CHAPTER 1: Introduction

1.1 Background

Literature indicates that although the direct contribution of agriculture to the economy is often relatively small, especially in the case of developed and some developing economies such as South Africa, the indirect contribution to the Gross Domestic Product (GDP) is often significant because of indirect links with other sectors in the economy. Apart from the direct and indirect contribution to the GDP of a country, the agricultural sector is often an important sector with regards to employment, rural stability, and also in supplying food at relatively low and stable prices to sustain and enhance economic and social development (Eicher & Staatz, 1998: 8 – 38; Fényes & Meyer, 2003: 21 – 45; Vink & Kirsten, 2003).

The significance of agriculture in terms of its economic and social contribution was highlighted with the significant increase in food prices during 2007 and 2008, widely termed the "food crisis." The unanticipated and significant increase in food prices caused unexpected inflationary pressure, which eventually led to major social unrest in various parts of the world, as well as economic instability. Much was written about the potential reasons for the soaring food prices, but at the end of the day it was ascribed to the following factors: rapid economic growth in emerging economies such as China and India led to an increase in the demand for food and commodities; in general, urbanisation that resulted in changing consumer preferences in terms of dietary composition, notably in respect to protein and starch; adverse weather conditions caused a decline in production of grain and grain stocks such as wheat, in various parts of the world. Other contributing factors were: the increased demand for maize and oilseeds for biofuel production; increases in production costs mainly due to an increasing oil price, and lastly, speculation in commodities to use as a hedge against a weakening US Dollar (International Food Policy Research Institute, 2007; United States Department of Agriculture, 2008).

Two questions arise as a result of the occurrence of the food crisis: first, were the dramatic increases in food prices and the resulting turbulence in food markets during 2007 and 2008 a once-off event, or could similar unanticipated events frequently occur in future? Secondly, if this is not a once-off unanticipated event, and is in fact a potential signal of an increasingly volatile and uncertain future food environment, what approach or combination of approaches should be followed in terms of agricultural commodity markets to facilitate good decision-making (strategic and policy decisions) to ensure the continued contribution of agriculture to the general economy and therefore society?

To find an answer to the first question, one needs to consider some developments during the past few decades that shed light on some present day trends and events, and the resulting volatility. The demand and supply of food is driven by changes in various spheres: namely, the economy, society, technology, the natural environment, institutions, and politics. During the past twenty to thirty years, it appears that the general rate of change in each of these various spheres is increasing rapidly, as is their level of inter-connectedness. The result is that a change in one sphere could potentially cause significant and unexpected shifts in some (or all) of the other spheres, causing further unestimable volatility.

Several examples exist to support this point. Thirty years ago, a computer was the size of a room, yet it had the computational power of a present day pocket calculator. Today, although smaller, their computational power is infinitely greater. Modern computers mean instant communication and information sharing through various communication channels, which have significant implications for politics, economics, and society in general (Rosenberg, 2004; Wellman, Salaff, Dimitrova, Garton, Gulia & Haythornthwaite, 1996). On the political front, dramatic global changes took place during the middle and late 80s when communism collapsed in the former Soviet Union. As a result, political, economic, and social changes are still taking place in several countries and regions around the world, such as China, the Middle East, South Africa, and South America (Zakaria, 2003). With regards to global economics, the rise of economic superpowers is rapidly occurring. For example, China and India's economies have been growing at a minimum rate of 8% per annum during the past five to ten years. These high economic growth rates cause significant increases in per capita income levels, resulting in increases in the demand for minerals, energy, and food (International Monetary Fund, 2008). This of course places a large burden on environmental sustainability, as well as social and political stability. In conjunction with the increasing pressures created by economic growth, are signs that the natural environment appears to be changing dramatically. Scientific evidence indicates that the natural environment thirty years from now will be significantly different. This has important implications for stable and affordable food production as well as economic, political and social stability (Millenium Ecosystem Assesment, 2005). On the social front, consumer preferences are changing rapidly too because of changes in living standards and styles as a result of changes in income and culture, due to this economic growth and urbanisation (International Food Policy Research Institute, 2007).

As indicated, the above mentioned changes and accelerated rate of change in the macro spheres, has an impact on the demand and supply of food. A number of examples exist to illustrate this, such as: the rapid growth in the demand for organically grown food and health food; the significant advances in the cultivation of genetically modified foodstuffs, and the rapid changes in food trade patterns resulting from multilateral and bilateral trade negotiations (Dimitri & Greene, 2002; International Food Policy Research Institute, 2007; Rippin, 2008; Kern, 2002). Other examples are changes in policy and legislation due to political changes, such as the change in agricultural marketing that took place in South Africa during the 1990s (Van Schalkwyk, Groenewald, Jooste, 2003).

Geographically, the production and consumption of food has changed dramatically during the past couple of years, and witnessed the rise of several global players such as Brazil, Argentina and China. A more recent example of dramatic changes in the global agricultural sector is the large scale movement towards producing fuel from food and fibre, especially in the USA. This movement has changed the economic structure of the international agricultural sector significantly, and permanently (International Food Policy Research Institute, 2007; United States Department of Agriculture, 2008). Combined with all these changes to the various spheres (both external and internal to the agricultural sector), two other trends have emerged. They are global population growth and a decline in land availability for food production. This has resulted in an agricultural sector that is very unstable in terms of supplying affordable food at stable quantities (International Food Policy Research Institute, 2007; United States Department of Agriculture, 2008).

Just (2001) expresses a similar view to what is set out in the previous paragraphs when he writes that agriculture in the twenty-first century is likely to face greater variability in the range and magnitude of events, especially in terms of the changes in the internal structure of agriculture. To support his point, he quotes Andrew Barkley's presidential address to the Western Agricultural Economics Association in 2001, where Barkley said: *"The agricultural economy of the United States is in a state of massive and rapid transition. Recent advances in information technology, biotechnology, and the organization of agribusiness firms have resulted in unprecedented change in the food and fibre industry."*

Based on the before mentioned arguments, one can therefore conclude that the rate of change, and therefore the level of risk and uncertainty of the agricultural sector's external and internal environments, appears to be increasing, hence the point that similar unanticipated events such as the food crisis of 2007/08 could occur in future, at a higher frequency. The implication of this point is that humans, and therefore governments and firms, will have to survive and thrive in such an increasingly volatile and uncertain environment. In order to do this, ways in which decisions are made on business strategy and policy will have to improve in order to ensure that good decisions can be made, which will ultimately lead to desired outcomes despite volatility and uncertainty. The problem is, however, that the fast-changing environment poses significant challenges to decision-makers in making correct policy and strategic business decisions, especially in terms of agricultural commodity markets. This is because change, and the accelerated rate of change, creates risks and uncertainties. This makes good policy and strategic decision-making in agricultural commodity markets a significant challenge.

1.2 Problem statement

Understanding and managing change, as indicated in the previous section, is a key challenge to survival and growth - for individuals, communities, societies, governments, and firms. Change creates such a key challenge, because through change, different spheres and levels of human existence are influenced and altered. In order to manage change, humans either react individually or devise institutions (Bowles, 2004). However, the exogenous environment as well as the underlying social interactions that give rise to institutions, also change as a result of changes in the shaping factors (Bowles, 2004: 49). Since economics is essentially the study of choice in order to understand allocation and distribution of resources, the study of change has always formed a key part of economics. Change influences choice and therefore allocation and distribution of resources. Bowles (2004: 6) writes: *"Contrary to its conservative reputation, economics has always been about changing the way the world works."*

The process of change in a system is driven by a factor, or combinations of factors, endogenous and exogenous to the system. Depending on the relative magnitude, direction, form, and combinations of the individual shaping factors, the process of change can be either sudden, or gradual and almost insignificant. Understanding the process of change by identifying and understanding the shaping factors, and also perceiving their impacts, is extremely difficult since it depends on the scale and scope of the analysis of the shaping factors. For example, when analysing global forces shaping global politics, economics, technology, social relationships, the natural environment, and therefore the human future, it is possible to identify an almost infinite list of forces. During 2002, Shell International made an attempt to do this and published a booklet on global scenarios for 2020 which indicates that globalisation, development of new technology, and liberalisation of markets appear to be the primary factors that shape the human future (Shell International, 2002:12).

