insurance contract is to a reasonable extent diversifiable within Australia.

8.2.4 Research question four

What are the challenges and opportunities associated with the offer of weather index insurance in Australia?

The fourth research question aims at elucidating the issues surrounding agro-risk management in Australia and to understand the policy environment and context in which the issues are situated. The question examined the risk and risk management in Australia, the need for policy change, insurance options and associated challenges, debts, lending and attrition from agriculture and finally some observations and suggestions. In this section, the issues enumerated above were woven into the discussion commencing with risk and risk management and ending with insurance options and associated challenges. The suggestions based on this section and previous analyses were made explicit in Section 8.6.

The discussion on challenges and opportunities suggest that farmers were exposed to weather risk to a very large extent. The exposure was found to be much higher in Australia than any other country as noted in other studies (Botterill 2003, 2012; Lindesay 2005; Wilhite 2005, 2007; Kimura & Antón 2011). The risks noted in this study were similarly advanced by others (Nguyen, Wegener & Russell 2006) that farmers tend to dread weather variability, price risk, marketing risk and institutional risks. Their decisions are therefore largely the product of how they possibly deem fit that these risks could be best managed to capture available benefits (Garrido & Bielza 2008) that farmers respond to incentives.

Price risk was the next risk of concern which was escalating due to the scrapping of the wheat board that assisted farmers in marketing their products while input cost remains a concern because Australian farmers import most of their inputs which are dependent on foreign exchange and export most of their produce (Craik & MacRae 2010; Botterill 2012; ABARE 2014). It has been empirically shown that exchange rate has a significant positive impact on Australia's flow of trade particularly the export (McKenzie 1998). This explains why price risk is placed ahead of input risk which is largely an import product because apart from labour, most other inputs were imported.

Although, the farmers exercised some fondness for the revenue insurance, there were challenges towards its implementation. Should the product be based on district averages of yield and market prices of commodities, then, basis risk will be a concern. If individual farm yields and price histories are adopted, then the new entrants into the industry may find it difficult to be supported since they do not have any record on which premium could be based. Such new entrants may require insurance more than the established farmers. Some legal considerations like third line forcing were found to be important in the analysis of the revenue insurance model offered by Latevo (MPCIC 2014). The concerns about the revenue formula is shared by Mahul and Wright (2003) who has shown that, the design, like other contracts is inefficient because it is based on imperfect estimators of both yield and/or price and acknowledged the impact of prudence and basis risk. He concluded that no singular insurance contract can satisfy the needs of farmers rather a combination of risk management mechanisms peculiar to the farmer affirms the need to offer a market opportunity for different insurance products to emerge.

Furthermore, the analysis by Bates and Rogerson (1980, p.515) suggests that extreme fragmentation is a major characteristic of losers in a coalition equilibrium. This fragmentation manifests in the form of small rural populace that is largely dispersed across the nation and it suggests that the Australian system may be following a market regulation theory (Posner 1974; Peltzman, Levine & Noll 1989; Gray & Lawrence 2001; Vanclay 2003; Van der Vegt 2009; Zweifel & Eisen 2012). One may be able to argue that the population is not the issue, rather the influence that the farmers are able to wield. For example, in US, there were less than one percent population of farmers (USEPA 2013) but they get so much supports on insurance beside other aids and assistance from government (Edwards 2009). Similarly, 87% of US farms were owned and operated by individuals or families with only 4% with corporate ownership. In addition, Australians did not experience major wars and depressions that have inflicted hardships on her population as those of European states and America Goldstein (1989). However, it is evident that the strength of Australia's taxation system could be used to her advantage in this regard. Efforts are also expected to be geared towards managing farmers' interest rate risk.

Since corporate farming will definitely reduce the participants in the coalition equilibrium, without necessarily decreasing the area used for agricultural purposes, it may be easier for these fewer individuals to exert more influence to capture policy makers in the long-run (Vanclay 2003). The influence will jeopardize net welfare benefit of the IAC (1986). Keogh (2012) did not acknowledge any winner in the debate between the models of agriculture to adopt in Australia but concluded that the model to be adopted should depend on context. The context of Australian agriculture necessitates the protection of Australian family farm structure to enhance rural wellbeing and demographic restructure (Fuller & Broadbent 2006; Wittmaack 2006; Hunter & Biddle 2011; Wilkinson, Barr & Hollier 2012). Irrespective of the farm structure adopted, insurance would have to play a major role in the Australian agro-risk management because it can reduce the cost of capital as noted in the qualitative analysis above. The interest rate risk is a major concern that runs through the strands of discussions with the farmers and this has become topical particularly because of the concerns about farm debt (Wilkinson, Barr & Hollier 2012; Rees 2012; Keogh, Tomlinson & Potard 2013; Kingwell 2013; Marshal 2013; Neales 2013; RRDF 2013).

So far, it seems that Australian farms have thrived on the sweat of rural families. This survival strategy is in consonance with the principle of auto-plunder of labour discussed in Chayanov and Chaianov (1986) which the corporates cannot withstand (Davidson, Timo & Wang 2010). Their protest to absorbing the cost of labour may have resulted in *'spending a dollar to save 30 cents'* particularly because '*it is against their DNA to pay taxes'* as noted in the Focus Group Interview. Gray and Lawrence (2001) noted that this stress-induced labour is taking a toll on rural households.

Keogh (2012, p.v) in responding to the conclusions of various researchers reiterated that the supposed contest between farm models should focus on; *looking carefully at the socioeconomic context, type of industry, and nature of the markets in which farm businesses are involved.* Australia's case seems to deserve a policy mix that will foster an optimal mix of farm models particularly in the broad acre farming industry given its socio-economic industry and the nature of the market it is operating in.

Furthermore, the lack of incentives of corporate farms to *pick up the troughs* is in line with the concept of principal agency problem (Ross 1973; Fleming, Heaney & McCosker 2005). Monitoring labour costs is a problem that corporates will have to resolve whereas; the farm families seem to have an edge in this regard. The discussions with farmers and other stakeholders seem to suggest that other models of agricultural productions are not prominent in Australia. Australian agricultural sector seems to be dichotomized between corporates and family farms. It may be needful for Australian agricultural stakeholders to promote other farming models that may be beneficial. Some risk management procedures were however highlighted in the interviews.

The findings from this study shows that the level of awareness of the new insurance options was very low a fact well noted by Vandenberghe (2010). One reason for lack of use of the products may therefore result from the low awareness. This result suggests that irrespective of the risk management packages available to Australian farmers, there will be need for rural extension to facilitate the adoption of such schemes (Cary 1993; Marsh & Pannell 2000).

Furthermore, not one of the farmers interviewed focuses on wheat production alone. The researcher could therefore conclude that crop diversification was well adopted by the farmers. Another important risk management noted was relocating to other shires with higher rainfall. Such relocation may be a good strategy if the variability per unit of rainfall is lower at the new location.

The participating farmers in the focus group were grain growers. Their responses showed that their livestock counterparts are getting more from government than them. The focus on assistance to the livestock sector more than the grain sector is not typical of Australian agriculture alone but also a characteristic feature of other western countries (USEPA 2013). *FA 10* emphasized this by saying that *there is a lack of appreciation of grains industry production*. It may be asked whether the nature of dual losses to the farmer caused the lack of adequate insurance market for livestock farmers or the sympathy did not allow the market to emerge. According to Keogh (2014), the livestock sector has a reservoir of emotion laden colourful stories on their side. The broad acre sector unfortunately cannot paint this picture to the public.

Furthermore, farmers' confession, during the Focus Group, that they need incentives to be profitable suggests that some farmers could make themselves profitable if they wanted to. In essence, Australian farmers to some extent may be making sub-optimal choices in order to avoid taxes. It seems however that they need some forms of taxation incentives to make them adjust their management decisions to become profitable. For example, one of the Focus Group participants confessed that; *taxing farmers hard in bad years is a disincentive*. In essence, Australian taxation system needs to be reviewed in a way to pay back farmers for their stress-induced labour that the economy has benefited from for a long time. The pay back could be done in such a way that facilitates their risk management efforts rather than a welfare system that makes them feel helpless. There seems to be a psychological component to the welfare system instituted. First, the mere presence of incentives could aid farming operations (Sobel 2005). Secondly, farmers tend to detest welfare options but would only take it in the absence of other possibilities.

The welfare approach to risk management has amounted to *penny-pinching* and was *much-maligned* under the EC (Gray & Lawrence 2001; NFF 2011). In a bid to pay themselves back, they *spend one dollar to save 30 cents* by buying machineries that may not be necessary. The theoretical justification of the taxation and the regressive nature of welfare are shown in Section 8.3.

The major change difference between the phased out EC and the current welfare system is that the EC focused on drought which was benchmarked as a once in 20 – 25 year event (Kimura & Antón 2011) but the waiver of asset test covers every form of events that could impinge on the revenue of the farmer. By implication, it would be expected that if 23% of drought affected farmers were paid in excess of $ 1 billion in 2007/2008 (Kimura & Anton 2011), if all farmers affected were to be paid, then,

$4.35 billion would have been paid. It means that, if welfare benefits were delivered in that year, all the affected farmers would have claimed. However, in anticipation of such benefits, taxes delivered from the agricultural sector will also reduce since farmers will have incentives to be profitless. The implication of waiving asset test for farmers could be worse than that of EC in that if farmers were expected to hold on to their lands because they have impounded the EC payments into their expected future cash flows, then the same argument is valid under the current policy. Also, in a probabilistic sense, the chance of getting such payment is higher under the current policy and they will therefore impound this into their Net Present Value (NPV) thereby further increasing what they will demand to give up their assets.

Although, it is not suggested that there should be a return to the EC, because some other challenges associated with it including the line on the map problem would remain. That is, it is difficult to draw the line to say that a particular area was or was not affected by drought. Besides, the EC short changes other farmers who were affected by other events impacting on their revenue. As equitable as the current policy is, it has to go one step further by not impinging on the prospects of profitability of the farmers and not inadvertently increase land value beyond what obtains under the EC. Secondly, it must improve on the psychological welfare of farmers by giving them the opportunity to be self-reliant and not dependents a situation that sounds frustrating to farmers and contrary to the self-reliant nature of Australia farmers.

The low cost of weather insurance and the probability of an increase in price in terms of drought suggest that it may be taken by farmers if it reflects the variability in commodity price expectations, otherwise farmers may shift towards revenue insurance. The revenue insurance model therefore will be a major challenger of the weather index insurance market if index insurance is not price to reflect commodity price expectations. The issue of commodity price expectations was well articulated by *FA 1* who was willing to pay as much as 20% premium if wheat prices are going down.

Although, the price expectation of broad acre farmers is favourable to their business in times of drought, livestock farmers seem to be at a dual disadvantage because they receive very low price as they are under pressure of destocking because of the increment in the cost of feeding their animals when there is drought. This disparity in price expectations between livestock and broad acre farmers suggest that livestock farmers may derive more utility from weather index insurance.

Perhaps, the disparity also explains why livestock farmers have always enjoyed more *free rides* from government besides the sympathy that they get because they are dealing with animals as opposed to crop farmers coupled with media attention. If revenue insurance is capturing the yield-price relationship, this relationship may not favour its use in the case of livestock. This relationship may reduce the chance of a payout for broad acre farming but the relationship is direct for livestock with an accompanying increase in probability of payout. Similarly, the design of the insurance for hay may allow for more advantage of economy of scale than for crops particularly if Normalized Difference Vegetative Index (NDVI) is adopted.

A very pertinent issue as it relates to equity is which crop or livestock, and also which form of insurance should be supported by the government? The culture in Australia's policy history is informed by equity and efficiency (Quiggin 1996) and it does not allow differentiation of such and the institution of a welfare system for farmers through asset test waiver is an evidence in Australia's attempt to be an equitable society. Hence, a tax incentive model helps to nullify the necessity to pose this question in that farmers are able to choose their insurance and factor into their production outlook the incentives that will accrue to them without the government deciding on what form of production to engage in or which particular form of insurance to take. As at the time the interviews were conducted, the asset test waiver was yet to be well disseminated to farmers. Perhaps, the asset test waiver would allow farmers who would not support direct payment of subsidies to insurers to have some form of assurance that if after hedging they are unprofitable or could not maintain themselves they are entitled to some welfare benefits. The welfare benefits without supports that could aid productivity may not be beneficial in the long-run because it will jeopardize the efficiency tenet of Australia's policy history. The researcher expects that over time, farmers will be able to adjust their practices in such a way that they will not depend on welfare rather insurance. The implication is that their cost of capital will reduce and more people will consider farming as a profession with an attendant impact on decentralizing the current Australia's demographic structure that is centred around the coastal regions (Hunter & Biddle 2011).

Although, the insurance option sounds promising, it is not without some challenges as insurers are concerned that expected demand may not match actual demands by farmers (Musshoff, Hirschauer & Odening 2008; Vandenberghe 2010). Similarly, farmers were concerned about the mode of dispensing supports to farmers. Should the supports be by tax incentives or subsidies to the insurers? The choice seems to be informed by the profitability of the farmers. Should farmers be profitable, then, they will prefer tax incentives since the prerequisite for the incentive is declaring profits. However, not all farmers make profits. The report by Australian Institute of Family Studies revealed that the lowest quartile of Australia's broad acre farms was not profitable for 18 years ending in 2006-2007 season (Hunter & Biddle 2011) a trend that has escalated to a rural debt of $66 billion in 2013 (Neales 2013). Those farmers who seem to be profitable may prefer the tax incentives while those who are not may prefer that subsidies be paid to the insurers directly. Further studies may be required in terms of farmers' risk management preferences to inform policies.

Also, since farmers' production and insurance decisions are responsive to economic incentives (Quiggin, Karagiannis & Stanton 1993), proper institutional design to manage the incentives in a way that does not lead to inefficiency and inequity is expected to payoff in the end (Yaron, Benjamin & Piprek 1997). The case of the American policy enumerated by Edwards (2009) shows that most of the subsidies actually benefited the largest producers rather than the small hold farmers. By implication, corporates tended to benefit more than the family farms.

Concerns were rife on the possibility of basis risk, however, an insurer allayed this concern by saying basis risk is no more a concern. The insurance option sounds promising because it could have impact on interest rate and credit capacity of farmers since interest on loans is *'a fairly large component of our(their) business'*. The importance of insurance with regards to lending was further attested to by the bankers as noted in previous studies (Gurenko 2006; Nieto et al. 2012). However the use of insurance brokers seemed to have created a gap between what obtains in the market and what farmers tend to be knowledgeable about as they tend to use brokers to find the best hedge rather than make the decisions themselves. Also, lack of insurance for livestock farmers could have resulted from the supports government offer livestock farmers. It is difficult to say whether the lack of insurance resulted from poor demand or the supports that the government give to the livestock farmers. The removal of such assistance targeted at livestock farmers would cause livestock farmers to demand for insurance and therefore the market will be able to emerge. The emergence of the livestock insurance market particularly weather insurance for fodders will give a broader portfolio to insurers offering the products for crop and livestock farmers thereby giving them the opportunity to further diversify their portfolio. The qualitative results have shown that inspite of all the challenges plaguing insurance, it could be more beneficial for all stakeholders because *it is easy to manage and less likely to be hoarded*. It is expected that this option will facilitate the attainment of mutual obligation and reciprocity.

8.3 Contributions

This study has made some contributions to the field of agricultural insurance generally and in the specific context of Australia. First, one of the models adopted in the analysis of the yield–index relationship disaggregated the relationship across the relationship continuum unlike in previous studies. Secondly, the range of measures of efficiency considered in this study is somewhat complete in that the three methods (Conditional Tail Expectations, Mean Root Square Loss and Certainty Equivalence of Revenue) adopted complemented each other. Besides, previous analyses have been largely quantitative in nature but this study adopted a mixed paradigm that adopts both quantitative and qualitative approaches. Furthermore, the deliberate choice of two climatologically diverse locations for the analysis suggests a sample that is more diverse and gives an idea of what should obtain if insurance contracts were pooled over time and space in Australia. The choice of different locations rather than a few locations enhances the richness of this study and the generalizability of its conclusions.

The major contribution of this study is the comparative analysis of the effect of commodity price assumptions made. The assumption of constant and variable price elucidated some subtle facts about the willingness of farmers to pay for weather insurance and by extension yield-based insurance. It was noted that the assumption of a constant price exaggerates the demand for insurance. This conclusion was well noted in the quantitative as well as the qualitative analyses. Farmers tend to hedge when prices were going down therefore assumption of a uniform price may not be very realistic.

Beyond the theoretical contributions, at the policy level the research shows that the recent policy change in Australia that waives the asset test for farmers to allow them to assess public welfare benefit is another direction towards the same end that the Exceptional Circumstance (EC) led to. The policy may be worse than the EC in that it gives a higher guarantee to farmers that they will obtain welfare benefits should they experience any form of revenue downturn. Although, the policy sounds equitable, it jeopardizes efficiency to a larger extent than the EC because the government may have to spend more on delivering welfare benefits to farmers. While farmers may want to be self-reliant, they will impound the welfare benefits into their production decisions. This payment will further impede the emergence of a more innovative insurance market and is therefore at cross purposes with the tenets of mutual obligations and reciprocity intended by the government of Australia. In view of the discussions above, some recommendations were imminent.

8.4 Policy implications and recommendations for future research

The recommendations from this study are focused on policy and further research. In terms of policy recommendations, the government should not, for whatever reason, support one insurance product at the expense of the others because no insurance will completely cater to the needs of farmers. Similarly, whatever policy gets instituted, it will not be equally beneficial to all stakeholders. However, attempts should be made to avoid polices that are at cross purposes. For instance, the current policy would inflate land value as much as the EC inflated land value and will jeopardize efficiency and reduce the willingness of farmers to pay for market options such as insurance that the government aims to promote.