Wack (1985b:150) writes that during steady times, changes in the aggregate environment and potential impacts are relatively easy to perceive since causality, and therefore risk, is fairly well understood. However, in times of turbulence and rapid change, decision-makers often fail to keep up with changes in reality, since the causes of turbulence are not well understood and quantified. Hence, the level of uncertainty increases. As a result, a decision-maker's framework of perceptions fail to reflect reality with accuracy, which could lead to bad decisions. The problem is that decision-makers never know when to expect a stable environment and when to expect a turbulent one, and therefore operate in an uncertain environment. Bernstein (1998: 151) states it slightly differently: *"The answers to all these questions depend on the ability to distinguish between normal and abnormal."* Based on the arguments of Wack and Bernstein, one could argue that normality and risk are similar concepts, while abnormality and uncertainty are similar concepts. In the case of normality or risk, causality is well understood, while in the case of abnormality or uncertainty, causality is not well understood, hence creating significant additional difficulties when making decisions.

In order to make decisions, in either normal or abnormal conditions, decision-makers make use of tools in an effort to make a good decision. Which approaches or tools to use is a difficult question, as circumstances change. What should be used when: events are normal or just a short-term deviation from the normal; when events are abnormal and could lead to permanent deviations from what was deemed to be normal before?

In agricultural economics, normality and abnormality, or risk and uncertainty, arising from external and internal change have been researched rather extensively. However, in light of a potentially faster-changing aggregate market environment, as explained in ection 1.1, three questions arise:

1) What methods and approaches are presently used to analyse risk and uncertainty (from an aggregate market perspective) in order to inform agricultural policy and strategic business decisions?
2) Are these methods still sufficient to capture the risks and uncertainties arising in an increasing volatile and uncertain agricultural sector, in order to facilitate informed decision-making?
3) If these methods are not sufficient, what alternative method(s) is available, and how can it be combined with existing methods and approaches?

A review of literature on policy and business strategy in agricultural economics, indicates that in the assumed presence of risk and uncertainty, formal decision analysis as termed by Hardaker, Huirne, Anderson and Lien (2004), is mostly used to inform decision-makers about the risks associated with making policy and strategic business decisions. In the economic and agricultural economic literature, decision analysis is predominantly developed by calculating objective probabilities for the various outcomes, and then attempting to maximise expected utility (Taylor, 2002: 254; Bowles, 2004: 101 – 102). This provides the decision-maker with an indication as to what decision to make in order to maximise expected utility. In the case of uncertainty, analysis is developed by replacing the objective probabilities with subjectively estimated probabilities, and then maximising expected utility. It is then assumed that these subjective probabilities are adjusted over time, using a process termed Bayesian updating, which was 'invented' by Reverend Thomas Bayes, an early writer on Probability Theory (Bowles, 2004; Hardaker *et al.*, 2004: 55 – 61; Taylor, 2002: 254).

Hardaker *et al.* (2004: 18) argue that formal analysis of risk and uncertainty has costs, especially the cost of the time that it takes to formally analyse each risk as well as potential options on how to manage and mitigate the effect of this risk. Hence, they state that not many decisions carry enough merit to make formal risk analysis worthwhile. However, Hardaker *et al.* argue that there are two situations in which formal analysis might be worthwhile. The first is where repeated risky decisions of the same nature need to be made on a continual basis. This necessitates setting up a formal strategy (achieved through formal analysis) which can be continuously consulted. The second instance is where the positive and negative outcome of a decision differs significantly from each other, and where the negative outcome could lead to the termination of the organisation. In such a situation, formal analysis could be beneficial.

Analysing the various options ensures that negative consequences are managed and mitigated, to such an extent that the survival and growth of the organisation is secured. However, in some situations, making an agricultural decision can be very complex. Using formal methods to analyse these situations is not always possible. Hardaker *et al.* indicate some characteristics of such complex decision situations, namely:

1. The available information about the problem is incomplete.
2. The problem involves multiple and conflicting objectives.

3. More than one person may be involved in the choice or may be affected by the consequences.

4. Several complex decision problems might be linked.

5. The environment in which the decision problem arises may be dynamic and turbulent.

6. The resolution of the problem might involve costly commitments that may be wholly or largely irreversible.

In situations of accelerated change, such as the present conditions experienced by the agriculture industry, the six characteristics, or at least a combination of some of the characteristics, are often present. This results in an extremely complex decision-making environment. Formal decision analysis techniques are therefore not always relevant and fail to guide the decision-maker as to which decision and action needs to be taken. Hence, in rapidly changing environments, it is insufficient to solely align with risk and uncertainty analysis currently used in agricultural economic literature.

From the definitions of risk and uncertainty (which are explained in detail in chapters two and three), it is possible to argue that, since researchers mainly focus on either objective or subjective probabilities to analyse and communicate risk and uncertainty, researchers in actual fact don't take full cognisance of uncertainty. The possibility exists that the probabilities - whether objective or subjective - might be either over- or underestimated, since discontinuities might occur in respect of the key assumptions, inter-relationships, or factors used in the framework of analysis. Hence, in the situation where the rate of change increases, as discussed in the background, the possibility of the probability distributions being over- or underestimated increases significantly. This could well lead to spurious analysis, which could lead to incorrect decisions. Hence the need to identify the failings of the current decision-making methods used in agricultural economics to analyse risk and uncertainty.

To support this point, a number of literary examples are included. The paper by Butt & McCarl (2005: 434) serves as a first example, and illustrates how risks are both of an exogenous and endogenous kind. In their paper, they develop a framework for projecting the effects of policy, and technological and environmental change on the prevalence of undernourishment in a country. The researchers do this by integrating a methodology developed by the Food and Agricultural Organisation (FAO) for estimating undernourishment in a specific country into a stochastic economic mathematical agricultural sector modelling framework. Changes in factors that can be simulated in this modelling framework are: climate, resources and resource limitations, demographics, market dynamics, adoption of improved cultivars, and crop land expansion. The researchers apply this modelling framework to Mali, a country in Sub-Saharan Africa, to explore alternative options for reducing undernourishment.

To project future levels of undernourishment, the researchers project future food consumption against production. In the modelling framework, future food consumption is mainly determined by population growth and trends in per capita food consumption; the latter is determined in turn by increase in income over time. Food production in turn is determined by area, and crop and range land productivity. The authors indicate that the latter factor is showing a declining trend due to increased cropping intensity and low levels of fertiliser use. Furthermore, high grazing and stress from periodic dry conditions leads to further decreases in range land productivity. In order to take account of variability in climate, which has an impact on crop and livestock production, the researchers include variability in crop yields based on the period 1985 to 1996, which implies twelve observations. A trend yield is included to take account of cultivar technology adoption. The researchers use the framework along with the crop yield variability to simulate different probability distributions, under various situations that they define as scenarios. The results of each 'scenario' then indicates different probabilities of undernourishment.

Referring to the definition of uncertainty and the cause of uncertainty (namely discontinuities), as well as looking at the modelling framework and the technique that is used in this paper, the first point is that the researchers make use of stochastic modelling, and therefore probabilities, to take account of risk. Looking at the results of the paper, one can conclude that - given the climate risks faced by Mali, the various situations or 'scenarios,' along with the probability distributions presented in Fig 2 (p443) of the paper - they give a good indication to decision-makers of the probabilities of undernourishment.

However, given the fact that per capita consumption and climate are two of the key driving variables in the modelling framework, discontinuities in either or both of these factors might cause the probabilities and probability distributions to be either over- or underestimated.

Brand & Chamie (2007) indicate that the rate of urbanisation, especially in Africa, is likely to increase significantly during the period 2000 to 2030. In Africa, they argue that the urban population might double during the next 30 years as opposed to current figures. If this is true, the urban population could change significantly in Mali during the period for which Butt & McCarl are doing projections. Urbanisation might cause significant discontinuities with respect to per capita income, since beliefs, preferences and constraints of people that move to urban areas might change significantly. Looking from a micro-economic perspective, this in turn will influence per capita consumption and therefore total consumption, which could have a dramatic effect on the probability of undernourishment. The same goes with climate change. Scientists are publishing more and more literature on the possible effects of climate change and changes in rainfall patterns and temperatures. In the case of Mali, Butt & McCarl indicate that pressure on crop land and range land is increasing due to changing production practices. Should climate change occur the way climate scientists are thinking, dramatic discontinuities might occur in production patterns and practices. This again could have significant consequences for the realism of the probability distributions presented by Butt & McCarl.

Several other examples of research papers exist where stochastic modelling or probabilities are used to inform and guide decisions in the face of risk and uncertainty. Examples of such research include Binfield, Adams, Westhoff and Young (2002), Rasmussen (2003), and Westhoff, Brown & Hart (2005). These studies do indicate the importance of taking risk or probabilities into account when analysing decision-making factors – whether it's a policy, production or another type of decision. However, discontinuities in endogenous and exogenous variables included in the modelling framework might cause the probabilities presented (or assumed) in these studies to be either over- or underestimated. Therefore, the main shortcoming with regards to these research results is that uncertainty (as per definition it includes possible discontinuities) is not explicitly accounted for. This point is confirmed in the writing of Binfield *et al.* (p7): "*By no means, however, have all possible sources of variability been captured. It would be a mistake to conclude that the extreme values achieved in this analysis represent the absolute extremes that are possible in the future.*" Or otherwise, as stated by Knight (1921:231): "*…since at best statistics give but a probability as to what the true probability is."* Westhoff *et al.* (2005) also concludes that stochastic analysis is not perfect in terms of indicating possible variability in outcomes.

Just (2001) and Taylor (2002) argue along similar lines and attempt to show that methods, especially system modelling methods in agricultural economics, tend to ignore the fundamental difference between risk and uncertainty, and therefore lead to results that mostly exclude uncertainty. Again, this leads to problems or shortcoming in terms of making informed policy decisions. A similar argument could be made in the case of strategic business decisions. This strengthens the argument that formal decision analysis, without due inclusion of uncertainty through the inclusion of possible discontinuities, might lead to spurious conclusions and therefore incorrect decisions with regards to agricultural policy and business strategy.

The insufficiency of the presently used methods does not imply that these methods should be discarded, since they remain useful for specific purposes. Wack (1985a: 73) argues this point when stating that modelling, and therefore decision analysis, mostly gives relatively correct answers compared to reality since "*…the world of tomorrow often remains unchanged relative to today.*" However, the danger with modelling is firstly that the models are simplified representations of reality, or parts of reality, and secondly, models are based on historical structures and relationships between various factors in the system. The problem with modelling, as argued by Wack, arises from three aspects. A discontinuity might occur in a variable included in the model. Secondly, a discontinuity might occur in a factor that historically did not influence the system but due to the event, suddenly does influence the system being modelled. Lastly, relationships and therefore correlations change as a result of a discontinuity and could significantly influence probability distributions. Therefore, when only modelling and probabilities are used to analyse a decision and communicate risk and uncertainty, the occurrence of a discontinuity or discontinuities that will make a strategy or policy obsolete, is much higher.

Two implications with regards to policy and strategic business decisions arise from this argument. Firstly, firms and governments should take risk into account when making policy or strategic business decisions. They should use modelling and probabilities since modelling often works when change and the rate of change is well understood. Secondly, they must also have the ability to anticipate major discontinuities, and design strategies and policies that ensure their strategies and policies don't become obsolete should these discontinuities occur. In other words, businesses and government should also take uncertainty, along with risk, into account when making policy and strategic business decisions. The question is how?

Although Just (2001) and Taylor (2002) argued along similar lines, as presented in this section and the previous section, and although Just did present some potential solutions on how to mitigate this problem, neither of the two authors offered tried-and-tested solutions. This is clear from Just's remark: *"For the remainder of this article, I attempt to suggest some marginal possibilities…. Although these suggestions are easy to criticise, I encourage them with the apparent reality of the propositions of this article."*

The aim of this thesis is to build on the ideas of Just (2001) and Taylor (2002). It proposes and tests an approach to policy and business strategy decision-making in agricultural commodity markets. It sets out to prove itself more effective in capturing both risk and uncertainty as opposed to current individual decision analysis techniques being applied in agricultural economics. By using this proposed approach, policy and business strategy decision-making will hopefully improve in the face of greater risk and uncertainty.

1.3 Hypothesis

It is hypothesised that the simultaneous use of two methods, namely, scenario thinking and stochastic modelling, facilitates a more complete understanding of the risks and uncertainties pertaining to policy and strategic business decisions in agricultural commodity markets. This is likely to facilitate better decision-making in an increasingly turbulent and uncertain environment.

The hypothesis is based on two arguments. Firstly, the environment faced by the decision-maker essentially consists of both risk and uncertainty. Risk is defined as the situation wherein a probability can be attached to the occurrence and outcome of an event; uncertainty is defined as a situation in which no probability can be assigned to the occurrence or outcome of an event due to possible discontinuities and, therefore, changes in the cause-and-effect relationships in a system. The existence of both risk and uncertainty emphasise the importance of making use of techniques in the decision-making process to assist the decision-maker in understanding both risk and uncertainty. The second argument fuelling the hypothesis is that the underlying cognitive development processes of the two techniques are fundamentally different.

The importance of these two arguments in the development of the hypothesis is two-fold. Firstly, the underlying processes involved in scenario thinking and stochastic modelling are fundamentally different, since stochastic modelling informs risk through either objective or subjective probabilities, while scenario thinking informs uncertainty through the analysis of discontinuities. Secondly, based on the theories of cognitive development proposed by Vygotsky and Piaget (discussed in chapter 4), the cognitive developmental processes underlying modelling and scenario thinking are, to an extent, different. Based on these two points, one can argue that although scenario thinking and stochastic modelling are fundamentally different, the processes and results of the two techniques are actually complimentary. Using both techniques simultaneously leads to a more complete understanding of risk and uncertainty, thereby leading to a more complete learning experience. Using the two methods in conjunction will therefore ensure that the mental model, or perceptions, of the decision-maker 1) reflect actual risk and uncertainty, and 2) are enabled, by following two different learning processes, to accurately assess reality and change in accordance with the changes in the agricultural environment. By adjusting the decision-maker's mental model to reflect reality more accurately, his or her understanding and insight into the decision-making environment improves. This is likely to lead to better decisions, despite an increasingly turbulent environment. This makes the conjunctive application of both approaches essential in the decision-making process.

1.4 Research objective, methods, and contribution

1.4.1 Objective

The objective is to test whether stochastic modelling used in agricultural economics, or the conjunctive use of scenario thinking and stochastic modelling as proposed in chapter four of this thesis, is more effective in capturing the relevant risks and uncertainties of an increasingly turbulent environment to the extent that good policy and strategic business decisions can be made. This will be achieved by means of comparing results from the two different approaches to an actual market outcome in three case studies. The results will be used to demonstrate which approach captured risk and uncertainty most effectively given the actual market outcome, and therefore which approach led to better decisions.

The testing procedure consists of three steps:

1) Compare an actual agricultural commodity market outcome to the simulation results of an existing stochastic multi-market model of the same agricultural commodity market, in order to determine whether the simulation process and results sufficiently captured the risks and uncertainties that eventually led to the actual market outcome;
2) Compare the same actual agricultural commodity market outcome to analysis results where the proposed framework of this thesis as presented in chapter four has been applied. This is an attempt to determine whether the conjunctive use of the two techniques captured the risks and uncertainties sufficiently, which ultimately led to the actual market outcome.
3) Compare the results of step one and two, to determine which approach captured the risks and uncertainties more sufficiently and therefore led to better decisions given the actual market outcome in each of the three situations.

Thus, by comparing the results as described above in point three it would be possible to determine which of the two approaches, stochastic modelling on its own or the proposed framework of this thesis as presented in chapter four, captured risk and uncertainty more effectively and therefore led to better decisions given the actual outcome of the market.