Although, social welfare means of risk management may be equitable, farmers will benefit more from programmes that target their debts and aid ex ante financial planning. Given that insurance improves farmers' cash flow, it may reduce their cost of debt and alleviate the current trend in Australia's rural debt. It is also recommended that insurance in whatever form will have to discriminate clients by risk profile. In essence, the pricing of insurance would have to be from location to location and it should consider commodity price variability and forecast which impinges on the willingness of farmers to pay for insurance.

Government regulatory bodies will have to consider the legal and regulatory requirements to govern the operations of recent innovative insurance options emerging in the market to avoid anti-competitive behaviour and abuse of legal standards. Also, governments' standards will have to ensure that subsidy regime in whatever form is getting to the targets. However, the dynamic nature of policy will have to be recognized. To this effect, stamp duties on insurance premium should be abolished and a regressive tax benefit should be instituted on insurance premium. In essence, the benefits to be derived from insurance premium should reduce with insurable interest to prevent the wealthier farmers from benefitting much more than the poorer farmers who are less capable of managing their risks. The Australian taxation system remains a potent tool in achieving this objective through subsidies on insurance premium.

However, given concerns that farmers who are not making any profit will not be able to benefit from tax benefits on insurance premium, the instituted asset test waiver should deliver benefits to aid survival not to enrich farmers particularly the graziers who have been enriched in the past by such schemes. Enriching farmers through the welfare system will encourage suboptimal decision making. The government will by these incentives discourage the act of '*saving 30 cents with one dollar'* which farmers confessed to. In essence, the government will be able to bear the cost of the tax that is paid back because more farmers will pay taxes. In order to benefit from the tax incentives farmers would have to produce more efficiently and declare profits. However, to contain overproduction, the tax incentives should be regressive. Similarly, the tax incentives on premium should exclude derivatives. Tax benefits on derivatives will be far more detrimental to the Australian agricultural sector. The weather hedging products available in Australia is in the form of derivatives. The structural and functional form of the product sounds promising but it may have to metamorphose into insurance by requesting insurable interests from the clients before selling the product.

Furthermore, the findings of this research suggest that the FMD should be retained but its cap should be increased. It will also be an additional incentive for farmers to declare profits. The Farm Management Deposit (FMD) is an ex post mechanism which allows profitable farmers to gain tax advantage, but it does not sufficiently facilitate risk management. Although, like the FMD, insurance will benefit profitable farmers, but such farmers who are not profitable may then resort to welfare benefit. The insured farmer would have at least had access to loans at a cheaper rate and made adequate planning.

It may be viable to consider the design of weather insurance for livestock producers whose income decreases in drought while input cost increases. Besides, designing weather insurance for livestock farmers will be much easier and less costly than crop-specific weather insurance. The use of Normalized Difference Vegetative Index has proved beneficial in the design of weather insurance for graziers as documented in the literature review (Chapter 2). There should be no segmentation of the market when it comes to government assistance to avoid sub-optimal allocation of productive resources towards livestock production. If all form of supports given to livestock farming is removed, graziers will tend to seek insurance, the market will be bigger and more viable for insurers to offer their products. Therefore, every form of special treatment to the livestock industry should be stopped. Policy makers should not respond to emotion-laden media reports that gives undue advantages to livestock farmers. The current waiver of asset test that qualifies farmers for public welfare covers the livestock farmers as well. However, due attention will have to be paid to appropriate insurance product for the livestock industry which will provide additional diversification opportunities for a portfolio of weather insurance contracts. It is expected that as insurance becomes a prerequisite for lending with the benefit of taxation, the market will innovate and productivity will improve and the growth rate of debt will be at a rate that is justified by agricultural productivity. It is also expected that the recommendations above will facilitate reciprocity and mutual obligation tenets of the governments of Australia.

Pricing insurance would require risk discrimination. To appropriately discriminate risk, there will be need for appropriate provisioning of technological resources which would be the major role for the government of Australia. Furthermore, rural extension may be needed to promote the awareness of both government and insurance options because of the low awareness of the options among the farmers.

In terms of further research, it is recommended that there should be a cross-sectional analysis of current offerings of weather index insurance products in the market based on the cash flows of the farmers that have subscribed to them. In time, such analysis could be longitudinal. Such analysis will provide more real life context of the insurance options that are currently in very low demand. Similarly, analysis of weather index insurance should make a comparative analysis of the results on hedging efficiency based on farmers' risk aversion.

Similarly, although it has been noted that more complex weather indices may not necessarily deliver more benefits to farmers as there are mixed results (Chantarat

2009; Leblois & Quiron 2013), other indices, particularly those that consider soil moisture should be adopted in the analysis of weather index insurance. A model that prices in the variability in commodity prices could increase the value of weather index insurance. Also, future studies should consider the use of variable pricing model in the evaluation of weather index insurance contracts and as technology and information improves, scholars should endeavour to adopt disaggregated data in their evaluation of insurance products. In addition, a review of the Industries Assistance Commission Report with respect to crop and rainfall insurance is urgently needed. Data sharing should be decentralized and legal and regulatory requirements of the insurance industry should be bolstered.

Finally, it is recommended that the gap between policy makers and rural area dwellers be closed with adequate dialogue and research into the behaviour of farmers and other factors need to be factored into the benefits of risk management options beyond the regular quantitative valuations. Such side benefits to appropriate agro-risk management include a demographic restructure of Australia. The topic of weather index insurance demands multi-stakeholder team of interdisciplinary experts. However, the researcher has made efforts to capture as many details within his resource constraints that could reasonably deliver sufficient information for a study that could be considered as a pilot for such future interdisciplinary studies. Nevertheless, some limitations were imminent.

8.5 Limitations of the study

There are some limits to the generalizations of this study despite the contributions based on the outcomes obtained from it. First, the data used in the analysis were shire-wide data for both yield and rainfall. The prices available were also based on national prices. Each farmer would tend to have received different amounts of rainfall, had different amount of wheat yield and received different prices over the period of time analysed. However, should the actual data be available, the findings of this study would have been more prominent in that the locational differences would have been more evident. The major concerns were about the yield and rainfall data. Similarly, the current offering of weather insurance offers a combined drought and flood insurance and may be more profitable for farmers than modelled in this study.

Similarly, Constant Relative Risk Aversion was assumed in the analysis. The reality is that, farmers display different forms of aversion to risk. Also, the insurer was assumed to offer only weather insurance product. The reality is that Australian insurers have other products in their portfolio of products and would therefore have a higher capacity to diversify meaning that the effect of diversification could be more than has been modelled in this study. On the other hand, the administrative and underwriting costs were not considered in this analysis in that the analyses were based strictly on actuarial burns analysis as explained in the methodology (Chapter 3). Finally, the determination of the weights for each dekad could not be sufficiently specified as well as the rainfall caps. However, sensitivity analysis was conducted to cover some of the gaps.

8.6 Conclusion

The purpose of this study was to investigate the viability of weather index insurance for Australian wheat farmers. In a broader sense, it aims to consider the viability of weather index insurance for broad acre farmers in Australia particularly in the context of managing weather risk. This report however documents other risk management options and examined the context in which the weather insurance is to operate both from literature and some stakeholders in Australia agriculture. The available insurance options and government interventions were discussed and analysed with respect to relevant regulatory and insurance theories.

Regulatory economics and incentive theories were used to explain the state of Australian agro-risk management. It was concluded that Australian farmers perceived the Australian agro-risk management to be following the market for regulation theory. Principal-Agency Theory was observed in the management of agricultural risk particularly under the Exceptional Circumstance (EC) and the same theory explains the possible cost and benefit of corporate and family farm models. It was concluded that weather insurance solves some of the problems of the regular Multi-Peril Crop Insurance particularly moral hazard but its solution to this problem creates a disincentive for its uptake.

The quantitative analysis shows that the yield-index relationship does not have a uniform slope and the assumption of a uniform slope is faulty in the evaluation of the efficiency of the contracts. It was also noted that the efficiency of the contract does not necessarily reflect the extent of the relationship as previously noted even when the relationship is disaggregated at the corresponding levels of the efficiency.

A major contribution of this study is that the covariance structure of yield and price reduces the willingness of farmers to pay for insurance. Previous studies assumed that price was constant over the period under consideration whereas in reality it is not so. Therefore, implicit in the assumption is that price stabilization is costless. Impounding the cost of stabilization into the value of insurance therefore reduces its benefits. However, weather insurance may not be worthless but it could be worth less than the hype. The contribution does not only explain the poor take up of weather index insurance but also that of yield-based insurance in that yield – based insurance tacitly makes the same assumption by not capturing the variability in commodity prices. The assumption explains the philosophy behind revenue insurance which is not without its own challenges.

The conclusion was that there is no perfect insurance as only the farmer could choose a range of risk management options that maximises his own unique portfolio of assets, location of farm site, variability of rainfall and risk aversion. Also, it is expected that weather insurers will be profitable to the insurer only in the long-run as they diversify across space, time and product niches. One may be able to conclude that the extent of support for Australian farmers is at least exogenously inequitable in that they are competing in a global industry where their competitors are heavily subsidized. Nevertheless, the model of supports that should be adopted in Australia cannot follow those of other countries rather; a unique support system should be designed that optimally improves the net welfare of the Commonwealth of Australia.

Finally, farmers' management decisions were found to respond to tax incentives. The vital recommendation of this study is that the government should respond to risk management through a mix of market enhancing and social policies. In essence, it was recommended the welfare system for farmers should be retained but tax incentives should be instituted on insurance premium so that farmers can make their choices of insurance products to patronize. This mix is expected to be simultaneously equitable and efficient and will reduce the cost of debt, improve productivity and enhance market innovation.

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Appendices

Appendix 1: Descriptive statistics

Annual Precipitation					Shires	Yield				Actual Seasonal Precipitation			
Station number	Complete data	Annual precipitation	SD	Skewness		Mean t/ha	SD	CV	Skewness	Mean (mm)	SD	CV	Skewness
048020	99.47	508.62	154.57	0.20	Balonne	1.18	0.49	0.42	-0.54	195.13	91.79	0.47	0.15
39003	95.98	615.77	161.33	0.53	Banana	1.57	0.40	0.25	0.06	239.03	116.14	0.49	0.30
35206	98.13	587.05	226.93	1.84	Bauhinia	1.56	0.47	0.30	2.49	207.32	114.60	0.55	0.75
43043	97.81	609.14	177.12	0.51	Bendemere	1.59	0.56	0.35	0.21	208.54	86.92	0.42	0.57
43060	99.71	594.18	178.31	0.59	Booringa	1.29	0.59	0.46	1.43	218.49	96.59	0.44	0.51
43093	99.66	577.47	190.48	1.60	Bungil	1.67	0.65	0.39	0.40	221.61	95.76	0.43	0.47
41327	99.66	674.53	175.02	0.45	Cambooya	2.92	0.46	0.16	-0.74	269.98	92.65	0.34	0.01
41018	95.77	717.12	167.20	0.28	Clifton	2.66	0.44	0.16	-0.72	292.81	102.11	0.35	-0.20
39004	99.81	712.84	206.55	0.57	Duaringa	1.89	0.37	0.20	0.68	258.17	119.80	0.46	0.41
35021	99.47	580.31	213.35	0.95	Emerald	1.28	0.34	0.27	0.54	194.76	118.38	0.61	0.84
40428	99.75	706.91	164.98	1.36	Gayndah	1.58	0.49	0.31	0.52	271.05	86.49	0.32	-0.07
41391	99.64	649.52	162.26	0.96	Inglewood	1.38	0.28	0.20	0.35	265.40	91.07	0.34	0.36
41053	95.36	616.08	163.31	0.24	Jondarayan	2.83	0.45	0.16	-0.24	260.51	101.55	0.39	0.07

40111	98.80	825.56	216.66	0.25	Kilkivan	3.41	0.28	0.08	-0.87	289.91	105.17	0.36	0.01
40199	99.54	721.86	190.96	0.13	Kingaroy	1.90	0.54	0.29	-0.26	276.73	87.93	0.32	0.14
41069	95.94	684.39	172.28	0.60	Millmerran	2.24	0.36	0.16	-0.42	273.43	104.08	0.38	0.23
39073	95.06	688.30	179.79	1.03	Munduberra	2.03	0.52	0.26	0.55	278.95	95.50	0.34	0.30
41166	99.33	675.07	182.98	0.93	Pittsworth	2.71	0.47	0.17	-0.86	273.03	100.98	0.37	0.44
40212	99.36	1144.61	381.38	0.77	Rosalie	1.96	0.54	0.27	-0.73	393.41	178.01	0.45	0.89
41108	99.16	582.68	168.27	0.60	Tara	1.40	0.54	0.39	0.34	234.39	88.32	0.38	0.20
52020	98.46	522.33	151.52	-0.04	Waggamba	1.41	0.51	0.36	-0.12	212.72	94.50	0.44	0.28
41100	98.48	700.32	159.76	0.30	Waroo	1.27	0.52	0.41	-0.16	297.11	97.06	0.33	0.14
40138	99.58	694.90	163.94	0.72	Wondai	2.16	0.46	0.21	0.05	282.42	94.89	0.34	0.40
9575	98.71	654.95	125.78	-0.54	Boddington	2.70	0.25	0.09	-3.04	528.73	114.38	0.22	0.02
10526	98.71	375.98	77.05	0.19	Broomehill	2.83	0.40	0.14	-2.77	262.17	54.61	0.21	0.06
10006	99.01	313.11	78.45	0.40	Bruce Rock	1.97	0.27	0.14	-1.33	214.03	58.44	0.27	0.10
8121	95.74	355.98	92.03	0.35	Carnamah	2.45	0.15	0.06	-0.94	260.33	68.40	0.26	-0.18
8028	97.40	419.51	100.58	-0.01	Chapman	2.37	0.07	0.03	-0.62	344.88	93.01	0.27	-0.02
8067	99.77	316.50	85.51	0.35	Coorow	2.49	0.15	0.06	-0.74	230.35	70.18	0.30	0.53
10536	99.97	358.67	71.07	0.13	Corrigin	2.08	0.30	0.14	-0.94	240.58	56.16	0.23	-0.05
10035	99.06	347.32	81.51	-0.19	Cunderdin	2.63	0.13	0.05	-0.37	246.12	70.57	0.29	0.02

8061	99.81	352.12	91.61	1.08	Dalwallinu	2.11	0.18	0.08	-0.45	247.27	62.50	0.25	0.19
10546	98.47	358.45	82.36	0.51	Dumbleyung	2.47	0.14	0.06	-1.90	244.94	57.54	0.23	0.65
9789	99.99	612.28	115.13	0.55	Esperance	2.28	0.17	0.08	-0.42	436.32	91.39	0.21	-0.09
10058	97.22	359.24	79.70	0.22	Goomaling	2.79	0.06	0.02	-0.60	261.56	65.94	0.25	0.65
10515	99.95	406.31	79.60	-0.47	Irwin	3.10	0.12	0.04	1.32	301.68	64.85	0.21	0.01
10541	99.03	372.12	84.45	-0.06	Jerramungup	2.62	0.18	0.07	-2.41	236.53	62.60	0.26	0.73
10579	99.87	453.75	83.65	0.25	Katanning	2.74	0.32	0.11	-3.14	330.05	67.15	0.20	0.03
10073	99.33	304.13	74.89	0.35	Kellerberin	2.05	0.19	0.09	-1.35	207.39	59.08	0.28	0.25
9647	99.78	1161.70	147.85	-0.17	Kent	2.41	0.09	0.04	-1.64	840.94	120.04	0.14	-0.12
10513	99.82	301.79	67.39	-0.05	Kondinin	2.09	0.21	0.10	-0.24	203.08	52.92	0.26	-0.17
10133	99.84	282.91	72.22	-0.26	Koorda	1.78	0.21	0.12	-0.34	189.27	49.83	0.26	-0.35
1910	99.55	310.46	64.90	-0.01	Kulin	2.07	0.21	0.10	-1.06	209.13	53.02	0.25	-0.23
10592	99.99	339.61	87.51	0.15	Lake Grace	2.25	0.11	0.05	-1.38	215.40	53.96	0.25	0.06
10092	99.97	325.04	76.07	0.35	Merredin	1.59	0.19	0.12	-0.17	211.11	49.46	0.23	0.23
8008	99.64	405.16	84.01	0.97	Moora	2.55	0.05	0.02	-0.70	308.39	65.00	0.21	0.39
8233	99.60	322.33	85.11	0.27	Morawa	2.10	0.19	0.09	-0.31	233.04	66.68	0.29	0.19
41275	99.69	684.85	159.22	0.49	Mount Marshal	1.64	0.19	0.12	-0.06	245.15	98.15	0.40	1.02
10030	99.30	297.24	77.28	0.15	Munkindubin	1.72	0.20	0.12	0.04	183.20	49.70	0.27	-0.18