As indicated, the general objective is attained by presenting three case studies. The three case studies that are used to test the hypothesis are taken from work done by the author in cooperation with colleagues at the Bureau for Food and Agricultural Policy (BFAP)[1] for three respective agribusinesses at different points in the past four years. The first case study involves a firm in the pork supply chain who had to make decisions on hedging of yellow maize for the 2005/06 maize season in attempting to manage feed costs and pig prices. The second case study involves a farmer co-operative who had to make financing decisions for the 2005/06 maize production season. The third case study involves a commercial bank that makes financing decisions in terms of agricultural commodity market conditions during the 2007/08 and 2008/09 maize production seasons.

1.4.2 Methods

The general objective will be attained by means of the following steps:

1) Select a suitable stochastic agricultural market model through a comprehensive review of the literature on risk analysis in the field of agricultural economics. The selected model will be used to test whether it captured risk and uncertainty sufficiently, and compared to an actual market outcome.
2) Select a suitable scenario thinking technique through a comprehensive review of the literature on scenario thinking and futures thinking. The selected technique will be applied in conjunction with the selected stochastic model in point 1 as proposed through the framework presented in chapter four of this thesis, to test whether conjunctively using the two techniques captures risk and uncertainty more effectively than using only the selected stochastic model.
3) Apply the stochastic model as selected in point 1, in order to simulate the South African yellow maize price for the 2005/06 season. The simulated results are compared to the actual yellow maize price for the 2005/06 season to determine whether the application of the selected model sufficiently captured the risks and

1 For more information on BFAP and its activities, visit www.bfap.co.za

uncertainties faced by decision-makers during the 2005/06 season, which led to the eventual actual yellow maize price of 2005/06. In addition, an actual case study of a private company that conjunctively applied both the selected stochastic model and scenario thinking technique, as proposed through the framework of this thesis as presented in chapter four, during the 2005/06 yellow maize season, is reviewed. The case study compares the yellow maize price and the actual outcome of the yellow maize price for the 2005/06 season, and examines whether the conjunctive use of the two techniques captured the risks and uncertainties sufficiently in order to lead to good and better decisions compared to a situation where only stochastic modelling is used to guide decision making.

4) The discussion of the second and third case studies follows a similar vein to the first case study. Firstly, the selected stochastic model was applied on its own and then compared to the actual outcome. Secondly, the case study results were reviewed in terms of which conjunctively applied both techniques, and compared to the actual outcome. This indicates whether the stochastic model on its own or the conjunctive use of the two techniques captured risk and uncertainty more sufficiently, and hence which approach led to the best decisions given the actual market outcome with respect to what the decisions were made.

1.4.3 Contribution of study

The increasing rate of change experienced in agricultural commodity markets increases both risk and uncertainty pertaining to making a decision in the market. Through the testing and acceptance of the proposed hypothesis, it will be shown that in an increasingly turbulent environment, with increasing risk and uncertainty, it is essential to conjunctively use scenario thinking and stochastic modelling to facilitate decision-making. Furthermore, it will be shown that an alternative to subjective probability assignment does exist to analyse uncertainty in agricultural economics.

1.5 Outline of chapters

The study consists of seven chapters. Chapter one provides the introduction and background. Chapter two reviews the body of literature on risk in agriculture in order to define risk and review different risk analysis techniques so that a suitable existing stochastic model can be selected to test the hypothesis. Chapter three reviews literature on uncertainty in order to define uncertainty, and describes the link between uncertainty and scenario thinking. It also reviews literature on scenario thinking in order to select a suitable scenario thinking technique to test the hypothesis. Chapter four initially presents the framework proposed by this thesis on how the two selected techniques can and should be used in conjunction. Secondly, it theoretically demonstrates how the combined use of the two techniques through the proposed framework of this thesis should sufficiently capture risk and uncertainty, and thirdly argues why the combined use of the two techniques should facilitate improved strategic and policy decisions in agricultural commodity markets. Chapter five presents two case studies (as explained in ections 1.4.1 and 1.4.2 of this chapter), and tests which approach captures risk and uncertainty most effectively and is best for making good policy and strategic business decisions in an increasingly turbulent environment. Chapter six presents the third case study. This case study is presented separately because it is work in progress, and hence the resulting scenarios that were developed are still playing out. Therefore, chapter six aims to apply the proposed framework of this study - in a past and future context. It will hopefully show the usefulness of the proposed framework of this thesis in the current volatile economic and agricultural economic markets. Chapter seven concludes the study and identifies potential areas for future research with respect to the combined use of scenario thinking and stochastic modelling.

CHAPTER 2: Risk and Stochastic Modelling

We are not certain, we are never certain. If we were, we could reach some conclusions, and we could, at last, make others take us seriously.

Albert Camus, 1956

(In Valsamakis, Vivian & Du Toit, 1996: 22)

2.1 Introduction

Risk is a key ingredient of the agricultural environment. For example, rainfall and temperature vary from season to season, causing crop yields and disease prevalence to fluctuate. This influences production, and as a result, stock levels and prices. An excellent example of where rainfall variability had a significant impact on stock levels and prices, is the case of Australia's drought during 2006 and 2007. This drought caused world wheat stocks to significantly decrease, and also resulted in dramatic increases of wheat prices (United States Department of Agriculture, 2008: 21). Other examples of factors that cause fluctuations, and therefore risk, in agricultural commodity markets are: the variability in economic factors such as oil prices; exchange rates; fertiliser prices and changes in internal structures and relationships within the sector, such as institutional changes or changes in the interaction between industry role players. Fluctuations of these factors cause variability in supply, demand, and prices, which ultimately influence the profitability and risk of agricultural production and food processing.

The challenge is that, despite the inherent and continued risk faced in agricultural commodity markets, decision-makers have to make ongoing policy and business strategy decisions that will impact on the future growth and survival of the institutions and the sector. Hence, present decisions and actions will create future conditions, which are often irreversible. The problem is that these decisions and resulting actions might become either obsolete or have unintentional negative consequences in future, given the occurrence of risky events. To combat this challenge, decision-makers need to take potential risks into account when making decisions, and ensure that unintentional negative consequences do not result from their decisions and actions. In order to do this, a sufficient understanding of the definition of risk is needed, as well as an understanding as to what tools are available to analyse risk.

The purpose of this chapter is therefore to define risk; identify and discuss the sources of risk in agriculture; discuss agricultural risk management, and lastly to review literature on different methods of risk analysis from an aggregate market perspective in agricultural economics. The chapter will conclude by selecting an appropriate risk analysis technique that will be used to test the hypothesis.

2.2 Definition and sources of risk

The concept of risk is derived from the Italian word *risicare,* which means "to dare," and was not well understood until approximately 1654 when the Theory of Probability was finally grasped (Bernstein, 1998: 3, 8). Bernstein writes that this occurred when Chevalier de Méré and Blaise Pascal solved a puzzle that was posed two hundred years earlier by the monk Luca Paccioli. This led to a prolonged process of formulating the Theory of Probability, during which concepts such as normal distribution, standard deviation, and regression to the mean were discovered (Bernstein, 1998: 5, 6). The formulation of the Probability Theory culminated in 1952 when Harry Markowitz mathematically proved that diversification is an excellent risk mitigation strategy (Bernstein, 1998: 6).

Bernstein views the Theory of Probability as the mathematical foundation of the concept of risk (Bernstein, 1998: 3). In contemporary literature, risk is generally defined as a situation in which probabilities (different possible outcomes) of a system or factor are known and can be calculated. Hardaker *et al.* (2004: 5) argue that this definition of risk is not useful, since objective probabilities are seldom known, and subjective probabilities therefore need to be calculated. As a result, they define risk as "uncertain consequences." Bowles (2004: 101) defines risk as being more finite - when the outcome of an action in the individual's choice set is a set of possible outcomes to which known probabilities can be attached.

Valsamakis, Vivian and Du Toit (1996: 23) argue wider on the definition of risk, and write: *"In his effort to understand or minimise uncertainty, man has attempted to determine causation, unfold patterns and give meaning to unexplained events, possibly in terms of a controlling power."* Ilbury & Sunter (2003: 42), although not referring directly to risk, also argue along this line of thought, and write about the 'rule of law' (or causality) and the motivation of people to analyse and understand cause-and-effect in order to quantify it.

The implication of these arguments is therefore to understand and define risk, causality between various factors, events, actions and resulting outcomes need to be understood and quantified. *The fact that causality is determined and quantifiable, leads to the possibility of calculating and assigning probabilities (either objective or subjective), to the occurrence of events.* Therefore, based on the ability to quantify the probability of the occurrence of events, a decision-maker can begin to think about the potential consequences, should a specific event occur. The insight gained by the decision-maker through this process, leads to the understanding of the risks faced, and hence partially assists the decision-maker in making a good and informed decision.

The literature on risk indicates that the sources of risk can be grouped into two major groups, namely, exogenous and endogenous sources of risk. Exogenous risk stems from factors *outside* of the system, and the effect of the risks basically feed *into* the system, thereby affecting the system. Examples include: climate changes that impact on farm-level; the international maize price that could affect the domestic maize price in the case of a small and open economy, specifically pertaining to maize; changing exchange rates that influence price levels etc. Endogenous sources of risks are risks that stem from within the system under study. From a micro-economic perspective, an example is changes in behaviour because of changes in beliefs and preferences (Bowles, 2004: 93 – 126).

Hardaker *et al.* (2004: 6) describe various categories of risk encountered in agriculture, namely: production risk; price or market risk; institutional risk; personal or human risk, and financial risk. All risks (excluding financial risk) are aggregated into what Hardaker *et al.* term 'business risk.' They define business risk as being comprised of all the risks that affect the profitability of the firm, excluding the risks that originate from the way the firm is financed. Hence, finance risk is defined as a set of risks that stem from the way the firm is financed. Therefore, the more debt used to finance the firm, the higher the leverage and therefore the higher the potential return or loss on the owner's equity.

2.3 Risk management

The understanding of risk alone does not assist a decision-maker in taking decisions. In order to take decisions that will most probably have positive consequences, or at least mitigate the majority of negative consequences, a process needs to be followed in order to take a decision. This process is described as risk management in the literature.

Dickson in Valsamakis *et al.* (1996: 13) defines risk management as the: *"identification, analysis and economic control of those risks which threaten the assets or earning capacity of an organisation."* Hardaker *et al.* (2004: 13) argue along the same lines, and describe risk management as the: *"systematic application of management policies, procedures and practises to the tasks of identifying, analysing, assessing, treating and monitoring risk."* Risk management can therefore be defined as a function falling under general management functions, with its focus being to mitigate negative consequences resulting from specific events, in order to enable the firm or institution to reach its desired goals (Head, 1982 in Valsamakis, 1996:15). In 1916 Fayol argued, according to Valsamakis *et al.* (1996: 13), that management entails various functions, one of which is 'security.' He argued that it is the responsibility of management to secure the well-being of revenue-generating assets. This implies that a systematic approach to risk management is critical.

According to Valsamakis *et al.* (1996: 15) a systematic approach to risk management mainly consists of four stages, namely:

1) *risk identification;*
2) *risk quantification;*
3) *risk control directed at loss elimination, or more usually, loss reduction;*
4) *risk financing, via transfer.*

Hence, risk management is a process whereby causality is determined in order to quantify the probability of occurrence, as well as the potential consequences. This assists the decision-maker in developing options on how to mitigate the potential negative consequences - by means of loss elimination or loss reduction mechanisms such as insurance or hedging.

Hardaker et al. (2004: 14 – 18) present a more detailed approach to risk management. Essentially, the approach consists of seven steps, each connected to the previous step but also indirectly to the other steps. Figure 2.1 presents the outline as explained by Hardaker *et al.*

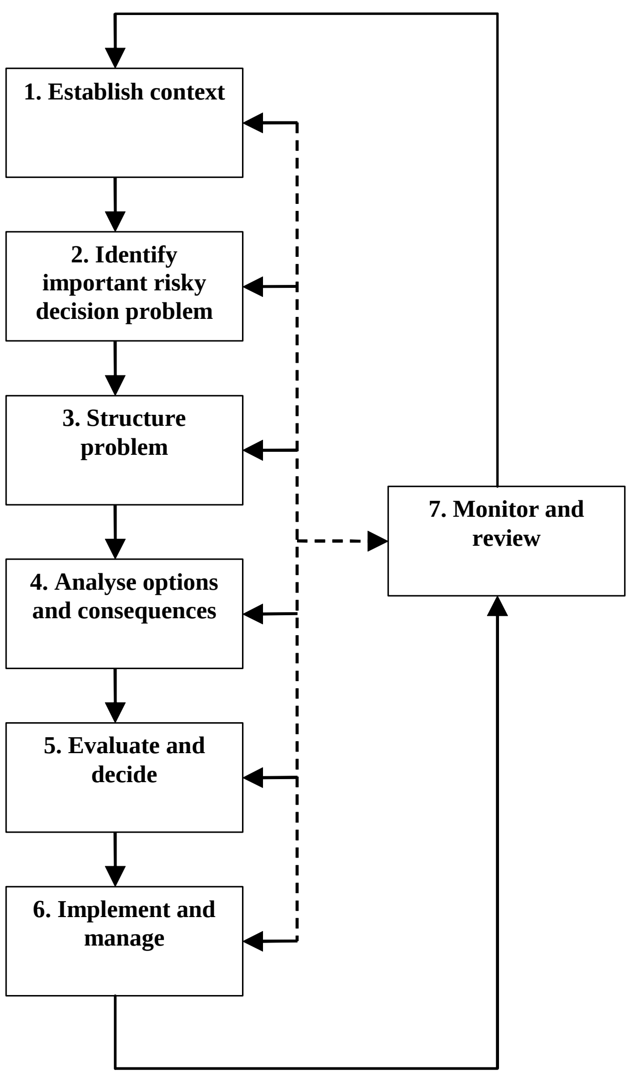

Figure 2.1: An outline of an approach to risk management (Hardaker *et al.*, 2004)

The first step of establishing context, consists of establishing the general milieu and parameters within which a specific risk or set of risks will be considered. This could be done by considering three different aspects of the organisation, namely: the strategic milieu, organisational milieu, and risk management milieu.

Considering the strategic milieu entails defining the inter-relationship between the organisation and its external environment. This includes considering the strengths, weaknesses, opportunities and threats of the organisation. When considering the strategic milieu, one should focus on identifying the key factors that determine the organisation's position relative to its environment, and which could significantly influence the ability (positively or negatively) of the organisation to fulfil the needs of its stakeholders.

The evaluation of the organisational milieu essentially deals with understanding the objective setting within the organisation, and the allocation of responsibilities, in order to reach the objectives. Hence, the consideration of the organisational milieu focuses on the question of whether the organisational structure and allocation of responsibilities are adequate enough to reach the set objectives.

The risk management milieu needs to be evaluated in order to understand how risk management procedures are structured within the organisation, and to determine whether protocols are sufficient enough to identify and manage the relevant risks as identified in the strategic and organisational milieus.

The second step in the risk management process entails the identification of the key risks faced by the organisation, hence, implying the prioritisation of the various risks faced by the organisation. This is done by listing the various risks in terms of importance or potential effect on the organisation.

Step three entails attempting to understand the underlying nature of the risk or risks as identified in step two. Various questions need to be answered during this stage according to Hardaker *et al.* For example: "Who faces the risk?"; "Who suffers if things go wrong?"; "What are the basic and proximate causes of the risk?"; "How is the risk currently managed?"; "What other options are available to manage the risk?" and "Who decides what to do?"

Following step three, options are analysed in terms of how to mitigate or act in the presence of adverse consequences, or in case the risky event should actually occur. The objective of this step is to separate the low-probability or low-impact events from the higher probability or higher impact events, which need additional and more formal analysis.

The fifth step entails evaluation and decisions. Decision-makers consider the risky consequences of the available decision options in order to reach a final decision or option that is likely to be the best, or most acceptable, in terms of mitigating the consequences of the risk or set of risks. This implies that the level of risk aversion of the organisation plays a key role in this step of determining which option should be taken.