10060	99.21	322.82	87.20	0.50	Narembeen	2.02	0.20	0.10	-0.36	207.77	54.60	0.26	0.38
10614	99.83	468.13	89.46	0.09	Narrogin	2.60	0.07	0.03	1.38	345.73	74.09	0.21	0.21
10111	99.60	406.38	91.93	0.27	Northam	2.52	0.29	0.12	-2.68	309.49	74.23	0.24	0.56
8100	96.83	434.61	106.35	-0.32	Northampton	2.87	0.05	0.02	-1.44	362.01	96.40	0.27	-0.06
10047	99.58	275.09	71.38	0.31	Nungarin	1.45	0.26	0.18	0.41	173.09	46.54	0.27	-0.06
10626	99.99	414.79	75.52	-0.29	Pingelly	2.46	0.07	0.03	-0.77	307.29	65.38	0.21	0.09
10628	99.30	341.39	81.94	0.06	Quairading	2.18	0.37	0.17	-2.34	236.83	64.78	0.27	0.33
10633	99.34	431.87	85.41	-0.08	Ravensthorpe	2.25	0.12	0.05	-1.33	251.18	70.77	0.28	0.55
10121	97.86	335.98	77.21	0.39	Tammin	2.53	0.22	0.09	-1.47	232.26	64.12	0.28	0.65
10126	98.65	318.49	77.90	0.49	Trayning	2.03	0.24	0.12	0.14	212.32	54.95	0.26	-0.13
10019	99.08	334.05	77.62	0.27	Westonia	1.57	0.20	0.13	0.24	217.13	52.70	0.24	0.00
10654	98.33	383.19	70.58	0.10	Wickepin	2.51	0.09	0.04	-2.12	278.05	61.28	0.22	0.41
12201	99.21	348.77	86.89	0.27	Yilgarn	1.58	0.18	0.11	0.31	214.66	54.99	0.26	-0.18
10115	99.76	370.72	79.91	0.10	York	2.55	0.32	0.13	-2.32	275.52	67.52	0.25	0.24

Appendix 2: Dekadal weights of wheat crops across shires for the season

Shires	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	Total
Balonne	0.01	0.05	0.08	0.12	0.00	0.24	0.16	0.00	0.00	0.12	0.00	0.00	0.12	0.05	0.00	0.05	0.00	0.00	1.00
Banana	0.16	0.08	0.06	0.11	0.07	0.09	0.00	0.06	0.14	0.00	0.00	0.01	0.08	0.00	0.00	0.06	0.08	0.00	1.00
Bauhinia	0.07	0.13	0.08	0.24	0.05	0.14	0.12	0.00	0.00	0.00	0.00	0.00	0.00	0.10	0.00	0.00	0.06	0.00	1.00
Bendemere	0.05	0.10	0.06	0.04	0.05	0.13	0.09	0.05	0.06	0.04	0.00	0.09	0.05	0.09	0.05	0.04	0.00	0.02	1.00
Booringa	0.02	0.07	0.07	0.10	0.03	0.06	0.07	0.03	0.11	0.11	0.13	0.09	0.05	0.00	0.00	0.01	0.05	0.01	1.00
Bungil	0.07	0.12	0.11	0.14	0.01	0.10	0.05	0.05	0.04	0.09	0.11	0.06	0.00	0.00	0.03	0.00	0.00	0.01	1.00
Cambooya	0.02	0.05	0.07	0.07	0.10	0.12	0.07	0.05	0.07	0.06	0.02	0.10	0.10	0.02	0.00	0.09	0.00	0.00	1.00
Clifton	0.00	0.00	0.20	0.10	0.06	0.13	0.09	0.00	0.06	0.00	0.03	0.08	0.02	0.12	0.00	0.11	0.00	0.00	1.00
Duaringa	0.08	0.03	0.07	0.15	0.10	0.00	0.00	0.05	0.08	0.00	0.00	0.00	0.00	0.18	0.00	0.19	0.07	0.00	1.00
Emerald	0.03	0.10	0.09	0.28	0.21	0.10	0.02	0.00	0.03	0.00	0.00	0.00	0.02	0.09	0.00	0.02	0.02	0.00	1.00
Gayndah	0.08	0.05	0.06	0.06	0.06	0.13	0.06	0.13	0.14	0.04	0.07	0.00	0.04	0.05	0.00	0.04	0.00	0.00	1.00
Inglewood	0.00	0.07	0.08	0.22	0.01	0.14	0.00	0.01	0.09	0.06	0.09	0.00	0.00	0.17	0.00	0.05	0.00	0.00	1.00
Jondarayan	0.04	0.07	0.07	0.02	0.09	0.16	0.13	0.12	0.10	0.04	0.02	0.13	0.00	0.00	0.00	0.03	0.00	0.00	1.00
Kilkivan	0.07	0.08	0.07	0.05	0.00	0.21	0.11	0.11	0.10	0.04	0.00	0.00	0.02	0.04	0.00	0.05	0.00	0.06	1.00
Kingaroy	0.00	0.06	0.07	0.15	0.08	0.15	0.09	0.16	0.11	0.00	0.05	0.01	0.04	0.00	0.00	0.00	0.00	0.03	1.00
Millmerran	0.04	0.12	0.07	0.16	0.03	0.19	0.09	0.02	0.00	0.04	0.03	0.07	0.02	0.05	0.00	0.06	0.00	0.01	1.00
Munduberra	0.01	0.15	0.06	0.23	0.07	0.13	0.00	0.06	0.06	0.04	0.06	0.00	0.02	0.06	0.02	0.00	0.02	0.01	1.00

Pittsworth	0.00	0.06	0.07	0.04	0.05	0.14	0.17	0.09	0.02	0.06	0.06	0.17	0.00	0.00	0.00	0.07	0.00	0.00	1.00
Rosalie	0.11	0.06	0.06	0.00	0.03	0.16	0.17	0.09	0.05	0.03	0.09	0.00	0.01	0.00	0.00	0.05	0.05	0.05	1.00
Tara	0.02	0.08	0.07	0.12	0.03	0.11	0.12	0.02	0.12	0.00	0.12	0.04	0.00	0.02	0.00	0.07	0.01	0.06	1.00
Waggamba	0.00	0.07	0.08	0.18	0.00	0.21	0.17	0.00	0.00	0.11	0.00	0.03	0.06	0.01	0.00	0.05	0.00	0.04	1.00
Waroo	0.00	0.11	0.09	0.27	0.00	0.19	0.14	0.07	0.00	0.01	0.05	0.00	0.04	0.01	0.00	0.03	0.00	0.00	1.00
Wondai	0.00	0.06	0.07	0.14	0.02	0.16	0.10	0.16	0.15	0.02	0.06	0.05	0.00	0.00	0.00	0.00	0.00	0.03	1.00
Boddington	0.17	0.04	0.06	0.00	0.00	0.06	0.00	0.00	0.02	0.12	0.07	0.08	0.00	0.02	0.16	0.10	0.09	0.00	1.00
Broomehill	0.00	0.08	0.07	0.00	0.00	0.13	0.00	0.10	0.02	0.00	0.00	0.11	0.04	0.16	0.00	0.04	0.15	0.09	1.00
Bruce Rock	0.05	0.08	0.06	0.09	0.07	0.06	0.00	0.15	0.08	0.00	0.04	0.00	0.15	0.09	0.03	0.05	0.00	0.00	1.00
Carnamah	0.01	0.09	0.06	0.05	0.03	0.06	0.11	0.13	0.05	0.11	0.00	0.07	0.04	0.09	0.00	0.04	0.04	0.02	1.00
Chapman	0.00	0.12	0.06	0.05	0.07	0.06	0.06	0.07	0.08	0.10	0.03	0.13	0.01	0.05	0.00	0.01	0.04	0.06	1.00
Coorow	0.03	0.05	0.06	0.10	0.00	0.05	0.14	0.12	0.09	0.08	0.05	0.03	0.05	0.07	0.00	0.05	0.02	0.00	1.00
Corrigin	0.12	0.10	0.05	0.06	0.03	0.07	0.02	0.03	0.03	0.03	0.05	0.07	0.08	0.13	0.09	0.01	0.02	0.00	1.00
Cunderdin	0.17	0.05	0.05	0.01	0.00	0.06	0.02	0.01	0.00	0.06	0.11	0.05	0.08	0.07	0.06	0.03	0.06	0.10	1.00
Dalwallinu	0.01	0.10	0.06	0.06	0.02	0.07	0.11	0.14	0.15	0.06	0.00	0.07	0.05	0.08	0.00	0.03	0.00	0.00	1.00
Dumbleyung	0.00	0.04	0.08	0.03	0.00	0.00	0.00	0.00	0.13	0.09	0.10	0.09	0.11	0.21	0.10	0.04	0.00	0.00	1.00
Esperance	0.23	0.02	0.05	0.00	0.00	0.00	0.00	0.05	0.09	0.09	0.09	0.07	0.10	0.12	0.00	0.00	0.07	0.00	1.00
Goomaling	0.12	0.04	0.06	0.08	0.00	0.07	0.00	0.01	0.07	0.11	0.16	0.09	0.04	0.02	0.01	0.02	0.04	0.07	1.00
Greenough	0.10	0.00	0.10	0.00	0.00	0.00	0.00	0.00	0.00	0.34	0.39	0.00	0.06	0.00	0.00	0.00	0.00	0.00	1.00

Irwin	0.00	0.00	0.27	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.23	0.00	0.00	0.00	0.02	0.15	0.00	0.33	1.00
Jerramungup	0.00	0.00	0.26	0.00	0.00	0.00	0.15	0.12	0.06	0.00	0.15	0.08	0.06	0.00	0.01	0.00	0.00	0.11	1.00
Katanning	0.00	0.08	0.07	0.01	0.00	0.16	0.00	0.08	0.00	0.00	0.00	0.04	0.03	0.11	0.00	0.20	0.12	0.09	1.00
Kellerberin	0.00	0.06	0.07	0.19	0.06	0.11	0.02	0.06	0.08	0.00	0.16	0.00	0.10	0.08	0.00	0.00	0.00	0.00	1.00
Kent	0.00	0.02	0.28	0.00	0.09	0.00	0.10	0.07	0.18	0.05	0.01	0.00	0.11	0.00	0.08	0.00	0.01	0.00	1.00
Kondinin	0.15	0.06	0.05	0.00	0.06	0.09	0.03	0.10	0.00	0.07	0.08	0.06	0.10	0.04	0.08	0.03	0.00	0.00	1.00
Koorda	0.07	0.08	0.06	0.03	0.09	0.09	0.08	0.13	0.03	0.03	0.07	0.00	0.11	0.04	0.02	0.07	0.01	0.00	1.00
Kulin	0.08	0.09	0.06	0.09	0.02	0.09	0.02	0.02	0.05	0.01	0.04	0.06	0.14	0.13	0.09	0.01	0.00	0.00	1.00
Lake Grace	0.03	0.06	0.06	0.06	0.01	0.05	0.05	0.11	0.10	0.00	0.17	0.15	0.08	0.07	0.00	0.00	0.00	0.00	1.00
Merredin	0.09	0.15	0.06	0.05	0.00	0.01	0.02	0.18	0.07	0.07	0.02	0.13	0.04	0.07	0.01	0.03	0.00	0.00	1.00
Moora	0.00	0.01	0.08	0.19	0.00	0.02	0.11	0.10	0.09	0.10	0.11	0.06	0.00	0.09	0.00	0.00	0.00	0.03	1.00
Morawa	0.00	0.09	0.07	0.11	0.04	0.08	0.08	0.06	0.10	0.09	0.07	0.02	0.03	0.12	0.00	0.00	0.00	0.04	1.00
Mount Marshal	0.00	0.11	0.10	0.04	0.02	0.00	0.12	0.24	0.06	0.03	0.00	0.00	0.00	0.00	0.00	0.24	0.00	0.04	1.00
Munkindubin	0.10	0.10	0.05	0.02	0.02	0.02	0.04	0.13	0.09	0.05	0.08	0.08	0.08	0.07	0.00	0.04	0.00	0.02	1.00
Narembeen	0.10	0.10	0.06	0.06	0.02	0.09	0.00	0.11	0.04	0.01	0.03	0.07	0.12	0.05	0.10	0.04	0.00	0.00	1.00
Narrogin	0.00	0.00	0.30	0.00	0.00	0.00	0.00	0.30	0.05	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.36	1.00
Northam	0.06	0.00	0.06	0.13	0.04	0.11	0.00	0.00	0.06	0.07	0.09	0.03	0.00	0.08	0.10	0.09	0.04	0.05	1.00
Northampton	0.00	0.09	0.06	0.09	0.08	0.11	0.11	0.14	0.05	0.01	0.00	0.14	0.02	0.00	0.00	0.03	0.02	0.05	1.00
Nungarin	0.11	0.07	0.05	0.00	0.02	0.05	0.05	0.13	0.08	0.10	0.10	0.07	0.08	0.06	0.00	0.00	0.00	0.02	1.00

Pingelly	0.15	0.05	0.05	0.00	0.00	0.09	0.03	0.00	0.04	0.10	0.10	0.03	0.06	0.03	0.10	0.06	0.06	0.04	1.00
Quairading	0.10	0.06	0.06	0.05	0.03	0.02	0.04	0.00	0.10	0.17	0.05	0.05	0.13	0.00	0.04	0.02	0.09	0.00	1.00
Ravensthorpe	0.11	0.06	0.06	0.00	0.07	0.05	0.17	0.13	0.01	0.00	0.06	0.09	0.06	0.00	0.11	0.00	0.04	0.00	1.00
Tammin	0.03	0.03	0.07	0.16	0.00	0.19	0.05	0.00	0.07	0.03	0.05	0.00	0.14	0.08	0.08	0.02	0.00	0.00	1.00
Toodyay	0.00	0.00	0.60	0.00	0.00	0.00	0.00	0.00	0.10	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.30	1.00
Trayning	0.09	0.10	0.05	0.06	0.06	0.08	0.02	0.14	0.04	0.03	0.09	0.06	0.08	0.04	0.02	0.04	0.00	0.00	1.00
Westonia	0.10	0.09	0.05	0.03	0.05	0.07	0.03	0.18	0.05	0.08	0.06	0.06	0.06	0.05	0.01	0.02	0.00	0.02	1.00
Wickepin	0.00	0.07	0.07	0.05	0.00	0.00	0.01	0.11	0.14	0.06	0.17	0.19	0.02	0.11	0.00	0.00	0.00	0.00	1.00
Yilgarn	0.10	0.13	0.05	0.01	0.01	0.06	0.08	0.10	0.02	0.10	0.02	0.10	0.07	0.07	0.07	0.01	0.01	0.00	1.00
York	0.03	0.00	0.07	0.03	0.04	0.12	0.04	0.00	0.12	0.08	0.10	0.07	0.00	0.00	0.04	0.18	0.06	0.03	1.00

Appendix 3: Hedging efficiency using Conditional Tail Expectations – uncapped optimized

Shires	Constant Price			Variable Price		
	Δ^{5th} (%)	Δ^{10th} (%)	Δ^{30th} (%)	Δ^{5th} (%)	Δ^{10th} (%)	Δ^{30th} (%)
Balonne	11.80	15.71	5.09	5.61	16.37	5.98
Banana	2.12	1.09	-.59	-4.70	-5.26	2.69
Bauhinia	9.05	5.63	-1.00	2.16	-2.33	4.20
Bendemere	19.57	13.43	4.50	14.83	9.73	5.51
Booringa	1.76	1.90	2.57	-3.71	-3.79	2.44
Bungil	5.47	5.99	4.00	-.34	2.02	3.88
Cambooya	6.00	.85	-1.68	-.86	-.87	2.36
Clifton	1.52	3.67	-.81	-4.58	-2.21	3.43
Duaringa	-2.29	-1.82	-2.50	-1.23	-1.39	.77
Emerald	-.85	-3.76	.05	1.08	-4.00	5.33
Gayndah	4.32	7.57	3.89	-1.83	-.09	3.10
Inglewood	2.56	2.62	.23	-4.19	-3.06	1.72
Jondarayan	-1.87	-2.54	-1.36	-5.26	-5.43	1.53
Kilkivan	-4.74	-5.98	-11.55	-7.99	-9.81	-3.70
Kingaroy	.46	6.85	3.19	-8.02	2.98	4.38
Millmerran	4.16	1.98	.35	-3.79	-3.54	1.25
Munduberra	.53	-.27	2.58	-6.51	-2.41	2.69
Pittsworth	-3.41	-1.69	-3.14	-5.09	-4.14	2.70
Rosalie	3.57	7.47	.70	-4.23	1.58	2.72
Tara	4.76	4.74	4.80	-.64	-1.13	4.04
Waggamba	9.50	9.99	3.94	10.33	4.17	4.74
Waroo	4.76	4.74	4.80	-.64	-1.13	4.04
Wondai	-.35	1.00	1.07	-4.83	-4.68	2.03
Boddington	7.01	4.95	-3.07	6.77	2.94	.43
Broomehill	10.79	5.93	-5.05	-1.18	2.55	-.95
Bruce Rock	10.05	5.26	-1.11	2.03	-.46	-.11
Carnamah	-.55	-1.82	-4.97	-3.51	-5.63	-4.10
Chapman	-1.63	-3.15	-7.77	-3.79	-7.07	-3.95
Coorow	-1.96	-5.23	-9.11	-4.35	-9.85	-6.25
Corrigin	6.86	3.15	-.18	4.33	.95	-1.33
Cunderdin	-.75	-1.40	-2.61	-2.63	-2.85	-.04
Dalwallinu	-2.61	-2.30	-8.67	-3.69	-4.01	-5.69
Dumbleyung	.66	-.67	-4.00	-.76	-2.89	-1.31
Esperance	-1.85	-2.88	-6.99	-4.30	-7.01	-2.26
Goomaling	-2.98	-3.84	-9.61	-5.90	-6.54	-4.12
Irwin	-2.76	-3.66	-10.55	-3.79	-4.76	-.86
Jerramungup	4.79	.05	-6.93	-6.21	-7.58	-4.65
Katanning	2.48	3.77	-7.35	-3.98	-1.42	-1.56
Kellerberin	.71	1.90	-4.00	-5.32	-3.13	-2.31
Kent	-2.73	-2.24	-6.69	-5.47	-5.64	-2.10
Kondinin	.25	-.33	-4.09	-2.45	-3.32	-1.39
Koorda	3.49	.10	-2.52	-4.64	-3.43	-.29
Kulin	2.19	.85	-2.99	-1.19	-3.73	-1.15