Step six entails the implementation and management of the option that was picked in step five, while step seven revolves around continuous monitoring and review. The purpose of step seven is to establish whether the risk management plan is working, and to identify additional aspects that need consideration to ensure that the risk management plan remains relevant.

Comparing the risk management approaches presented by Valsamakis *et al.* and Hardaker *et al.*, it is clear that the general logic behind the two approaches is fundamentally similar. Essentially, both approaches contain three phases, namely: observation and identification; prioritisation and analysis, and implementation, which includes management and control. Since the specific problem of this study essentially deals with the analysis of risk pertaining to agriculture in a fast-changing environment, the remainder of this chapter reviews the body of literature on risk analysis in agricultural economics. The purpose of the review will be to firstly develop an understanding of the various methods that can be used to test the hypothesis, and based on the gained understanding, select a suitable method.

2.4 Risk analysis in agricultural economics

Formal risk analysis has been a key area in the field of agricultural economics for many years. Since the age of industrialisation and therefore specialisation, the need to produce greater quantities of food at affordable prices has increased dramatically. During the 1930s, the whole economic system came under severe pressure, resulting in the Great Depression, which forced governments to relook their views towards the production of affordable food for the masses. This introduced significant food production policy interventions in agriculture to ensure stability and affordability. However, policy interventions influenced the profit and risk profile of food production and processing in such a way that incentives were often skewed so as to cause unintentional consequences (Van Schalkwyk *et al.*, 2003: 119 - 127). This partly motivated agricultural economists to study risk and the impact it has on the stability and affordability of food production. The result was that a number of formal risk analysis techniques were invented and adopted by agricultural economists in order to study the problems, challenges, and consequences risk creates, or as stated by Hardaker *et al.* (2004:23): *"to try to rationalise and assist choice in an uncertain world.*" The purpose of this section is to give a broad overview of the main risk analysis techniques in agricultural economic literature.

2.4.1 Basic assumptions

In order to analyse and understand the impact of each of these risks, various assumptions or axioms are made in the agricultural economic literature which underly the analyses, namely (Hardaker *et al.*, 2004: 35):

- *Ordering: faced with two risky prospects, a_1 and a_2, a decision maker either prefers one to the other or is indifferent between them.*
- *Transitivity: given three risky prospects, a_1, a_2, and a_3, such that the decision maker prefers a_1 to a_2 (or is indifferent between them) and also prefers a_2 to a_3 (or is indifferent between them), then the decision maker will prefer a_1 to a_3 (or be indifferent between them).*

- *Continuity: if a decision maker prefers a_1 to a_2 and a_2 to a_3, then there exists a subjective probability $P(a_1)$, not zero or one, that makes the decision maker indifferent to a_2 and a lottery yielding a_1 with probability $P(a_1)$ and a_3 with probability $1-P(a_1)$.*
- *Independence: if the decision-maker prefers a_1 to a_2 and a_3 is any other risky prospect, the decision maker will prefer a lottery yielding a_1 and a_3 as outcomes to a lottery yielding a_2 and a_3 when $P(a_1) = P(a_2)$."*

Based on these axioms, Daniel Bernoulli proposed a principle called the Subjective Expected Utility Hypothesis (Hardaker *et al.*, 2004: 35). The principle states that for a decision-maker for whom these axioms hold, a utility function U exists which has the following characteristics:

a) *If a_1 is preferred to a_2, then $U(a_1) > U(a_2)$ and vice versa.* The implication is that risky options faced by the decision-maker can be ordered according to the preferences of the decision-maker.

b) The expected utility of a risky option is its utility, hence $U(a_k) = E[U(a_k)]$ where $U(a_k) = \sum_j U(a_k |S_j)P(S_j)$ for a discrete distribution of outcomes. For a continuous outcome distribution function it is expressed as follows: $U(a_k) = \int U(a_k |S_j)P(S_j)$. The implication of these two utility equations is that higher order moments such as variance are not introduced into the choice between risky options, which implies that the choice between risky options hinges on the expected outcome and not the potential variability underlying the choice (Hardaker *et al.*, 2004).

c) The utility function, U, is defined as a positive linear transformation. The implication of this point is that it limits the way in which utilities can be interpreted and compared, since the origin and scale of the function is arbitrary (Hardaker *et al.*, 2004).

Based on the above description of the axioms and the resulting properties of the utility function, Hardaker *et al.* argue that it implies a unified theory of preferences and beliefs - preference is quantified by means of utility, and belief is quantified by means of probabilities, whether objective or subjective. Through this unified theory, it is possible to guide or prescribe to a decision-maker which option to choose when risk is present, by means of combining the decision-maker's beliefs and preferences. This is an important point, as nobody knows what the future holds and therefore cannot claim to be making the correct choice; the only thing that can be done is to make a good choice. A good choice is defined by Hardaker *et al.* (2004: 25) as a choice that is consistent with the decision-maker's beliefs about the risk faced when making the decision, and also with the decision-maker's preferences in terms of different consequences as a result of the choice being made. This approach to decision analysis, where the beliefs and preferences of the decision-maker are used to guide the decision-making process, is termed the prescriptive approach towards decision analysis (Hardaker *et al.*, 2004:36).

2.4.2 Probabilities and correlation

A key component of the prescriptive approach towards decision analysis or risk analysis, is probabilities. Probabilities are used to communicate or include the impact of risk on a decision by means of using it to understand the potential consequences should a specific choice be made. Probabilities can either be objective or subjective. According to Hardaker *et al.* (2004:38, 39), objective probabilities are founded in the view that probabilities should be based on a relative frequency ratio that stems from a large body of data on that specific variable. Hence, by using the data set, it is possible to calculate the potential occurrence of a specific value of the relevant variable. However, underlying structures and inter-relationships change, causing these frequencies to change over time. Hence, using the same body of data to calculate relative frequencies might not be accurate any more, due to underlying changes in the system. In such a case, Hardaker *et al.* argue that one should rather use subjective probabilities, which is defined and set up by making use of the subjective beliefs of the decision-maker about the potential occurrence of a specific event. This implies that the probabilities are based on the decision-maker's perceptions about underlying causalities and trends, and how these forces will play out in leading to the eventual outcome.

Several methods exist to elicit subjective probabilities from a decision-maker in order to incorporate it into the decision problem. A general approach called visual impact methods include probability trees, allocation of counters, and a reference lottery. The triangular distribution method can be used in the case where the decision-maker has clear beliefs about the lowest, highest and most likely value for a specific variable. In the case where data is available and the decision-maker is confident that the data does represent the current and future environment relatively well, statistical techniques can be used to calculate probability distributions. These can be used by the decision-maker to form an opinion on the probabilities faced. Along with statistical analyses, expert opinion can be used as an input for the decision-maker to form an idea on the potential probabilities faced in taking the decision. All of these probabilities can be updated by means of using Bayes' Theorem, which assists decision-makers in updating these subjective probabilities based on newly obtained information.

To run stochastic simulations with the various types of models as described in ection 2.4.3, two different sampling methods can be used, namely, Monte Carlo sampling and Latin hypercube sampling. These sampling methods are used to generate values based on pre-specified input distributions (Hardaker *et al.*, 2004:158). The mechanics of a stochastic simulation model are specified, based on a set of equations and inter-relationships. Each time the model is solved, a different set of values is generated by means of the sampling method underlying the model. This set of values is generated based on a specified structure in terms of the inter-relationships between the different variables. For example, when a high oil price is generated by means of the sampling method, a high fuel price also needs to be selected, since both these variables are directly and positively correlated. The same holds for above-normal rainfall and above-normal yields, except when rainfall is excessive and the crops actually begin to drown. Hence, as a result of drawing a different set of input variables, different outcomes to the model are simulated. This results in probability distributions being simulated for the respective key output variables. These probability distributions can be used by the decision-maker to form an idea of the underlying probabilities of various events, as well as the probability of the occurrence of potential consequences, especially negative consequences. Based on this information, the decision-maker can make a much more informed decision on what action to take.

Mathematically, there is a difference between the Monte Carlo sampling technique and the Latin hypercube technique. One of the most frequently used outputs of a sampling technique is a Cumulative Distribution Function (CDF). The CDF indicates what the probability of P is, so that the variable X will be less than or equal to x. Mathematically, it is expressed as follows:

$$F(x) = P\ (X \leq x) \tag{1.1}$$

Where: F(x) ranges from zero to one

The Monte Carlo technique firstly calculates the inverse of function 1.1, and secondly uses the inverse function to draw a specific probability from a sample. The drawn probability is then fed into the inverse function to calculate the matching x value. Mathematically, the inverse function is expressed as follows:

$$x = G(F(x)) \tag{1.2}$$

In the case where a large sample is taken in terms of probabilities, a large sample of x values will be calculated. These should represent the original distribution quite accurately. Because this sample is generated by picking uniformly distributed values F(x) between zero and one, it means that every value of F(x) between zero and one has an equal probability of being picked. The problem with this is that it leads to samples of x being drawn from the more dense part of the distribution, implying that only with a very large sample is one likely to recreate the original distribution accurately. This implies that in the case where only a small sample can be drawn, Monte Carlo simulation is not likely to generate an accurate distribution of the original distribution, leading to inaccurate results and potentially bad decisions. This led to the development of the Latin hypercube sampling technique.

The Latin hypercube sampling technique works on the same principle as Monte Carlo in terms of taking the inverse of the function and then drawing x values accordingly. The difference between Monte Carlo and Latin hypercube is that Latin hypercube divides the CDF into *n* intervals, which have equal probability to be drawn. Secondly, sampling without replacement takes place. This implies that each observation can only be drawn once. The result of using Latin hypercube is that the original distribution can be recreated fairly accurately with only a small sample being drawn. In the case of a very skew original distribution, Latin hypercube does not recreate an even more skewed distribution, but rather an accurate representation of the original. This implies that Latin hypercube can recreate the original distribution more efficiently than Monte Carlo sampling (Hardaker *et al.*, 2004: 167).

The most important advantage of using Latin hypercube is that it regenerates the tails of distributions more accurately, implying that outlying events with low probabilities of occurrence are still included in the regenerated distributions. This is important because events that are outliers (with low probabilities of occurrence) are normally the events that wreak havoc in the business and policy environment. Examples include a hundred-year drought or flood, or, an oil price of $200/barrel. Events such as these are extremely important to take cognisance of during the planning process, since their occurrence can lead to the policy or business strategy becoming obsolete, causing the firm or sector to experience disastrous times. By using Monte Carlo, events such as these tend to disappear from the 'radar,' implying that if it is not included in the decision-making process, significant risks are unknowingly taken by the decision-maker.

Another key challenge in stochastic simulations is how to take account of inter-relationships between risk factors. To explain this point, rainfall is often a key risk variable since it influences crop yields. In the case where above-average rainfall occurs (without detrimental affect on crops), the sampling technique needs to draw an above-average yield too, in order to represent reality as accurately as possible. Several techniques exist which offers this function, namely, the hierarchy of variables approach, use of historical data and lookup table, using a correlation matrix, and using copulas. Since a correlation matrix is most often used to represent the underlying inter-relationships between key variables in a system, it will be discussed. The other three methods are less commonly used at this point in time.

Correlation measures the stochastic dependency between two or more variables. This is done by means of analysing the dependency between the first-order co-moments of two or more variables, namely, the covariance (Hardaker *et al.*, 2004: 170). This can be done by analysing the inter-relationships (assuming it is linear) between two or more variables by means of linear correlation, or analysing the inter-relationships (assuming it is non-linear) by means of rank order correlation. Linear correlation seldom works as inter-relationships are more frequently non-linear than linear; secondly, mathematically, it is not possible to draw linear relationships when the respective functions of the different variables are non-linear. In such a case, rank order correlation is used.

Rank order correlation analyses the relationship between two or more variables by looking at the rank of the values of each variable within their different distributions. Hence, rank correlation does not use values to calculate correlations, as is the case of linear correlation, but rather looks at ranking of values. The implication is that stochastic dependency might not always be reflected correctly by rank correlation, as ranks are used, which infers that some information in the data (in terms of dependency) gets lost.

Another method to analyse stochastic dependency is to use copulas. A copula unites two or more marginal distributions, and through that analysis, the stochastic dependency between two or more variables in a more complete manner. It does not just look at covariance or ranks, but also includes more levels of stochastic dependency (Hardaker *et al.*, 2004:172).

2.4.3 Risk analysis methods

A review of literature indicates that risk analysis in agricultural economics can be divided into two main literary bodies, namely: the analysis of risk in terms of its impact on aggregate supply, demand and prices, and the analysis of risk impact in terms of decision-making on individual firm level, based on risk preference assumptions. Since this thesis focusses on risk analysis of agricultural commodity markets, only the body of literature applicable to this perspective will be reviewed[2].

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[2] A large body of South African literature on risk in agricultural economics exists. However, not all focus on the analysis of the impact of risk on aggregate markets, nor utilise a specific risk analysis

The body of literature on risk analysis from an aggregate perspective can be divided in three sub-areas, namely: regression modelling, time series econometrics, and mathematical programming. The remainder of this section will review literature on each of these sub-approaches with the aim of selecting an approach and within that approach select a specific model which exists at the point in time of writing this thesis that can be used to test the hypothesis.

2.4.3.1 Regression modelling

Just (2001) describes alternative levels of econometric model specifications that include some form of risk, and which have been used to model and therefore simulate aggregate economic systems and the impact of risk on the aggregate system in terms of demand, supply and price impacts. He defines these different model specifications as static specifications. With static, he implies model specifications that do not adjust over the sample or prediction period, based on actual underlying structural changes that occur or which could potentially occur (Just, 2001: 1131 – 1138).

a) Static models with static parameters

Static models with static parameters are described as models of the form $y_t = f(x_t, \varepsilon_t|\theta)$, where:

y_t is a vector of observed endogenous variables at time *t;*

x_t is an observed vector of exogenous variables at time *t;*

θ is a fixed vector of unknown parameters which implies *f* has a fixed form throughout the sample and prediction period; and

ε_t is a vector of unobserved random disturbances with a static distribution determined by parameters also in θ. Thus, ε_t incorporates risk in the modelling framework.

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technique as reviewed in this thesis. Hence, the research will not be included in the review. This includes the work of Mac Nicol, Ortmann, and Ferrer (2008); Jordaan and Grové (2008); Geyser and Cutts (2007); Grové (2006); Gakpo, Tsephe, Nwonwu, Viljoen (2005), and Viljoen, Dudley and Gakpo (2000).

According to Just, this model specification implicitly represents simultaneous equation models where $y_t = f(x_t, \varepsilon_t|\theta)$ is the reduced form. This type of modelling specification is often used in agricultural economic literature to study economic systems from an aggregate perspective, and to model the impact of risk in terms of supply, demand, and prices.

b) Dynamic models with static parameters

The typical modelling specification of dynamic models, according to Just (2001), are: $y_t = f(y_{t-1}, x_t, \varepsilon_t|\theta)$. The specification implies that although y_t is a function of y_{t-1} and is therefore dynamic, the parameters in terms of θ remain static, implying that the model structure does not change as changes occur in the market system environment. The error term ε_t again captures the stochastic nature of the system.

c) Dynamic models with unobserved static variation

According to Just (2001), these types of models are specified as $y_t = f(y_{t-1}, x_t, \varepsilon_t|\theta_t)$ where $\theta_t = g(z_t, \delta_t \mid \omega)$.

z_t is an observed vector of exogenous or predetermined variables;

δ_t is a vector of unobserved random disturbances with a static distribution determined by ω;

ω is a fixed vector of unknown parameters implying that g has a fixed form throughout the sample and the prediction period.

Thus, as written by Just, θ_t implies varying parameters which represent both unknown parameters and also unobserved exogenous variables.