Lake Grace	1.51	-2.19	-7.61	-3.65	-6.42	-.95
Merredin	1.99	-.04	-2.45	-5.67	-4.68	-3.14
Moora	-3.30	-3.87	-7.16	-5.48	-6.82	-3.66
Morawa	-1.64	-3.66	-4.91	-4.34	-8.02	-2.40
Mount Marshal	-1.60	-3.63	-5.85	-4.70	-4.63	-.02
Munkindubin	-1.17	.21	-2.59	-5.42	-3.73	-2.30
Narembeen	.77	-.28	-2.02	-.91	-2.84	-1.40
Narrogin	-3.88	-7.09	-12.78	-6.23	-11.07	-2.11
Northam	7.25	1.05	-4.42	5.87	-3.68	-.60
Northampton	-1.94	-3.36	-9.33	-4.68	-7.03	-5.36
Nungarin	2.35	.27	-1.99	-6.22	-7.29	-3.08
Pingelly	-1.66	-2.29	-6.44	-3.54	-3.81	-.03
Quairading	16.58	9.04	-1.25	15.58	8.07	-1.40
Ravensthorpe	1.12	-.58	-7.27	-4.01	-5.88	-5.74
Tammin	.47	.27	-4.40	.25	-4.05	-1.13
Trayning	1.20	-1.89	-3.13	-6.28	-5.35	-2.91
Westonia	-2.67	-2.32	-3.34	-5.63	-7.36	-4.99
Wickepin	-.76	-3.39	-9.00	-4.96	-8.80	-3.47
Yilgarn	-1.90	-1.69	-1.82	-5.20	-5.03	-4.30
York	9.07	3.75	-2.02	8.19	-.59	.81
Descriptive and One-sample t-test statistics for changes in CTE for all shires						
All Mean	2.09	0.89	-3.00	-2.09	-3.02	-0.39
Minimum	-4.74	-7.09	-12.78	-8.02	-11.07	-6.25
Maximum	19.57	15.71	5.09	15.58	16.37	5.98
SD	4.95	4.55	4.37	4.98	4.65	3.18
t	3.35	-3.00	-3.00	-2.09	-3.02	-0.39
Descriptive and One-sample t-test statistics for changes in CTE for each shire						
QLD t	3.01	3.11	-5.44	-3.33	-071	-0.96
Mean (SD)	3.41(5.42)	3.44(5.31)	1.07	-1.30	-0.80(5.42)	7.04
WA t	1.85	-1.11	0.83(3.72)	-1.50(5.53)	-7.49	2.94(2.01)
Mean (SD)	1.33(4.54)	-0.58(3.31)	-10.98	-3.28	-4.30(3.63)	-7.78

Appendix 4: Hedging efficiency using Conditional Tail Expectations – uncapped equally weighted

Shires	Constant Price			Variable Price		
	Δ^{5th} (%)	Δ^{10th} (%)	Δ^{30th} (%)	Δ^{5th} (%)	Δ^{10th} (%)	Δ^{30th} (%)
Balonne	-10.83	-8.74	2.66	-10.67	-5.64	4.21
Banana	-.22	-2.32	-2.10	-7.53	-7.09	1.28
Bauhinia	1.34	2.88	-3.73	-4.69	-2.98	1.21
Bendemere	20.78	12.98	3.89	16.21	9.45	4.98
Booringa	-1.55	1.03	1.46	-5.44	-2.40	1.21
Bungil	-7.92	-2.44	2.44	-10.63	-5.78	3.95
Cambooya	2.96	.43	-3.31	-1.96	-1.09	.51
Clifton	4.42	3.94	-3.04	-.88	-3.10	-.03
Duaringa	-2.81	-2.14	-4.54	-.76	-1.47	1.15
Emerald	.57	-.57	0.81	1.08	.30	4.93
Gayndah	-.45	7.35	2.77	-8.98	-4.59	1.43
Inglewood	-5.28	-2.83	-2.34	-7.08	-6.07	1.41
Jondarayan	-.95	-.02	-2.25	-4.16	-1.52	.45
Kilkivan	-3.84	-8.46	-14.04	-6.82	-8.89	-6.03
Kingaroy	-.39	3.62	2.23	-9.10	-2.34	2.25
Millmerran	3.09	2.75	-3.35	-1.83	-3.23	.84
Munduberra	-2.02	-3.62	1.73	-5.69	-9.68	2.25
Pittsworth	-3.87	.28	-2.85	-2.40	-3.11	1.40
Rosalie	8.59	5.06	-2.23	7.05	6.73	2.82
Tara	-2.44	1.39	3.47	-7.14	1.02	3.32
Waggamba	5.04	2.96	2.70	7.11	-.75	5.22
Waroo	-2.44	1.39	3.47	-7.14	1.02	3.32
Wondai	1.80	1.66	0.76	-1.98	-1.68	1.14
Boddington	4.10	1.24	-6.01	2.61	-1.97	-2.21
Broomehill	8.25	3.38	-5.13	5.86	.46	-1.34
Bruce Rock	8.73	3.96	-3.39	.35	-2.13	-2.00
Carnamah	-1.16	-3.90	-6.60	-4.39	-5.84	-3.92
Chapman	-1.66	-2.76	-6.83	-3.47	-4.56	-.52
Coorow	-2.98	-3.85	-9.07	-5.11	-8.18	-4.87
Corrigin	6.86	4.35	0.85	4.33	1.13	-.23
Cunderdin	-.60	-2.26	-4.35	-1.32	-3.42	-2.09
Dalwallinu	.10	-3.51	-8.51	-3.31	-8.44	-3.87
Dumbleyung	1.65	-2.06	-5.93	.76	-3.53	-.84
Esperance	-4.29	-3.39	-4.82	-5.93	-6.96	-1.63
Goomaling	-2.08	-3.42	-7.03	-4.86	-5.69	-2.76
Irwin	-2.55	-3.80	-8.92	-4.10	-5.86	-2.42
Jerramungup	2.83	-2.41	-12.94	-4.27	-8.15	-3.84
Katanning	10.59	3.65	-6.56	9.82	.76	-2.72
Kellerberin	-2.81	-4.44	-8.33	-3.93	-6.15	-4.97
Kent	-4.08	-4.36	-10.64	-6.22	-7.19	-4.89
Kondinin	.98	-.92	-4.58	.57	-3.22	-1.53
Koorda	2.68	-1.60	-4.04	-1.64	-5.11	-1.26
Kulin	2.31	-.54	-2.64	-1.03	-3.85	-1.29

Lake Grace	-2.36	-2.92	-7.60	-2.88	-6.31	-.52
Merredin	-1.74	-.95	-3.70	-5.67	-3.24	-2.21
Moora	-2.97	-3.71	-11.38	-4.69	-6.09	-5.00
Morawa	-3.03	-3.30	-4.74	-6.33	-7.18	-1.55
Mount Marshal	-4.65	-4.39	-4.14	-6.35	-8.22	-.99
Munkindubin	-.52	-3.41	-3.95	-4.55	-6.92	-1.07
Narembeen	.32	-.86	-4.36	-1.56	-2.68	-1.87
Narrogin	-3.38	-4.13	-7.76	-5.43	-6.29	-1.63
Northam	6.60	1.54	-2.40	4.98	-1.23	-1.39
Northampton	-1.58	-2.68	-8.85	-3.39	-4.40	-3.70
Nungarin	-.29	-2.08	-2.42	-3.81	-3.90	-2.72
Pingelly	-2.80	-3.92	-7.37	-4.49	-6.65	-2.98
Quairading	14.80	6.68	-1.68	13.22	4.77	-.99
Ravensthorpe	.89	-1.68	-7.81	-4.35	-7.06	-6.04
Tammin	-.68	1.04	-7.79	-1.40	-2.76	-3.03
Trayning	1.59	-1.89	-5.45	-5.74	-4.97	-4.72
Westonia	-.05	-1.06	-3.71	-4.12	-4.99	-3.22
Wickepin	-.92	-.64	-7.84	-3.12	-3.05	-1.43
Yilgarn	-3.47	-6.04	-4.66	-1.88	-7.55	-2.47
York	8.78	6.99	-2.33	9.42	1.89	-.63
Descriptive and One-sample t-test statistics for changes in CTE for all shires						
All Mean	0.56	-0.59	-3.98	-2.24	-3.61	-0.86
Minimum	-10.83	-8.74	-14.04	-10.67	-9.68	-6.04
Maximum	20.78	12.98	3.89	16.21	9.45	5.22
SD	5.17	3.87	4.16	5.40	3.70	2.77
t	0.85	-1.22	-7.60	-3.29	-7.74	-2.46
Descriptive and One-sample t-test statistics for changes in CTE for each shire						
QLD t	0.12	0.74	-2.04	-2.40	-2.52	3.87
Mean (SD)	0.16(6.17)	0.72(4.68)	-2.70(6.34)	-3.19(6.38)	-2.30(4.37)	1.88(2.33)
WA t	1.09	-2.72	-3.18	-2.25	-8.99	-10.35
Mean (SD)	0.79(4.57)	-1.35(3.14)	-2.06(4.09)	-1.69(4.75)	-4.37(3.07)	-2.43(1.49)

Appendix 5: Hedging efficiency using Conditional Tail Expectations – 60mm capped equally weighted

Shires	Constant Price			Variable Price		
	Δ^{5th} (%)	Δ^{10th} (%)	Δ^{30th} (%)	Δ^{5th} (%)	Δ^{10th} (%)	Δ^{30th} (%)
Balonne	-11.83	-9.67	2.59	-11.65	-6.09	4.31
Banana	.40	-2.90	-2.42	-6.78	-7.79	.92
Bauhinia	1.30	1.94	-3.39	-4.73	-4.01	1.91
Bendemere	10.07	12.43	3.80	8.27	8.81	5.33
Booringa	-2.43	-2.50	1.34	-6.53	.67	1.70
Bungil	-6.95	-1.73	2.53	-9.33	-8.11	4.89
Cambooya	2.89	1.23	-2.49	-.09	-.03	.94
Clifton	4.11	4.53	-2.56	-1.28	-2.31	.30
Duaringa	-.92	.79	-3.53	-2.01	-.51	2.60
Emerald	-.78	-2.41	.83	-.72	-.16	4.91
Gayndah	-.45	4.64	2.29	-8.98	-6.17	.84
Inglewood	-2.88	-1.45	-1.94	-3.85	-4.94	1.18
Jondarayan	-.78	-2.41	.83	-.72	-.16	4.91
Kilkivan	-2.80	-6.60	-11.58	-4.47	-6.58	-5.42
Kingaroy	-.58	2.74	1.86	-9.35	-3.43	1.69
Millmerran	2.96	2.50	-2.79	-2.01	-1.24	1.19
Munduberra	-2.38	-3.36	1.31	-6.16	-9.35	2.49
Pittsworth	-4.29	-.92	-2.24	-2.90	-2.52	1.40
Rosalie	14.93	8.38	-3.28	12.13	6.60	2.15
Tara	-1.67	2.62	3.05	-6.07	4.43	3.06
Waggamba	5.25	2.65	3.35	7.36	3.08	5.08
Waroo	-1.67	2.62	3.05	-6.07	4.43	3.06
Wondai	-.44	1.67	.53	1.06	.33	1.21
Boddington	4.10	1.24	-6.01	2.61	-1.97	-2.21
Broomehill	8.25	3.27	-5.18	5.86	.30	-1.33
Bruce Rock	8.73	3.90	-3.33	.35	-2.22	-2.01
Carnamah	-1.38	-3.98	-6.44	-4.71	-5.95	-3.96
Chapman	-1.96	-2.11	-6.85	-3.94	-4.21	-.63
Coorow	-3.14	-3.49	-9.44	-5.34	-7.69	-4.96
Corrigin	6.90	4.41	.69	4.32	.57	-.05
Cunderdin	-.60	-2.27	-4.03	-1.32	-3.45	-1.99
Dalwallinu	-.03	-3.53	-8.31	-3.82	-8.47	-4.04
Dumbleyung	1.47	-1.71	-5.68	.48	-3.81	-.05
Esperance	-4.27	-3.29	-4.24	-5.89	-6.79	-1.96
Goomaling	-2.12	-3.72	-7.92	-4.93	-6.14	-2.71
Irwin	-2.67	-3.30	-7.94	-4.29	-5.10	-2.16
Jerramungup	2.14	-3.09	-13.18	-5.26	-9.11	-3.92
Katanning	9.29	3.33	-6.41	9.82	.31	-2.70
Kellerberin	-3.21	-4.25	-8.16	-4.48	-5.88	-5.00
Kent	-2.44	-5.93	-9.04	-3.72	-8.19	-3.68
Kondinin	1.38	-.99	-4.54	.49	-3.32	-1.53
Koorda	2.01	-1.82	-4.01	-2.54	-5.40	-1.13
Kulin	2.30	-.75	-2.73	-1.04	-4.13	-1.12

Lake Grace		-1.97	-2.97	-7.53	-2.30	-6.38	-.58
Merredin		-1.74	-.62	-3.46	-5.67	-3.34	-2.01
Moora		-2.25	-2.30	-11.31	-3.55	-3.97	-5.02
Morawa		-3.03	-3.40	-4.36	-6.33	-7.32	-1.58
Mount Marshal		-3.92	-4.21	-4.30	-5.35	-7.99	-.67
Munkindubin		-.57	-3.31	-3.95	-4.61	-6.79	-1.09
Narembeen		.55	-.71	-4.54	-1.22	-2.47	-1.82
Narrogin		-3.38	-4.01	-6.56	-5.43	-6.11	-1.28
Northam		6.47	1.86	-2.67	4.80	-.18	-1.09
Northampton		-1.51	-1.78	-7.44	-3.28	-3.68	-3.16
Nungarin		-.24	-3.05	-2.38	-3.74	-3.62	-2.79
Pingelly		-2.80	-3.53	-7.48	-4.49	-6.06	-2.58
Quairading		15.05	6.85	-1.92	13.55	5.31	-.66
Ravensthorpe		1.21	-1.20	-7.25	-3.88	-6.95	-5.73
Tammin		-.68	.92	-7.97	-1.40	-3.07	-3.00
Trayning		2.73	-.67	-4.81	-4.16	-3.35	-4.68
Westonia		-.33	-1.96	-4.16	-4.52	-6.18	-3.29
Wickepin		-.90	-1.13	-7.80	-3.08	-3.31	-1.07
Yilgarn		-1.96	-6.27	-4.92	-5.29	-7.85	-2.63
York		10.10	5.67	-2.33	9.43	-.06	.08
Descriptive and One-sample t-test statistics for changes in CTE for all shires							
All	**Mean**	0.58	-0.62	-3.79	-2.11	-3.32	-0.65
	Minimum	-11.83	-9.67	-13.18	-11.65	-9.35	-5.73
	Maximum	15.05	12.43	3.80	13.55	8.81	5.33
	SD	4.80	3.82	3.97	5.16	4.00	2.85
	t	0.96	-1.29	-7.57	-3.24	-6.58	-1.82
Descriptive and One-sample t-test statistics for changes in CTE for each shire							
QLD	**t**	0.04	0.64(4.68)	0.38(3.51)	-2.82(5.86)	-1.52(4.84)	2.20(2.31)
	Mean (SD)	0.05(5.35)	-2.78	-13.39	-2.27	-9.05	-9.54
WA	**t**	1.25	-1.35(3.07)	-5.75(2.72)	-1.70(4.73)	-4.35(3.04)	-2.29(1.52)
	Mean (SD)	0.89(4.49)	0.64(4.68)	0.38(3.51)	-2.82(5.86)	-1.52(4.84)	2.20(2.31)

Appendix 6: Hedging efficiency using Conditional Tail Expectations – 50 mm capped optimized

Shires	Constant Price			Variable Price		
	Δ^{5th} (%)	Δ^{10th} (%)	Δ^{30th} (%)	Δ^{5th} (%)	Δ^{10th} (%)	Δ^{30th} (%)
Balonne	11.80	16.53	5.37	5.61	15.19	6.19
Banana	8.93	7.01	-0.95	0.77	1.90	2.39
Bauhinia	2.07	4.37	-0.48	3.48	-0.28	4.58
Bendemere	20.39	12.63	4.29	15.76	8.36	4.97
Booringa	4.20	2.14	2.78	-0.98	-0.88	2.03
Bungil	0.29	5.45	4.23	-7.28	-0.50	4.19
Cambooya	5.99	2.76	-1.74	-0.88	0.96	2.09
Clifton	3.73	2.86	0.34	-1.64	-4.88	3.34
Duaringa	2.57	-0.61	-2.74	-4.64	-3.35	1.16
Emerald	0.93	-1.49	0.35	1.63	-1.09	3.90
Gayndah	5.20	7.59	3.93	-0.67	2.55	2.85
Inglewood	3.22	2.24	0.58	-4.49	-2.77	2.04
Jondarayan	-1.97	-1.34	-0.42	-5.40	-5.87	2.30
Kilkivan	-3.09	-3.91	-6.76	-6.55	-8.15	-0.85
Kingaroy	4.91	6.02	3.08	3.78	6.07	4.75
Millmerran	4.07	1.34	0.74	-3.90	-4.38	1.28
Munduberra	0.62	1.16	2.07	-6.39	-2.45	2.03
Pittsworth	-4.34	0.39	-2.14	-6.20	-5.31	2.02
Rosalie	5.75	3.45	0.45	-0.19	0.62	3.63
Tara	2.89	4.77	4.56	-3.23	-2.52	4.28
Waggamba	10.74	4.93	3.90	11.77	0.14	4.46
Waroo	0.32	9.88	4.99	0.39	7.46	4.29
Wondai	0.21	0.78	1.59	-4.10	-0.79	2.99
Boddington	5.38	4.25	-4.18	4.44	0.97	-0.08
Broomehill	10.79	5.91	-5.10	-1.18	2.53	-1.01
Bruce Rock	10.03	5.91	-0.71	2.61	-0.30	0.16
Carnamah	-0.44	-2.31	-5.62	-4.10	-6.32	-4.53
Chapman	-1.51	-1.86	-6.85	-3.60	-3.84	-2.43
Coorow	-2.07	-4.01	-8.92	-4.71	-8.40	-6.45
Corrigin	7.03	4.22	-0.07	2.88	1.09	-0.90
Cunderdin	-0.58	-1.44	-2.38	-2.37	-2.92	0.10
Dalwallinu	-4.05	-3.01	-8.47	-5.73	-6.94	-6.60
Dumbleyung	0.70	-0.63	-4.47	-0.70	-1.98	-0.55
Esperance	-2.08	-2.63	-5.64	-4.64	-5.75	-2.62
Goomaling	-2.51	-4.15	-9.84	-5.17	-7.01	-3.44
Irwin	-2.26	-4.46	-10.69	-3.63	-6.75	-1.40
Jerramungup	4.79	-0.11	-5.65	-6.21	-7.81	-4.57
Katanning	6.94	4.65	-7.42	6.76	-0.20	-1.31
Kellerberin	0.73	1.18	-4.10	-5.29	-4.12	-2.55
Kent	-1.71	-0.51	-5.47	-3.92	-4.10	-2.68
Kondinin	0.25	-0.30	-4.20	-2.46	-3.29	-1.28
Koorda	2.42	0.42	-1.48	-6.09	-3.01	-0.61
Kulin	2.19	0.76	-3.21	-1.19	-3.98	-0.92

Lake Grace	1.12	-2.15	-7.71	-4.24	-5.25	-1.20
Merredin	1.99	-0.14	-1.97	-5.67	-4.87	-1.90
Moora	-4.37	-6.48	-12.03	-6.40	-9.56	-5.59
Morawa	-4.38	-5.80	-7.80	-7.36	-9.69	-3.45
Mount Marshal	-3.47	-5.62	-8.52	-6.47	-7.21	-2.26
Munkindubin	-2.22	-1.06	-4.47	-6.10	-4.52	-3.10
Narembeen	1.35	-0.50	-2.58	-0.09	-3.18	-1.99
Narrogin	-4.72	-7.25	-14.91	-6.75	-8.07	-2.58
Northam	7.53	2.33	-4.84	6.26	-1.89	-0.38
Northampton	-2.24	-2.92	-10.58	-4.14	-5.67	-5.66
Nungarin	0.66	-2.16	-4.25	-7.43	-8.96	-4.30
Pingelly	-2.86	-2.59	-9.69	-4.79	-4.20	-1.47
Quairading	20.08	11.18	-0.13	18.03	9.20	0.11
Ravensthorpe	-0.47	-1.63	-10.17	-5.61	-6.65	-6.16
Tammin	-0.98	-1.59	-7.38	-1.07	-5.00	-2.63
Trayning	-1.99	-5.01	-6.03	-5.39	-8.04	-4.61
Westonia	-3.27	-0.44	-2.70	-6.48	-5.70	-4.17
Wickepin	0.18	-2.54	-9.78	-3.52	-7.55	-3.46
Yilgarn	-2.19	-2.26	-2.69	-5.61	-5.77	-4.90
York	8.97	3.62	-1.28	8.05	-0.76	0.95
Descriptive and One-sample t-test statistics for changes in CTE for all shires						
All Mean	2.10	.92	-3.27	-1.78	-2.78	-.50
Minimum	-4.72	-7.25	-14.91	-7.43	-9.69	-6.60
Maximum	20.39	16.53	5.37	18.03	15.19	6.19
SD	5.36	4.68	4.76	5.45	4.81	3.31
t	3.11	1.56	-5.45	-2.60	-4.60	-1.20
Descriptive and One-sample t-test statistics for changes in CTE for each shire						
QLD t	3.47	3.95	1.96	-.48	.00	9.44
Mean (SD)	3.89(5.37)	3.87(4.70)	1.22(2.98)	-0.58(5.78)	0.00(5.27)	3.08(1.57)
WA t	1.31	-1.30	-10.530	-3.01	-7.44	-8.04
Mean (SD)	1.07(5.15)	-0.78(3.78)	-5.85(3.51)	-2.48(5.21)	-4.39(3.73)	-2.56(2.01)

Appendix 7: Hedging efficiency using Mean Root Square Loss analyses – uncapped optimized

Shires	Constant Price			Variable Price		
	Δ^{5th} (%)	Δ^{10th} (%)	Δ^{30th} (%)	Δ^{5th} (%)	Δ^{10th} (%)	Δ^{30th} (%)
Balonne	-8.02	-9.93	-29.95	-7.42	-9.34	-26.08
Banana	-2.68	-.20	-5.65	4.89	12.32	7.12
Bauhinia	-8.51	-6.20	-12.05	1.02	2.46	.29
Bendemere	-13.44	-17.85	-37.75	-10.81	-14.66	-16.24
Booringa	.13	-2.49	-6.19	1.65	3.97	-1.18
Bungil	-3.43	-8.64	-18.73	1.35	-1.25	-13.03
Cambooya	-8.10	-3.35	-7.35	1.82	3.26	6.69
Clifton	-5.19	-12.66	-18.02	7.71	5.50	.86
Duaringa	6.46	8.48	21.94	3.85	5.50	37.11
Emerald	.21	10.17	18.50	.83	5.51	5.67
Gayndah	-5.77	-11.65	-22.53	.21	-2.20	-6.66
Inglewood	-2.04	-6.83	-6.57	5.45	3.44	-.79
Jondarayan	3.82	10.86	11.69	12.72	15.95	17.57
Kilkivan	22.42	28.87	45.07	15.02	21.90	15.90
Kingaroy	-3.44	-7.84	-19.58	3.71	-2.88	-13.97
Millmerran	-4.31	-8.46	-5.61	9.65	10.78	-.80
Munduberra	2.51	3.66	-.70	10.52	5.21	-18.22
Pittsworth	1.24	6.20	-.63	5.94	7.95	7.92
Rosalie	-4.45	-10.47	-9.42	3.08	-4.71	-8.80
Tara	-7.20	-8.60	-5.56	-1.51	-1.49	1.17
Waggamba	-8.04	-10.93	-18.07	-6.90	-6.84	-3.06
Waroo	-4.48	-9.23	-17.95	-3.19	-4.15	-12.78
Wondai	-2.49	-2.50	-10.35	5.67	6.37	-3.64
Boddington	-23.21	-35.57	-27.15	-5.67	-7.48	-3.51
Broomehill	-13.23	-31.37	-19.42	1.61	-5.11	7.77
Bruce Rock	-17.02	-20.91	-22.60	-.96	1.24	16.81
Carnamah	7.36	13.46	36.59	7.75	16.33	35.50
Chapman	50.29	109.01	268.21	8.78	19.89	35.76
Coorow	14.39	53.02	98.28	14.00	32.17	60.50
Corrigin	-11.67	-15.34	-33.77	-7.11	-.44	3.82
Cunderdin	21.07	19.24	29.43	5.78	5.95	15.06
Dalwallinu	17.46	15.24	79.43	11.25	12.09	57.48
Dumbleyung	2.96	1.57	21.80	3.22	6.33	10.58
Esperance	15.76	24.66	70.66	8.94	16.01	29.07
Goomaling	141.31	184.85	472.94	12.12	16.67	37.61
Irwin	117.56	155.06	600.05	6.91	10.37	39.28
Jerramungup	-15.07	-8.77	43.11	13.61	18.33	38.28
Katanning	-.34	-29.60	8.38	5.26	-1.24	21.40
Kellerberin	4.84	-16.26	5.70	14.98	10.41	25.49
Kent	43.06	43.55	122.63	10.92	14.24	28.47
Kondinin	9.29	2.70	27.49	8.59	11.10	25.12
Koorda	-3.71	-2.15	14.17	9.47	10.44	27.57
Kulin	.61	-3.66	-2.89	6.53	8.46	13.29

Lake Grace	-2.81	38.50	99.17	8.37	16.74	24.08
Merredin	.43	-2.11	15.65	14.47	16.63	39.25
Moora	120.54	157.03	293.46	16.04	20.31	30.43
Morawa	6.91	21.31	37.31	11.04	24.76	40.88
Mount Marshal	11.24	25.04	68.87	9.61	10.77	36.71
Munkindubin	5.88	1.97	15.07	13.93	11.34	36.11
Narembeen	5.74	3.28	5.89	5.59	9.72	19.47
Narrogin	229.75	447.64	889.43	15.80	30.63	49.01
Northam	-19.97	-12.16	-5.98	-3.73	3.63	10.31
Northampton	99.18	168.88	425.42	11.11	19.09	35.45
Nungarin	-1.78	1.40	13.77	11.73	21.94	31.91
Pingelly	40.35	67.77	180.12	5.72	6.89	18.85
Quairading	-29.64	-39.46	-37.99	-14.08	-14.30	-49.56
Ravensthorpe	-1.50	7.81	88.55	10.04	16.63	40.98
Tammin	4.40	-3.46	8.14	2.79	9.79	18.80
Trayning	5.18	16.42	28.42	13.76	17.12	26.32
Westonia	15.84	22.10	39.72	14.72	21.14	44.07
Wickepin	36.84	86.63	161.23	10.62	22.75	30.71
Yilgarn	15.70	16.47	37.03	11.39	15.43	36.32
York	-30.45	-26.89	-22.10	-10.41	-4.08	-.64
Descriptive and One-sample t-test statistics for changes in MRSL for all shires						
All Mean	13.00	22.02	63.15	5.71	8.50	-22.52
Minimum	-30.45	-39.46	-37.99	-14.08	-14.66	-56.76
Maximum	229.75	447.64	889.43	16.04	32.17	23.47
SD	43.00	72.31	160.83	7.21	10.30	19.49
t	2.40	2.42	3.12	6.29	6.55	-9.17
Descriptive and One-sample t-test statistics for changes in MRSL for each shire						
QLD t	-1.62	-1.39	-1.81	2.17	1.58	-2.60
Mean (SD)	-2.38(7.06)	-3.03(10.41)	-6.76(17.90)	2.84(6.27)	2.72(8.27)	-10.06(18.58)
WA t	2.66	2.63	3.43	6.41	7.51	-11.54
Mean (SD)	21.84(51.89)	36.42(87.57)	103.36(190.79)	7.36(7.26)	11.82(9.96)	-29.68(16.27)

Appendix 8: Hedging efficiency using Mean Root Square Loss analyses – uncapped equally weighted

Shires	Constant Price			Variable Price		
	Δ5th (%)	Δ10th (%)	Δ30th (%)	Δ^{5th} (%)	Δ^{10th} (%)	Δ^{30th} (%)
Balonne	2.01	2.80	-8.93	4.47	4.47	-10.25
Banana	1.96	6.70	-1.71	10.17	15.56	10.58
Bauhinia	-.77	-2.60	6.13	6.55	5.61	12.66
Bendemere	-13.43	-16.31	-28.58	-11.97	-14.75	-16.92
Booringa	4.82	1.09	3.68	3.85	2.80	-2.00
Bungil	7.59	3.67	-11.10	8.88	5.61	-11.63
Cambooya	-4.44	-.99	6.39	2.72	2.59	10.10
Clifton	-11.41	-12.68	3.66	-1.28	7.19	4.81
Duaringa	10.43	9.15	27.10	2.88	4.61	31.09
Emerald	-1.81	2.38	21.06	-.15	-2.24	10.86
Gayndah	-.34	-11.33	.48	7.14	2.63	-1.89
Inglewood	11.86	8.27	20.34	12.45	11.86	11.20
Jondarayan	-.05	.08	21.38	9.56	5.98	20.38
Kilkivan	18.49	43.39	82.27	12.79	19.18	19.91
Kingaroy	-2.30	-4.11	-7.03	4.95	2.83	-11.12
Millmerran	-3.66	-10.69	20.90	2.25	9.38	20.49
Munduberra	6.96	16.82	25.38	11.58	20.72	-.49
Pittsworth	5.47	3.20	12.68	3.60	5.93	19.97
Rosalie	-5.64	-8.28	.81	-6.83	-10.79	1.22
Tara	-.53	-2.06	-6.12	1.70	-1.62	-10.58
Waggamba	-5.92	-4.29	-3.39	-2.72	-1.74	.16
Waroo	2.45	3.75	-.82	3.68	4.58	-.14
Wondai	-2.81	-5.53	6.11	4.49	.89	-4.04
Boddington	-10.99	-7.79	15.17	.48	1.70	15.26
Broomehill	-14.98	-17.16	1.07	-3.30	-2.07	10.29
Bruce Rock	-12.91	-15.65	-7.14	2.50	5.77	26.53
Carnamah	11.71	30.05	55.88	9.42	17.18	40.52
Chapman	47.37	79.44	231.25	5.54	9.91	27.06
Coorow	21.57	37.88	101.43	13.84	27.02	60.70
Corrigin	-11.67	-17.68	-29.76	-7.11	-1.75	3.00
Cunderdin	15.74	28.91	65.41	3.38	8.15	21.86
Dalwallinu	4.95	27.98	79.22	7.89	24.98	57.53
Dumbleyung	-7.23	14.97	51.51	-.16	5.22	23.02
Esperance	31.46	30.18	53.95	13.34	14.74	17.91
Goomaling	104.27	157.89	334.21	9.44	14.48	27.42
Irwin	110.15	167.52	497.34	7.78	13.29	30.48
Jerramungup	-11.00	11.29	128.22	10.79	20.80	57.45
Katanning	-33.34	-29.46	6.93	-12.39	-7.12	17.80
Kellerberin	15.20	29.58	48.39	10.96	19.37	48.23
Kent	65.79	76.95	224.73	14.76	18.67	41.22

Kondinin	1.87	6.97	29.64	-.50	10.57	26.65
Koorda	.32	7.84	22.18	1.95	15.52	27.55
Kulin	-.01	2.51	-3.55	6.14	7.04	16.76
Lake Grace	24.42	42.26	98.65	5.26	13.79	25.19
Merredin	15.86	2.83	30.74	13.57	13.48	41.66
Moora	100.82	146.45	488.46	10.38	15.73	51.52
Morawa	21.81	21.45	42.65	14.56	19.07	33.83
Mount Marshal	25.35	31.59	46.73	14.45	21.25	18.52
Munkindubin	2.25	21.33	18.03	11.15	22.10	34.87
Narembeen	9.01	6.02	29.34	7.32	8.04	32.88
Narrogin	200.75	251.78	515.95	12.05	14.71	26.14
Northam	-17.43	-15.54	-18.93	-1.92	-.27	5.07
Northampton	66.21	117.22	400.94	7.50	9.28	33.86
Nungarin	4.43	10.99	20.25	4.66	12.73	38.40
Pingelly	65.11	116.62	216.81	9.40	16.48	28.14
Quairading	-26.78	-28.59	-33.96	-12.08	-10.54	-4.31
Ravensthorpe	1.29	21.98	94.00	11.01	18.88	45.20
Tammin	11.74	-8.99	44.17	5.86	5.97	39.91
Trayning	2.11	16.25	63.51	12.26	15.11	35.57
Westonia	2.45	12.89	34.82	7.58	15.12	37.80
Wickepin	24.12	17.53	136.98	4.48	5.54	27.41
Yilgarn	21.36	53.67	63.36	7.55	23.40	42.75
York	-30.06	-39.42	-19.06	-10.59	-10.72	2.52
Descriptive and One-sample t-test statistics for changes in MRSL for all shires						
All Mean	13.84	22.90	69.37	5.08	8.79	20.61
Minimum	-33.34	-39.42	-33.96	-12.39	-14.75	-16.92
Maximum	200.75	251.78	515.95	14.76	27.02	60.70
SD	37.46	51.78	126.47	6.82	9.41	18.81
t	2.93	3.51	4.35	5.91	7.41	8.70
Descriptive and One-sample t-test statistics for changes in MRSL for each shire						
QLD t	0.54	0.39	1.89	3.16	2.61	1.71
Mean (SD)	0.82(7.31)	0.98(12.08)	8.29(21.04)	3.95(6.00)	4.40(8.10)	4.54(12.71)
WA t	2.98	3.68	4.48	5.00	7.72	12.40
Mean (SD)	21.334(45.20)	35.51(61.10)	104.49(147.35)	5.73(7.25)	11.32(9.27)	29.85(15.22)

Appendix 9: Hedging efficiency using Mean Root Square Loss analyses – 60 mm capped equally weighted

Shires	Constant Price			Variable Price		
	Δ^{5th} (%)	Δ^{10th} (%)	Δ^{30th} (%)	Δ^{5th} (%)	Δ^{10th} (%)	Δ^{30th} (%)
Balonne	2.41	3.20	-5.88	4.99	4.76	-5.77
Banana	.71	8.11	-.75	8.73	17.15	14.00
Bauhinia	-.77	-1.35	8.05	6.63	7.15	16.24
Bendemere	-7.12	-15.09	-24.99	-6.83	-13.93	-16.91
Booringa	6.51	5.52	.77	5.17	1.78	-2.94
Bungil	6.32	1.07	-5.47	7.67	7.44	-8.28
Cambooya	-3.21	-3.74	4.33	.90	.60	11.05
Clifton	-10.57	-14.39	2.30	-.45	5.48	7.51
Duaringa	2.68	-1.39	19.44	6.72	5.39	22.80
Emerald	2.24	6.86	19.60	3.26	-.63	9.88
Gayndah	-.33	-6.36	-5.60	7.14	5.56	-2.77
Inglewood	5.96	4.24	19.89	6.83	9.77	8.36
Jondarayan	1.43	-.25	19.67	11.86	7.09	19.14
Kilkivan	12.22	34.90	63.31	8.27	14.70	16.64
Kingaroy	-2.04	-2.05	-2.92	5.24	4.79	-6.59
Millmerran	-4.00	-7.61	16.11	2.64	4.34	14.85
Munduberra	6.96	16.82	25.38	11.58	20.72	-.49
Pittsworth	6.47	4.99	11.61	4.78	4.76	18.54
Rosalie	-12.24	-12.70	6.02	-8.66	-9.11	7.12
Tara	-.32	-3.68	-6.83	2.16	-3.86	-9.84
Waggamba	-6.14	-5.36	-4.86	-3.00	-6.02	-1.55
Waroo	3.58	2.91	1.88	5.00	4.81	1.78
Wondai	.08	-4.67	9.04	1.16	-2.39	3.69
Boddington	-12.50	-10.02	8.27	-.41	1.05	12.71
Broomehill	-14.98	-16.79	1.38	-3.30	-1.78	10.39
Bruce Rock	-12.91	-15.38	-7.00	2.50	5.99	26.76
Carnamah	13.58	30.93	54.27	10.35	17.64	39.10
Chapman	56.41	63.89	231.85	5.73	9.20	28.23
Coorow	23.18	34.44	103.25	14.62	25.23	61.41
Corrigin	-11.71	-17.44	-31.33	-7.13	-.44	2.62
Cunderdin	15.74	29.16	59.23	3.38	8.23	20.75
Dalwallinu	3.15	28.06	76.15	9.42	24.97	56.33
Dumbleyung	-5.43	13.88	46.99	.40	6.24	21.06
Esperance	31.22	30.27	43.52	13.24	14.57	21.52
Goomaling	106.38	173.70	379.77	9.63	15.80	30.90
Irwin	115.67	142.84	437.92	8.27	11.17	26.80
Jerramungup	-6.17	18.07	132.14	13.32	23.41	58.96
Katanning	-31.46	-28.14	5.53	-12.33	-6.02	18.53
Kellerberin	17.51	28.15	46.70	12.55	18.50	47.79
Kent	35.92	106.67	188.74	9.65	20.08	33.05
Kondinin	.80	7.51	30.30	-.72	10.83	25.27
Koorda	4.01	9.22	22.71	4.45	16.41	28.69
Kulin	.03	3.70	-3.75	6.17	7.71	16.22

Lake Grace	19.94	43.01	98.03	3.88	13.99	24.81
Merredin	15.86	.99	26.36	13.57	12.99	37.49
Moora	70.29	85.10	484.61	7.07	9.36	50.93
Morawa	22.44	23.38	34.48	18.57	25.04	34.52
Mount Marshal	20.45	30.33	58.73	11.75	20.55	19.36
Munkindubin	2.52	20.68	18.10	11.36	21.64	34.95
Narembeen	7.29	4.77	29.61	6.42	8.01	33.48
Narrogin	200.86	243.57	442.78	12.05	14.23	23.41
Northam	-16.90	-17.44	-19.35	-1.56	-1.46	4.38
Northampton	62.92	83.71	331.99	7.18	7.72	29.21
Nungarin	4.18	17.10	21.01	4.48	11.94	38.72
Pingelly	65.06	105.03	219.04	9.40	14.71	27.95
Quairading	-27.12	-29.04	-34.24	-12.59	-11.49	4.07
Ravensthorpe	-2.59	17.78	85.50	9.66	18.53	42.99
Tammin	11.74	-9.18	45.82	5.86	6.38	40.64
Trayning	-6.58	6.06	55.03	7.94	10.31	37.10
Westonia	4.49	19.76	43.29	8.59	18.56	41.11
Wickepin	23.66	23.16	135.13	4.38	5.70	27.67
Yilgarn	16.21	55.82	66.11	11.62	24.36	43.90
York	-31.13	-35.01	-17.69	-11.67	-6.61	3.80
Descriptive and One-sample t-test statistics for changes in MRSL for all shires						
All Mean	12.74	21.15	65.41	5.07	8.63	20.70
Minimum	-31.46	-35.01	-34.24	-12.59	-13.93	-16.91
Maximum	200.86	243.57	484.61	18.57	25.23	61.41
SD	36.34	48.15	117.58	6.66	9.42	17.90
t	2.78	3.49	4.42	6.05	7.23	9.18
Descriptive and One-sample t-test statistics for changes in MRSL for each shire						
QLD t	.382	.20	2.09	3.73	2.38	2.52
Mean (SD)	0.47(5.9)	0.43(10.62)	7.40(16.98)	3.99(5.14)	3.93(7.91)	5.06
WA t	2.84	3.68	4.57	4.88	7.76	12.76
Mean (SD)	19.80(44.04)	33.06(56.78)	98.77(136.71)	5.69(7.38)	11.33(9.23)	29.69(14.72)

Appendix 10: Hedging efficiency using Mean Root Square Loss analyses – 50 mm capped optimized

Shires	Constant Price			Variable Price		
	Δ^{5th} (%)	Δ^{10th} (%)	Δ^{30th} (%)	Δ^{5th} (%)	Δ^{10th} (%)	Δ^{30th} (%)
Balonne	-8.02	-9.80	-29.95	-7.42	-8.72	-25.55
Banana	-11.36	-15.58	-0.85	1.18	-6.31	10.25
Bauhinia	-2.89	-5.34	-11.85	-1.34	-1.35	1.78
Bendemere	-13.39	-15.59	-34.12	-11.32	-12.43	-15.20
Booringa	-2.21	-3.48	-1.18	-0.16	1.21	-0.75
Bungil	-2.13	-8.24	-20.32	4.62	1.19	-10.56
Cambooya	-8.07	-8.35	-6.03	1.85	-0.50	6.37
Clifton	-9.69	-9.42	-20.08	1.47	10.48	-0.59
Duaringa	-7.53	5.76	19.80	9.65	11.23	34.85
Emerald	-1.95	3.03	23.53	-4.73	-0.27	12.84
Gayndah	-5.73	-13.13	-24.19	0.39	-3.58	-7.72
Inglewood	-3.31	-7.22	-6.19	5.23	2.79	0.87
Jondarayan	4.23	5.99	7.29	13.14	17.53	13.48
Kilkivan	22.42	28.87	45.07	15.02	21.90	15.90
Kingaroy	-5.76	-7.60	-20.71	-2.19	-6.69	-16.65
Millmerran	-4.03	-6.85	-7.40	9.95	13.30	-2.21
Munduberra	2.16	-0.93	-1.26	10.28	5.10	-3.69
Pittsworth	3.39	2.25	0.90	8.54	9.32	-0.47
Rosalie	-3.88	-5.19	-6.19	-0.84	-1.01	-8.78
Tara	-4.41	-8.41	-8.48	0.85	0.14	-2.67
Waggamba	-9.41	-6.63	-20.43	-8.49	-1.84	-6.15
Waroo	-0.09	-10.06	-20.96	-0.01	-5.60	-15.98
Wondai	-2.25	-2.87	-7.09	5.16	-0.27	-1.08
Boddington	-17.21	-26.79	-16.82	-3.28	-3.66	-0.41
Broomehill	-13.23	-31.31	-19.23	1.61	-5.07	7.81
Bruce Rock	-15.91	-23.74	-23.14	0.25	0.38	14.85
Carnamah	8.02	18.16	43.47	12.35	18.55	37.89
Chapman	46.47	55.70	231.21	8.20	10.22	31.14
Coorow	16.33	39.69	94.89	12.51	27.82	62.70
Corrigin	-11.47	-18.84	-33.31	-6.35	-0.10	4.28
Cunderdin	18.55	18.50	27.38	5.06	6.17	16.01
Dalwallinu	23.46	24.46	77.35	16.33	19.49	57.21
Dumbleyung	2.50	0.72	29.95	3.07	4.42	11.19
Esperance	17.74	21.90	48.96	9.82	12.25	33.32
Goomaling	117.43	201.66	482.32	10.08	18.05	37.70
Irwin	99.01	202.19	599.53	8.82	16.29	43.42
Jerramungup	-15.07	-7.06	28.24	13.61	18.97	33.71
Katanning	-23.29	-34.52	6.91	-6.13	-4.31	22.66
Kellerberin	4.70	-12.27	6.66	14.89	12.52	26.04
Kent	24.58	13.74	91.65	7.00	9.92	22.51
Kondinin	9.29	2.79	27.85	8.59	11.00	23.53
Koorda	2.20	-2.87	5.23	13.56	9.28	21.25
Kulin	0.61	-3.93	0.94	6.53	8.74	14.65

Lake Grace	1.05	35.74	101.10	9.98	13.49	24.36
Merredin	0.43	-1.17	9.65	14.47	17.93	27.11
Moora	170.02	279.53	548.23	18.81	29.01	44.57
Morawa	32.04	41.25	65.29	17.40	26.33	38.88
Mount Marshal	23.98	39.93	83.84	14.38	19.62	42.51
Munkindubin	11.93	8.53	29.68	16.11	14.66	43.22
Narembeen	1.64	5.42	14.32	3.39	10.74	21.17
Narrogin	279.32	454.03	1028.97	13.59	22.44	48.22
Northam	-21.04	-18.11	-3.74	-4.50	-0.26	11.26
Northampton	106.49	149.78	484.55	9.58	14.95	36.20
Nungarin	6.10	13.49	23.07	15.02	27.00	40.93
Pingelly	75.61	77.34	296.16	9.21	9.26	28.59
Quairading	-35.23	-44.88	-41.95	-16.23	-17.25	-11.71
Ravensthorpe	18.17	22.03	143.88	14.65	18.04	47.73
Tammin	13.05	8.28	36.63	5.99	13.10	26.69
Trayning	17.95	43.36	55.23	11.30	25.49	36.75
Westonia	20.23	9.81	33.71	17.00	17.67	41.04
Wickepin	17.95	67.11	178.47	6.81	19.19	34.66
Yilgarn	18.17	21.63	38.86	12.53	17.80	40.94
York	-30.06	-26.33	-27.84	-10.12	-3.66	-2.81
Descriptive and One-sample t-test statistics for changes in MRSL for all shires						
All Mean	15.06	24.22	73.93	5.82	8.45	17.78
Minimum	-35.23	-44.88	-41.95	-16.23	-17.25	-25.55
Maximum	279.32	454.03	1028.97	18.81	29.01	62.70
SD	48.69	78.87	184.48	8.12	10.85	20.79
t	2.46	2.44	3.18	5.69	6.18	6.79
Descriptive and One-sample t-test statistics for changes in MRSL for each shire						
QLD t	-2.15	-2.20	-1.73	1.55	1.12	-.35
Mean (SD)	-3.21(7.17)	-4.30(9.35)	-6.55(18.12)	2.21(6.83)	1.98(8.52)	-.94(12.92)
WA t	2.76	2.70	3.47	6.13	7.42	11.04
Mean (SD)	25.56(58.56)	40.62(95.31)	120.20(218.86)	7.90(8.15)	12.16(10.37)	28.54(16.35)

Appendix 11: Hedging efficiency using Certainty Equivalence of Revenue –uncapped optimized

Shires	Constant Price			Variable Price		
	Δ^{5th} (%)	Δ^{10th} (%)	Δ^{30th} (%)	Δ^{5th} (%)	Δ^{10th} (%)	Δ^{30th} (%)
Balonne	2.43	3.03	8.88	2.40	2.84	7.38
Banana	.19	-.27	.35	-.23	-.95	.44
Bauhinia	1.05	.77	1.10	.20	.26	1.42
Bendemere	1.64	2.11	4.16	1.81	2.32	3.51
Booringa	.22	.48	1.40	-.08	-.40	1.01
Bungil	.58	1.27	2.93	-.04	.51	2.72
Cambooya	.26	.10	.12	.16	.23	.16
Clifton	.13	.38	.56	-.49	-.18	.78
Duaringa	-.25	-.35	-.57	.05	.11	-1.67
Emerald	.07	-.15	-.51	-.04	.07	.85
Gayndah	.53	1.00	1.93	.03	.55	1.77
Inglewood	.05	.22	.46	-.45	-.20	.60
Jondarayan	-.15	-.38	-.33	-.59	-.57	-.50
Kilkivan	-.71	-.82	-1.08	-1.27	-1.56	-.77
Kingaroy	.42	.80	2.00	-.26	.68	2.49
Millmerran	.13	.26	.41	-.49	-.60	.51
Munduberra	.00	.05	.59	-.64	.01	1.01
Pittsworth	-.08	-.30	-.25	-.15	-.15	.22
Rosalie	.48	1.55	1.38	-.25	1.45	1.90
Tara	.90	1.27	1.74	.51	.57	.57
Waggamba	1.62	2.05	3.28	1.50	1.59	1.58
Waroo	1.56	2.42	4.25	1.46	1.55	3.00
Wondai	.16	.22	.66	-.37	-.26	.87
Boddington	.26	.38	.33	.57	.58	.35
Broomehill	.21	.81	.37	-.03	.79	-.55
Bruce Rock	.40	.50	-.03	-.10	.01	-.81
Carnamah	-.27	-.30	-1.22	-.96	-1.37	-2.52
Chapman	-.36	-.68	-1.27	-.51	-1.54	-2.48
Coorow	-.33	-1.02	-2.32	-.67	-2.18	-3.95
Corrigin	.25	.30	.40	.57	.01	-.31
Cunderdin	-.31	-.31	-.32	-.09	-.07	-.51
Dalwallinu	-.71	-.80	-3.00	-1.21	-1.28	-4.03
Dumbleyung	-.25	-.29	-.39	-.01	-.31	-.83
Esperance	-.36	-.49	-1.09	-.71	-.97	-1.76
Goomaling	-.69	-.77	-1.82	-.61	-.98	-2.69
Irwin	-.45	-.53	-1.76	-.40	-.63	-2.41
Jerramungup	-.20	-.62	-1.97	-1.09	-1.54	-3.19
Katanning	-.19	.35	-.47	-.31	.47	-1.40
Kellerberin	-.37	-.21	-.39	-.97	-.76	-1.29
Kent	-.55	-.60	-1.34	-1.04	-1.20	-1.93
Kondinin	-.34	-.52	-1.48	-.81	-.83	-1.34
Koorda	-.02	-.06	-.71	-.74	-.62	-1.11
Kulin	-.21	-.20	-.60	-.68	-.69	-.95

Lake Grace	-.21	-.73	-1.09	-.46	-1.22	-1.21
Merredin	-.17	-.11	-.87	-.97	-1.03	-2.06
Moora	-.63	-.75	-.99	-1.30	-1.80	-2.20
Morawa	-.27	-.56	-1.97	-1.08	-1.61	-2.30
Mount Marshal	-.23	-.42	-1.27	-.36	-.33	-1.70
Munkindubin	-.20	-.16	-.94	-.64	-.54	-1.75
Narembeen	-.21	-.27	-.65	-.51	-.78	-1.16
Narrogin	-.88	-1.47	-2.44	-1.27	-2.31	-3.24
Northam	.34	-.01	-.21	.18	-.45	-.89
Northampton	-.47	-.64	-1.42	-.65	-1.41	-2.92
Nungarin	.02	-.92	-1.95	-.81	-1.39	-2.11
Pingelly	-.36	-.45	-.73	-.15	-.08	-.70
Quairading	1.40	1.69	.86	1.86	1.73	.90
Ravensthorpe	-.19	-.27	-1.74	-.88	-1.25	-3.24
Tammin	-.21	-.24	-.53	.04	-.46	-1.03
Trayning	-.23	-1.56	-2.05	-1.03	-1.32	-1.67
Westonia	-1.57	-1.85	-2.30	-1.38	-1.70	-3.26
Wickepin	-.59	-.96	-1.42	-1.04	-2.12	-2.46
Yilgarn	-.29	-.29	-1.25	-1.00	-1.23	-2.55
York	.69	.61	.47	1.09	.74	.60
Descriptive and One-sample t-test statistics for changes in CER for all shires						
All Mean	0.02	-0.01	-0.14	-0.31	-0.41	-0.64
Minimum	-1.57	-1.85	-3.00	-1.38	-2.31	-4.03
Maximum	2.43	3.03	8.88	2.40	2.84	7.38
SD	0.65	0.92	1.92	0.76	1.05	2.04
t	.21	-.06	-.59	-3.20	-3.08	-2.47
Descriptive and One-sample t-test statistics for changes in CER for each shire						
QLD t	3.18	3.24	3.21	.66	1.58	3.47
Mean (SD)	.49(.74)	.68(1.01)	1.45(2.18)	.12(.7)	.34(1.04)	1.30(1.79)
WA t	-3.01	-3.53	-7.37	-4.74	-5.72	-9.33
Mean (SD)	-.22(.46)	-..36(.66)	-1.04(.89)	-.50(.67)	-.79(.86)	-1.72(1.16)

Appendix 12: Hedging efficiency using Certainty Equivalence of Revenue – uncapped equally weighted

Shires	Constant Price			Variable Price		
	Δ^{5th} (%)	Δ^{10th} (%)	Δ^{30th} (%)	Δ^{5th} (%)	Δ^{10th} (%)	Δ^{30th} (%)
Balonne	-1.12	-1.72	3.22	-1.52	-1.91	3.68
Banana	-.36	-.81	-.24	-.55	-.86	-.12
Bauhinia	-.24	.12	-.99	-.33	-.31	-.62
Bendemere	1.60	1.88	3.45	1.84	2.29	3.54
Booringa	-.10	.16	.54	-.50	-.31	.75
Bungil	-.85	-.35	2.19	-1.51	-.81	3.05
Cambooya	.14	.06	-.39	-.03	.08	-.34
Clifton	.34	.34	-.30	.32	-.25	-.28
Duaringa	-.56	-.57	-1.12	.01	.10	-.90
Emerald	.18	.13	-.45	.30	.54	.15
Gayndah	.16	1.02	.58	-1.25	-.46	.45
Inglewood	-.50	-.37	-.61	-1.35	-1.27	-.44
Jondarayan	-.06	-.01	-.59	-.55	-.29	-.61
Kilkivan	-.53	-1.17	-1.75	-.97	-1.72	-1.55
Kingaroy	.31	.50	.77	-.44	-.07	1.50
Millmerran	.04	.28	-.68	.01	-.25	-.69
Munduberra	-.08	-.48	-.14	-1.04	-1.83	.54
Pittsworth	-.36	-.32	-.77	-.01	-.06	-.89
Rosalie	.97	1.22	.01	1.45	2.16	.60
Tara	.27	.54	1.54	-.24	.57	2.47
Waggamba	1.32	1.16	1.28	.90	.92	.99
Waroo	-.54	-.77	.58	-1.18	-1.64	.15
Wondai	.15	.40	.03	-.34	.20	.67
Boddington	-.06	-.14	-.54	-.34	-.44	-1.48
Broomehill	.12	.18	-.34	.53	.59	-.76
Bruce Rock	.28	.28	-.61	-.19	-.23	-1.65
Carnamah	-.31	-.65	-.95	-.95	-1.26	-2.68
Chapman	-.36	-.44	-.90	-.23	-.49	-1.30
Coorow	-.44	-.71	-2.05	-1.09	-1.97	-3.65
Corrigin	.25	.44	.46	.57	.29	-.07
Cunderdin	-.27	-.31	-.54	-.09	-.42	-1.33
Dalwallinu	-.20	-.75	-1.57	-.33	-2.00	-3.57
Dumbleyung	-.12	-.36	-.71	.13	-.01	-1.43
Esperance	-.71	-.68	-.81	-1.01	-.96	-1.00
Goomaling	-.48	-.59	-.97	-.71	-1.04	-1.99
Irwin	-.44	-.56	-1.46	-.52	-.95	-2.18
Jerramungup	-.23	-.48	-3.62	-.99	-1.60	-4.89
Katanning	.66	.56	-.42	1.02	.96	-1.43
Kellerberin	-.48	-.96	-1.91	-.71	-1.73	-3.47
Kent	-.87	-.92	-1.82	-.93	-1.29	-3.14
Kondinin	-.16	-.23	-1.15	.08	-.50	-1.47
Koorda	-.10	-.31	-.69	.13	-.65	-1.35
Kulin	-.18	-.19	-.65	-.62	-.58	-1.23

Lake Grace	-.38	-.72	-1.46	-.11	-.48	-1.11
Merredin	-.50	-.29	-.57	-.62	-.70	-1.99
Moora	-.51	-.63	-1.95	-.76	-1.00	-3.53
Morawa	-.75	-.70	-.81	-1.44	-1.66	-1.99
Mount Marshal	-.65	-.66	-.90	-.78	-1.04	-.80
Munkindubin	-.12	-.60	-1.00	-.58	-.89	-1.44
Narembeen	-.32	-.27	-1.44	-.73	-.68	-1.89
Narrogin	-.80	-.88	-1.28	-.58	-.72	-1.46
Northam	.12	.10	.20	-.26	-.45	-.65
Northampton	-.38	-.44	-1.18	-.41	-.63	-2.41
Nungarin	-.09	-.46	-1.50	-.14	-.57	-2.45
Pingelly	-.48	-.78	-1.14	-.73	-1.30	-2.08
Quairading	1.33	1.38	1.28	1.62	1.45	.86
Ravensthorpe	-.23	-.47	-2.28	-.69	-1.23	-3.49
Tammin	-.54	-.33	-1.19	-.22	-.20	-2.97
Trayning	-.15	-.34	-2.71	-.84	-.89	-2.56
Westonia	-.12	-.18	-1.32	-.81	-1.07	-2.50
Wickepin	-.36	-.36	-1.10	-.07	-.13	-1.64
Yilgarn	-.35	-1.03	-2.21	-.82	-1.61	-2.60
York	.67	.82	.35	.97	.98	-.02
Descriptive and One-sample t-test statistics for changes in CER for all shires						
All Mean	-0.14	-0.20	-0.59	-0.34	-0.51	-1.03
Minimum	-1.12	-1.72	-3.62	-1.52	-2.00	-4.89
Maximum	1.60	1.88	3.45	1.84	2.29	3.68
SD	0.52	0.66	1.24	0.72	0.92	1.72
t	-2.07	-2.39	-3.79	-3.70	-4.40	-4.73
Descriptive and One-sample t-test statistics for changes in CER for each shire						
QLD t	.06	.32	.97	-1.65	-.98	1.75
Mean (SD)	.01(.64)	.05(.82)	.27(1.32)	-.30(.88)	-.23(1.10)	.53(1.44)
WA t	-3.27	-4.36	-7.82	-3.59	-5.54	-10.67
Mean (SD)	-.22(.42)	-.34(.50)	-1.09(.88)	-.36(.63)	-.68(.77)	-1.91(1.13)

Appendix 13: Hedging efficiency using Certainty Equivalence of Revenue – 60mm capped equally weighted

Shires	Constant Price			Variable Price		
	Δ^{5th} (%)	Δ^{10th} (%)	Δ^{30th} (%)	Δ^{5th} (%)	Δ^{10th} (%)	Δ^{30th} (%)
Balonne	-1.26	-1.94	1.58	-1.74	-2.13	1.74
Banana	-.19	-.94	-.38	-.41	-1.03	-.51
Bauhinia	-.24	.02	-1.00	-.33	-.48	-.73
Bendemere	.90	1.84	3.08	1.16	2.33	3.62
Booringa	-.28	-.16	.80	-.81	-.29	1.20
Bungil	-.61	.09	1.65	-1.22	-.99	2.82
Cambooya	.11	.15	-.25	.07	.21	-.34
Clifton	.34	.44	-.18	.29	-.05	-.35
Duaringa	-.33	-.21	-.79	-.13	-.05	-.24
Emerald	.06	-.08	-.42	-.08	.27	.19
Gayndah	.16	.63	.82	-1.25	-.98	.54
Inglewood	-.27	-.11	-.51	-.98	-.98	-.25
Jondarayan	-.06	.01	-.52	-.59	-.30	-.54
Kilkivan	-.45	-.86	-1.43	-.97	-1.32	-1.42
Kingaroy	.27	.29	.44	-.49	-.44	.98
Millmerran	.05	.17	-.51	.01	-.03	-.31
Munduberra	-.08	-.48	-.14	-1.04	-1.83	.54
Pittsworth	-.47	-.43	-.68	-.07	-.04	-.78
Rosalie	1.78	1.82	-.64	1.75	1.80	-.25
Tara	.20	.72	1.49	-.32	.95	2.31
Waggamba	1.35	1.29	1.51	.95	1.44	1.46
Waroo	-.72	-.57	.08	-1.68	-1.90	-.54
Wondai	.08	.30	-.12	-.05	.37	.25
Boddington	.02	-.06	-.43	-.18	-.31	-1.07
Broomehill	.12	.17	-.35	.53	.58	-.76
Bruce Rock	.28	.27	-.63	-.20	-.24	-1.65
Carnamah	-.34	-.68	-.92	-.98	-1.29	-2.63
Chapman	-.38	-.41	-.88	-.19	-.39	-1.37
Coorow	-.49	-.71	-2.18	-1.14	-1.81	-3.71
Corrigin	.25	.43	.46	.57	.21	-.03
Cunderdin	-.27	-.31	-.50	-.09	-.42	-1.25
Dalwallinu	-.18	-.75	-1.53	-.39	-1.99	-3.54
Dumbleyung	-.13	-.40	-.68	.13	-.09	-1.17
Esperance	-.70	-.68	-.74	-1.00	-.96	-1.28
Goomaling	-.49	-.64	-1.08	-.74	-1.16	-2.16
Irwin	-.46	-.50	-1.26	-.58	-.76	-1.88
Jerramungup	-.26	-.64	-3.76	-1.25	-1.89	-5.02
Katanning	.63	.52	-.42	1.02	.89	-1.45
Kellerberin	-.53	-.92	-1.89	-.87	-1.68	-3.41
Kent	-.47	-1.19	-1.49	-.67	-1.50	-2.41
Kondinin	-.15	-.24	-1.08	.09	-.52	-1.37
Koorda	-.23	-.35	-.68	-.05	-.73	-1.38
Kulin	-.18	-.21	-.67	-.63	-.60	-1.17

Lake Grace		-.34	-.72	-1.39	-.11	-.49	-1.09
Merredin		-.50	-.29	-.50	-.62	-.65	-1.69
Moora		-.40	-.42	-1.98	-.37	-.48	-3.47
Morawa		-.75	-.70	-.81	-1.44	-1.64	-1.89
Mount Marshal		-.44	-.61	-1.02	-.52	-1.00	-.84
Munkindubin		-.12	-.58	-1.03	-.58	-.87	-1.46
Narembeen		-.26	-.27	-1.51	-.61	-.70	-1.92
Narrogin		-.81	-.87	-1.10	-.58	-.70	-1.19
Northam		.11	.12	.19	-.27	-.29	-.55
Northampton		-.37	-.38	-.92	-.37	-.46	-1.99
Nungarin		-.08	-.60	-1.52	-.13	-.53	-2.47
Pingelly		-.48	-.72	-1.11	-.73	-1.14	-1.98
Quairading		1.40	1.69	.86	1.86	1.73	.90
Ravensthorpe		-.22	-.43	-2.17	-.56	-1.16	-3.26
Tammin		-.54	-.32	-1.22	-.22	-.19	-3.02
Trayning		-.05	-.13	-2.57	-.41	-.59	-2.59
Westonia		-.12	-.31	-1.63	-.82	-1.28	-2.76
Wickepin		-.35	-.38	-1.07	-.06	-.07	-1.58
Yilgarn		-.30	-1.11	-2.32	-1.01	-1.71	-2.69
York		.68	.78	.34	1.05	.82	.06
Descriptive and One-sample t-test statistics for changes in CER for all shires							
All	**Mean**	-0.12	-0.18	-0.62	-0.33	-0.50	-1.03
	Minimum	-1.26	-1.94	-3.76	-1.74	-2.13	-5.02
	Maximum	1.78	1.84	3.08	1.86	2.33	3.62
	SD	0.52	0.69	1.12	0.73	0.94	1.61
	t	-1.84	-2.11	-4.43	-3.66	-4.21	-5.06
Descriptive and One-sample t-test statistics for changes in CER for each shire							
QLD	**t**	.11	.49	.75	-1.93	-1.00	1.55
	Mean (SD)	.01(.65)	.09(.85)	.17(1.08)	-.34(.86)	-.24(1.14)	.41(1.27)
WA	**t**	-3.03	-4.03	-7.95	-3.20	-5.21	-10.25
	Mean (SD)	-.20(.41)	-.34(.53)	-1.08(.86)	-.33(.65)	-.65(.79)	-1.85(1.14)

Appendix 14: Hedging efficiency using Certainty Equivalence of Revenue –50mm capped optimized

Shires	Constant Price			Variable Price		
	Δ^{5th} (%)	Δ^{10th} (%)	Δ^{30th} (%)	Δ^{5th} (%)	Δ^{10th} (%)	Δ^{30th} (%)
Balonne	2.43	2.99	8.86	2.40	2.74	7.22
Banana	0.68	0.88	0.06	0.00	0.90	0.18
Bauhinia	0.41	0.74	1.40	0.25	0.26	1.20
Bendemere	1.61	1.83	3.82	1.79	2.10	3.23
Booringa	0.30	0.64	1.15	0.19	-0.03	1.06
Bungil	0.39	1.31	3.11	-0.61	0.01	2.45
Cambooya	0.25	0.29	0.10	0.16	0.35	0.18
Clifton	0.32	0.28	0.71	0.09	-0.37	0.85
Duaringa	0.15	-0.16	-0.58	-0.31	-0.22	-1.27
Emerald	0.15	0.23	-0.63	0.58	0.64	-0.17
Gayndah	0.49	1.03	2.03	0.00	0.75	1.85
Inglewood	0.09	0.25	0.50	-0.42	-0.10	0.54
Jondarayan	-0.18	-0.22	-0.10	-0.63	-0.73	-0.15
Kilkivan	-0.71	-0.82	-1.08	-1.27	-1.56	-0.76
Kingaroy	0.66	0.87	2.05	0.59	1.28	2.82
Millmerran	0.12	0.22	0.45	-0.51	-0.74	0.36
Munduberra	0.02	0.20	0.47	-0.62	-0.07	0.80
Pittsworth	-0.22	-0.18	-0.19	-0.33	-0.33	0.51
Rosalie	0.46	0.55	1.03	0.23	0.39	2.11
Tara	0.78	1.23	1.94	0.09	0.26	1.46
Waggamba	1.74	1.56	3.58	1.67	0.74	1.87
Waroo	0.55	2.51	4.92	0.48	1.95	4.16
Wondai	0.12	0.27	0.59	-0.39	0.19	0.94
Boddington	0.19	0.27	0.12	0.29	0.25	0.03
Broomehill	0.21	0.81	0.37	-0.03	0.78	-0.56
Bruce Rock	0.37	0.56	-0.01	-0.18	0.04	-0.63
Carnamah	-0.27	-0.37	-1.42	-1.19	-1.67	-2.74
Chapman	-0.36	-0.37	-0.98	-0.44	-0.63	-1.85
Coorow	-0.35	-0.71	-2.46	-0.69	-1.98	-4.11
Corrigin	0.28	0.30	0.47	0.63	-0.06	-0.21
Cunderdin	-0.29	-0.30	-0.29	-0.06	-0.05	-0.53
Dalwallinu	-0.55	-1.08	-3.11	-1.35	-1.58	-4.18
Dumbleyung	-0.24	-0.27	-0.39	0.00	-0.15	-0.69
Esperance	-0.38	-0.43	-0.79	-0.74	-0.78	-2.19
Goomaling	-0.54	-0.77	-1.76	-0.42	-0.95	-2.45
Irwin	-0.41	-0.72	-1.92	-0.53	-0.83	-2.63
Jerramungup	-0.20	-0.89	-1.93	-1.09	-1.56	-2.89
Katanning	0.35	0.53	-0.45	0.58	0.63	-1.42
Kellerberin	-0.37	-0.24	-0.43	-0.96	-0.85	-1.34
Kent	-0.34	-0.33	-1.00	-0.89	-0.99	-1.77
Kondinin	-0.34	-0.50	-1.52	-0.81	-0.83	-1.25
Koorda	-0.17	-0.11	-0.48	-0.96	-0.69	-0.88
Kulin	-0.21	-0.21	-0.73	-0.68	-0.70	-0.98

Lake Grace	-0.21	-0.66	-1.08	-0.61	-1.02	-1.23
Merredin	-0.17	-0.12	-0.63	-0.97	-1.16	-1.23
Moora	-1.08	-1.66	-2.29	-1.60	-2.86	-3.51
Morawa	-1.07	-1.26	-1.67	-1.58	-2.12	-2.73
Mount Marshal	-0.76	-1.15	-2.12	-0.81	-1.11	-2.43
Munkindubin	-0.55	-0.51	-1.55	-0.84	-0.80	-2.21
Narembeen	-0.12	-0.30	-0.92	-0.26	-0.82	-1.30
Narrogin	-1.18	-1.76	-3.38	-1.09	-1.74	-3.30
Northam	0.40	0.27	-0.18	0.32	0.01	-0.85
Northampton	-0.79	-0.83	-2.25	-0.63	-0.98	-3.03
Nungarin	-0.43	-1.76	-2.75	-1.14	-1.92	-2.82
Pingelly	-0.79	-0.80	-1.51	-0.45	-0.43	-1.45
Quairading	1.56	1.79	1.31	2.04	2.14	1.56
Ravensthorpe	-0.63	-0.67	-2.81	-1.36	-1.52	-3.83
Tammin	-0.64	-0.73	-1.33	-0.24	-0.81	-1.79
Trayning	-1.27	-3.20	-3.49	-0.75	-2.22	-2.66
Westonia	-2.06	-1.93	-2.10	-1.64	-1.62	-2.89
Wickepin	-0.33	-0.78	-1.58	-0.52	-1.65	-2.70
Yilgarn	-0.34	-0.38	-1.53	-1.07	-1.40	-2.88
York	0.68	0.59	0.55	1.08	0.71	0.75
Descriptive and One-sample t-test statistics for changes in CER for all shires						
All Mean	-0.04	-0.07	-0.25	-0.29	-0.40	-0.67
Minimum	-2.06	-3.20	-3.49	-1.64	-2.86	-4.18
Maximum	2.43	2.99	8.86	2.40	2.74	7.22
SD	0.73	1.05	2.08	0.85	1.12	2.15
t	-.48	-.50	-.96	-2.7	-2.86	-2.48
Descriptive and One-sample t-test statistics for changes in CER for each shire						
QLD t	3.26	3.86	3.21	.84	1.8	3.62
Mean (SD)	.46(.67)	.72(.89)	1.49(2.22)	.15(.85)	.37(.97)	1.37(1.81)
WA t	-3.56	-3.81	-7.04	-4.57	-5.61	-9.04
Mean (SD)	-.34(.60)	-.52(.86)	-1.25(1.12)	-.54(.75)	-.85(.96)	-1.85(1.29)

Appendix 15: Loss ratio for 60mm capped optimized contract for a one year risk pooling

Year	Strike								
	5%			10%			30%		
	QLD	WA	All	QLD	WA	All	QLD	WA	All
1971	0.00	0.43	0.29	0.00	1.18	0.79	1.70	0.02	1.13
1972	0.55	0.00	0.17	0.72	0.03	0.25	1.00	2.87	1.60
1973	0.00	0.00	0.00	0.00	0.00	0.00	0.02	0.00	0.01
1974	0.00	0.00	0.00	0.00	0.00	0.00	0.15	0.07	0.12
1975	0.00	0.00	0.00	0.00	0.00	0.00	0.02	0.00	0.02
1976	0.00	1.66	1.12	0.00	1.66	1.11	1.38	0.03	0.92
1977	8.51	0.00	2.98	7.35	0.18	2.67	0.00	0.29	0.10
1978	0.00	0.00	0.00	0.00	0.00	0.00	0.44	0.00	0.29
1979	0.00	2.53	1.71	0.00	2.69	1.80	2.53	0.37	1.80
1980	0.00	8.86	6.00	0.03	7.64	5.12	4.35	2.55	3.77
1981	0.00	0.00	0.00	0.00	0.00	0.00	0.41	0.00	0.27
1982	4.63	0.00	1.42	4.36	0.32	1.59	0.71	3.55	1.66
1983	0.00	0.62	0.42	0.00	0.40	0.27	0.53	0.00	0.35
1984	0.00	0.00	0.00	0.00	0.00	0.00	0.22	0.00	0.14
1985	0.00	0.00	0.00	0.00	0.00	0.00	0.73	0.00	0.48
1986	0.00	0.00	0.00	0.00	0.00	0.00	0.22	0.03	0.16
1987	0.00	1.81	1.22	0.00	1.23	0.82	1.20	0.23	0.87
1988	0.00	0.00	0.00	0.00	0.00	0.00	0.10	0.00	0.06
1989	0.00	1.23	0.83	0.00	0.99	0.66	1.20	0.22	0.87
1990	0.00	0.00	0.00	0.00	0.03	0.03	0.51	0.74	0.65
1991	8.14	0.40	2.76	7.02	0.40	2.48	0.44	4.50	1.77
1992	0.00	0.00	0.00	0.84	0.00	0.27	0.06	1.30	0.50
1993	0.00	0.00	0.00	0.00	0.00	0.00	0.09	0.66	0.27
1994	13.28	1.99	5.72	12.67	2.09	5.62	2.22	6.41	3.66
1995	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.57	0.54
1996	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1997	0.00	0.00	0.00	0.00	0.00	0.00	0.40	0.73	0.52
1998	0.00	0.68	0.46	0.00	0.64	0.43	0.44	0.00	0.29
1999	0.00	0.00	0.00	0.00	0.00	0.00	0.03	0.00	0.02
2000	0.00	2.62	1.77	0.16	3.64	2.48	3.84	1.91	3.18
2001	0.00	0.77	0.52	0.00	0.90	0.60	0.99	0.64	0.89
2002	2.31	4.43	3.71	2.20	4.68	3.82	3.46	2.09	2.97
2003	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.65	0.21
2004	1.91	0.00	0.59	1.60	0.07	0.74	0.35	2.45	1.13
2005	0.00	0.00	0.00	0.00	0.00	0.00	0.06	0.00	0.04
2006	0.61	1.99	1.54	0.48	2.23	1.64	2.56	0.91	1.99
2007	0.00	0.31	0.21	0.04	1.05	0.71	1.90	0.40	1.39
2008	0.00	0.00	0.00	0.00	0.03	0.02	0.62	0.13	0.45
2009	0.06	0.00	0.02	2.51	0.03	0.81	0.30	4.69	1.73
2010	0.00	9.66	6.54	0.00	7.89	5.27	4.81	0.00	3.18
Mean	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
SD	2.80	2.16	1.73	2.57	1.91	1.55	1.27	1.54	1.08

Appendix 16: Risk pooling for 60mm capped optimized contracts

Loss ratio	Strike = 5%				Strike = 10%				Strike = 30%			
	Years of risk pooling				Years of risk pooling				Years of risk pooling			
	1	2	5	10	1	2	5	10	1	2	5	10
Queensland												
<0.5	80.0	69.2	36.1	35.5	77.5	64.1	36.1	29.0	52.5	46.2	22.2	3.2
0.5 to ≤1	5.0	5.1	27.8	12.9	5.0	5.1	27.8	19.4	15.0	10.3	30.6	54.8
1 to ≤ 2	2.5	5.1	22.2	29.0	2.5	10.3	22.2	29.0	15.0	28.2	41.7	41.9
2 to ≤ 3	2.5	5.1	8.3	22.6	5.0	5.1	8.3	22.6	7.5	10.3	5.6	0.0
> 3	10.0	15.4	5.6	0.0	10.0	15.4	5.6	0.0	10.0	5.1	0.0	0.0
Western Australia												
<0.5	67.5	53.8	50.0	22.6	65.0	51.3	44.4	32.3	57.5	41.0	22.2	6.5
0.5 to ≤1	7.5	23.1	19.4	22.6	7.5	17.9	22.2	12.9	15.0	23.1	41.7	41.9
1 to ≤ 2	12.5	10.3	16.7	54.8	10.0	15.4	19.4	54.8	7.5	20.5	33.3	51.6
2 to ≤ 3	5.0	5.1	13.9	0.0	7.5	7.7	13.9	0.0	10.0	12.8	2.8	0.0
> 3	7.5	7.7	0.0	0.0	10.0	7.7	0.0	0.0	10.0	2.6	0.0	0.0

Both states												
<0.5	62.5	46.2	36.1	6.5	55.0	48.7	25.0	9.7	45.0	35.9	17.1	0
0.5 to ≤1	7.5	23.1	19.4	41.9	17.5	15.4	27.8	45.2	20.0	20.5	40.0	74.2
1 to ≤ 2	15.0	12.8	38.9	51.6	10.0	20.5	44.4	45.2	22.5	30.8	42.9	25.8
2 to ≤ 3	5.0	12.8	5.6	0.0	7.5	10.3	2.8	0.0	2.5	12.8	0.0	0.0
> 3	10.0	5.1	0.0	0.0	10.0	5.1	0.0	0.0	10.0	0.0	0.0	0.0

Appendix 17: Survey instrument on drought risk management practices of Australian farmers

Adewuyi Ayodele Adeyinka

PhD Candidate

School of Commerce

West Street

Toowoomba, Qld 4350

Australia

Dear Sir/Madam:

This questionnaire aims to explore the risk management practices of Australian farmers particularly in times of drought. It has been sent to farmers across Australia including you. This study will facilitate the understanding of agricultural risk management from the farmers' point of view and the outcome will inform government policy on possible options. Therefore, by participating in this survey you are making your voice to be heard and contributing to policy.

Participation in this study is completely voluntary; however, your participation is very crucial in ensuring high quality research. Please, complete the questionnaire attached and return by mail to the address below the survey using reply-paid envelope. Should you be interested in participating in an interview, please, indicate your contact details at the appropriate section on the survey. Should you be interested in the summary of the outcomes of the survey, kindly notify the researcher through the e-mail address provided. Note that e-mailing the researcher reduces your level of anonymity.

Thank you in anticipation of your participation.

Kind regards

Adewuyi Ayodele Adeyinka

Participants' code: ___________

Contact (Voluntary only if interested in interview)

____

1. **Demographics**

D1. Farm location: ______________ Post code ________ Shire _______ D2. Farm size: _______

D3: Age: Below 25 years ( ) 25 to 35 years ( ) 35 to 50 years ( ) above 50 years ( )

D4: What crops do you grow?

____

1. **Agricultural Risk exposure**

What is your perception of the following risks?

	To a minimal extent	Reasonable extent	Moderate extent	Large extent	Very large extent
Price risks					
Yield risks					
Input risks					
Others (Mention)					

2. **Risk management**

How are you managing these risks? (Please, circle as appropriate)

Price risks	Forward selling			
Yield risks	Insurance	Spatial diversification	Crop diversification	Storage
Input risks	Family labour	Timing of purchases		
Other risks (Please mention)				

3. **Awareness of current risk management practices (Please, tick as appropriate)**

Are you aware of the following risk management products?

YieldShield Yes ( ) No ( ) How? __________Weather certificates Yes ( ) No ( ) How? _______

Named Peril insurance Yes ( ) No ( ) How? ____ Revenue insurance Yes ( ) No ( ) How? __________

4. **Efficiency of current risk management practices**

Have you or anyone you know benefited from any government support to farmers like Exceptional Circumstances Interest Rate Subsidy (ECIRS), Exceptional Circumstances Exit Plan (ECEP), Exceptional Circumstances Relief Package (ECRP), Farm Management Deposit (FMD), etc.?

Yes ( ) No ( )

To what extent have the following programs been helpful and efficient?

	To a minimal extent	Reasonable extent	Moderate extent	Large extent	Very large extent
ECIRS					
ECRP					
ECEP					
FMD					
Others					

Please, explain your responses to the above ratings?

Exceptional Circumstance Interest Rate Subsidy:

____

Exceptional Circumstance Relief Package:

____

Exceptional Circumstance Exit Package:

____

Farm Management Deposit Scheme:

____

Others:

____

______

5. **Would you prefer a Multi-Peril Crop Insurance that is based on revenue to one based on yield? Yes ( ) No ( )**
6. **Please, explain your response to Question 6 above**

   ____

   ____

   ____

7. **Please, suggest some improvements to drought risk management practices in Australia**

   ____

   ____

   ____

8. **Willingness to pay for weather insurance/derivatives**

What percentage of your revenue would you be willing to spend to hedge weather risks? _______

How far from your farm would you want the weather station for your contracts to be? _________

How far is the closest weather station that you know to your farm?

____

9. **How do you hope to adapt to yield variability in the future?**

   ____

10. **Do you adopt weather forecast information in your production decision? Yes ( ) No ( )**
11. **How do you do this?**

    ____

12. **What is your view on the state of insurance for farmers in Australia relative to other countries?**

    ____

    __

    ____

    ____

13. **Do you think Australian farmers need some government supports to manage their risks? Yes ( ) No ( )**
14. **Please, explain your reason for Question 13 above**

    ____

    ____

    ____

15. **Why do you think such supports have been lacking so far?**

    ____

    ____

    ____

16. **If government supports were to be available in Australia, what form should it take? (Please <u>tick only one</u>): Tax incentives ( ) Emergency payouts ( ) Subsidy to insurers ( )**

    Others (please specify): _____________

17. **Please, explain your response to Question 16 above (Remember you were to tick only one option)**

    ____

    ____

    ____

18. **Can you bet on the weather (buying weather derivative) if you did not have any crop sown? Yes ( ) No ( )**

19. **Why or why not?**

____

20. **How far ahead of the planting season do you make your production decisions? _________**

21. **If you were to buy weather insurance/derivatives, which one would you buy? (Please tick)**

Product	Tick
Rainfall certificates – Drought only	
Flood only	
A combination of flood and drought	
Temperature certificates	
Temperature and rainfall certificates	
Others and other combinations	

Please, return to:
Adewuyi Ayodele Adeyinka
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University of Southern Queensland
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Cell: 042210738
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Appendix 18: Participants' information sheet

University of Southern Queensland

USQ AUSTRALIA

The University of Southern Queensland

Participant Information Sheet

HREC Approval Number: H13REA190

Viability of Weather Index Insurance in Managing Drought Risk in Australia

Principal Researcher: Adewuyi Ayodele Adeyinka

Other Researcher(s): Prof. Chandrasekhar Krishnamurti and Dr. Tek Narayan Maraseni

I would like to invite you to take part in this research project.

1. Procedures

Participation in this research will involve responding to questions on how you manage risk on your farm. Although, there are several risks you face as a farmer, the focus of this interview/survey is on weather risk management particularly drought.

The interview/survey will take about 30 minutes of your time. The researcher is interested in recording your responses to the interview so that it could be easy to store the information you provide and be able to transcribe at a later date. Please, note that you are not required to mention your name. A numerical code will be allocated to you so that you may not be identified. Please, note further that you are not required to disclose any information that you consider as being confidential.

It is hoped that this study will give you an opportunity to air your opinions on the current state of weather risk management for Australian farmers. This is therefore a great opportunity for you to make your voice heard by stakeholders in an attempt to better the lots of Australian growers.

This research has been approved and is monitored by the Human Research Ethics Committee of the University of Southern Queensland. Should you have any questions or concerns about the conduct of the research at any point in time, you may raise them through the Ethics Officer using the contact details below.

2. Voluntary Participation

Participation is entirely voluntary. **If you do not wish to take part you are not obliged to.** If you decide to take part and later change your mind, you are free to withdraw from the project at any stage. Any information already obtained from you will be destroyed while it could be identified. Note that responses are coded and therefore participants may not be identified except through the codes they are allocated. If your numerical code is forgotten, you may not be able to withdraw your responses.

Your decision whether to take part or not to take part, or to take part and then withdraw, will not affect your relationship with the University of Southern Queensland or any organization whatsoever.

Please notify the researcher if you decide to withdraw from this project.

Should you have any queries regarding the progress or conduct of this research, you can contact the principal researcher:

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School of Commerce
Business, Education, Law and Arts
University of Southern Queensland
West Street, Toowoomba QLD 4350
Cell: 042210738
Office: 0746311274
Emial: AdewuyiAyodele.Adeyinka@usq.edu.au

If you have any ethical concerns with how the research is being conducted or any queries about your rights as a participant please feel free to contact the University of Southern Queensland Ethics Officer on the following details.

Ethics and Research Integrity Officer
Office of Research and Higher Degrees
University of Southern Queensland
West Street, Toowoomba 4350
Ph: +61 7 4631 2690
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Appendix 19: Consent form

University of Southern Queensland

The University of Southern Queensland

Consent Form

HREC Approval Number: **H13REA190**

TO: Participant's identification number (___)

Full Project Title: Viability of Weather Index Insurance in Managing Drought Risk in Australia

Principal Researcher: Adewuyi Ayodele adeyinka

Associate Researcher(s): Prof. Chandrasekhar Krishnamurti and Dr. Tek Narayan Maraseni

- I have read the Participant Information Sheet and the nature and purpose of the research project has been explained to me. I understand and agree to take part.
- I understand the purpose of the research project and my involvement in it.
- I understand that I may withdraw from the research project at any stage and that this will not affect my status now or in the future.
- I confirm that I am over 18 years of age.
- I understand that while information gained during the study may be published, I will not be identified and my personal results will remain confidential
- I understand that audio tape will be used to gather information from me and the information transcribed without any form of identification that could link me to the responses. The tape will be securely kept by the researcher under lock in file cabinet until after the completion and publication of the results. Access to the tapes will be for research purposes only.

Name of participant…………………………………………………………………......

Signed…………………………………………………….**Date**……………………….

If you have any ethical concerns with how the research is being conducted or any queries about your rights as a participant please feel free to contact the University of Southern Queensland Ethics Officer on the following details.

Ethics and Research Integrity Officer
Office of Research and Higher Degrees
University of Southern Queensland
West Street, Toowoomba 4350
Ph: +61 7 4631 2690
Email: ***ethics@usq.edu.au***

Appendix 20: Focus group interview guide

1. **What are the risks Australian farmers are exposed to and how do they manage them? (Price, yield and input)**

2. **Level of awareness of risk management options and preferences after explaining how they function – options were enumerated as follows: YieldShield, Weather Certificate, Named Peril Crop Insurance, Revenue-based insurance**

3. **Opinions on policy evolution and government options – EC, FMD and current tenets**

4. **Risk management in the future**

5. **What is the extent of supports for Australian farmers relative to others?**

6. **Do you think Australian farmers need more supports?**

7. **If yes, what form of supports/ which method should it take? Tax incentives, subsidies, debt buy back, emergency supports?**

8. **Debt position of Australian farmers – good or bad?**

9. **How has risk management in Australian agriculture contributed to this debt situation?**

10. **Price – yield relationship in times of drought.**

11. **What major policies have influenced the current debt situations the most?**

12. **Support subsidies, why or why not?**

13. **What form should additional supports for Australian farmers take if it is necessary?**

14. **What is your perception of the debt position of Australian farmers?**

15. **Family farms versus Corporate/multinationals – implications for Australian agriculture (How does this relate to risk management in Australian agriculture? Related this to debt and weather insurance).**

Appendix 21: Ethics approval

University of Southern Queensland

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OFFICE OF RESEARCH AND HIGHER DEGREES
Ethics Committee Support Officer
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EMAIL ethics@usq.edu.au

15 August 2013

Mr Adewuyi Ayodele Adeyinka
37AA Student Village
West Street
TOOWOOMBA QLD 4350

Dear Adewuyi

The Chair of the USQ Fast Track Human Research Ethics Committee (FTHREC) recently reviewed your responses to the FTHREC's conditions placed upon the ethical approval for the below project. Your proposal now meets the requirements of the *National Statement on Ethical Conduct in Human Research (2007)* and full ethics approval has been granted.

Approval No.	**H13REA190**
Project Title	Viability of weather index insurance in managing droug risk in Australia
Approval date	15 August 2013
Expiry date	15 August 2016
FTHREC Decision	**Approved**

The standard conditions of this approval are:

(a) conduct the project strictly in accordance with the proposal submitted and granted ethics approval, including any amendments made to the proposal required by the HREC
(b) advise (email: ethics@usq.edu.au) immediately of any complaints or other issues in relation to the project which may warrant review of the ethical approval of the project
(c) make submission for approval of amendments to the approved project before implementing such changes
(d) provide a 'progress report' for every year of approval
(e) provide a 'final report' when the project is complete
(f) advise in writing if the project has been discontinued.

For (c) to (e) forms are available on the USQ ethics website: http://www.usq.edu.au/research/ethicsbio/human

Please note that failure to comply with the conditions of approval and the *National Statement (2007)* may result in withdrawal of approval for the project.

You may now commence your project. I wish you all the best for the conduct of the project.

AJackson

Annmaree Jackson
Ethics Committee Support Officer

Copies to: AdewuyiAyodele.Adeyinka@usq.edu.au
Chandrasekhar.Krishnamurti@usq.edu.au