Just (2001:1138) indicates that models of this specification typically include random parameter models (which are less common according to him), and switch regression models. Switching regression models are typically regime switching models that simulate an economic system based on fixed specifications of the switching process, and fixed specifications of the alternative regimes.

d) Dynamic models with unobserved stochastic evolution

Just indicates that models of this specification have the form $y_t = f(y_{t-1}, x_{t,}, \varepsilon_t|\theta_t)$ where $\theta_t = g(\theta_{t-1}, z_{t,}, \delta_t \mid \omega)$. This implies that the parameters evolve over time, and therefore, such models could simulate some form of evolution in an aggregate market.

e) Dynamic models with unobserved exogenous change

Models with this specification include some stable and potentially dynamic relationships where an unknown parameter(s) or unobserved exogenous variable(s) can change so that it cannot be described by estimable specifications or stochastic processes.

Various examples of the types of models in especially categories *a*, *b* and *c* are found in the South African agricultural economic literature, as well as international literature. In recent South African literature, regression modelling that includes some form of risk have been used by Breitenbach & Meyer (2000); Meyer & Kirsten (2005) and Meyer, Westhoff, Binfield & Kirsten (2006)[3].

Breitenbach & Meyer (2000) developed a partial-equilibrium model in order to model fertiliser use in the grain and oilseed production sectors of South Africa. The model was used to analyse the potential impact of changes in the physical and economic environment on production of grains and oilseeds, and the resulting impact on fertiliser use. Different 'scenarios' were modelled, and results indicated that the total area under cultivation decreased and appears to have moved closer to the expected optimum production pattern. This results in lower production levels and also lower exports. As a result of the decrease in the area under cultivation, fertiliser use also decreases. The modelling framework includes supply, demand, and a link between demand and supply in order to simulate market equilibrium, as well as risk, by means of including gross income

[3] Another recent example of econometric modelling based research in South African literature is the work of Sparrow, Ortmann & Darroch (2008). Their paper is however not discussed since it does not analyse an agricultural commodity market from an aggregate perspective.

variations. Gross income variations were deflated and used as a measure of risk, and risk was assumed to be an additional cost, which means the supply curve shifted to the left. Shortcomings of the study indicated by the authors are that modelling results were only as reliable as the input data, and stepped demand functions were not used. This could have resulted in different equilibrium results. Also, the model was validated by comparing actual modelling results with current market situations, implying that the assumption was made that future market situations will be structurally similar to current situations, hence making the model accurate in terms of simulating the future market conditions. This, however, is not correct, since future market structures are not necessarily a direct function of past or present market structures, as argued in the introduction of this thesis.

Meyer & Kirsten (2005) present a partial-equilibrium model of the South African wheat sector, and use the model to create a baseline projection in terms of the supply and use of wheat in South Africa for the period 2004 to 2008. The model is also used to analyse the impacts of different policy alternatives on the wheat sector for the same period. The result of the study indicates that the areas cultivated in both the summer and winter rainfall areas, are likely to decrease over time as a result of higher prices of substitute products such as sunflower. This results in farmers more readily planting alternate crops (such as sunflower) than wheat. Other results of the study indicate that, should the import tariff on wheat be eliminated, domestic prices will decrease as a result of cheaper wheat imports; this will therefore lead to a further decrease in the cultivated wheat area in both the summer and winter rainfall regions. Shortcomings of the specific study are that not all cross-commodity interactions are taken into account, and the future projections are based on a limited set of assumptions. These assumptions include factors that will influence the future wheat price, such as: the exchange rate, the international wheat and sunflower prices, the gross domestic product deflater, and population. Should any of these assumptions change as a result of a significant structural change, the baseline would be incorrect, and hence an incorrect deduction (in terms of the impact of changes in policy) might be made, leading to incorrect decisions.

Meyer *et al.* (2006) developed an econometric regime-switching model within a partial equilibrium framework for the South African agricultural sector. The model includes 18 agricultural commodities and consists of 126 behavioural equations, along with a number of identities. The model has the ability to distinguish between different equilibrium conditions within the same market, depending on the domestic demand and supply situation, as well as the external economic and agricultural economic environment relative to the South African agricultural sector.

The three market equilibrium conditions that are simulated by the model are called the import parity regime, near-autarky regime, and the export parity regime. The import parity regime represents a situation where the difference between the import parity price and the domestic price is greater than the transfer costs. This makes arbitrage possible, and hence imports of the specific commodity possible. The implication of the import parity regime is that the domestic price is largely influenced by world prices, the exchange rate, transport costs and all other costs involved in importing the product. Therefore, the domestic price is driven largely by the external macro-economic and agricultural market environment. The export parity regime represents just the opposite situation, wherein the difference between the domestic price and the export parity price exceeds the transfer costs, making it possible (and profitable) for export to take place. This regime again implies that the domestic price is largely driven by external macro-economic and agricultural market conditions. The near-autarky regime represents the situation wherein the domestic price falls between import and export parity prices, and hence prevents significant levels of trade. The near-autarky regime implies that the domestic price is largely driven by the domestic demand and supply situation, and to a very small extent by external macro-economic and agricultural market conditions.

The regime-switching model is used to analyse the impact of a 10% increase in world prices of white maize, yellow maize and wheat, by means of comparing it to a baseline that was simulated by the same model. Results indicate that the level of market integration between the domestic market and the international market do indeed increase in the case of the import or export parity regime, when compared to the near-autarky regime. This supports the argument that different equilibrium conditions exist within the same market, given the domestic demand and supply situation as well as the external macro-economic and agricultural market situation. The authors conclude by stating that this model has already been used by various South African agri-businesses during past production seasons to do market analyses.

Although not highlighted by the authors, a shortcoming of the model and therefore modelling results, is that the baseline projections and 'scenario' projections are based on projections of exogenous factors such as the exchange rate, oil price and world prices. Should the projections on the exogenous factors be incorrect, the results and therefore deductions based on these results might be incorrect, leading to incorrect decisions that are based solely on the modelling results. A major strength of the model presented in the paper is that it accurately simulates different market conditions, and hence does take some form of risk into account, aside from the standard procedure of including risk by means of the error term. Therefore, the model of Meyer *et al.* (2006) is an excellent example of the type of model that Just (2001) refers to as a dynamic model with unobserved static variation. This makes the model of Meyer *et al.* (2006) more advanced - from a risk analysis perspective - than the models presented by Breitenbach & Meyer (2000) and Meyer & Kirsten (2005).

In international literature, several recent examples are cited where some form of regression modelling (that includes risk) has been used to analyse an aggregate market system. Examples in the literature include the work of Binfield *et al.* (2002); Barrett & Li (2002); Westhoff *et al.* (2005); Koizumi & Ohga (2006); Cutts, Reynolds, Meyer & Vink (2007); Tokgoz, Elobeid, Fabiosa, Hayes, Babcock, Yu, Dong, Hart & Beghin (2007); Elobeid, Tokgoz, Hayes, Babcock & Hart (2007) and Baker, Hayes & Babcock (2008).

The review of both the South African and international literature - where regression modelling has been used with some form of risk included in order to analyse agricultural commodity markets - reveals the following strengths and weaknesses. Firstly, most of the analyses are based on projections of exogenous factors that influence the specific market that is being analysed. The fact that the actual outcome of the exogenous factors could differ significantly from the projections used in the analyses, increases the risk of making inaccurate deductions based on the modelling results, which could lead to incorrect decisions. Regression models do pose the possibility of drawing erroneous conclusions that might lead to incorrect decisions. A strength, however, of the regression models reviewed is that it is fairly accurate in terms of representing actual inter-relationships and trends based on historical data. This makes these models highly applicable in terms of understanding the underlying causality structures and inter-relationships that could cause variation in the market and therefore the economic system. Hence, this type of model does add significant value in analysing the impact of different types of risk on a market system. The fact that the model structure is based on historical data, implies that the regression model might not accurately simulate the same market system in the case of a significant structural change, hence creating a dilemma for the modeller and decision-maker in determining how to use the model. However, since most of these models are built in a fairly 'free' form by means of statistical relationships and coefficients, it is easy to adjust the structure of the model as needed, based on perceived structural changes, thereby improving the model through time to more accurately reflect reality. This, however, creates statistical theoretical problems since correct estimation procedures are not followed in the case where the structure of the model is adjusted 'by hand' and based on expert opinion.

2.4.3.2 Time series econometric modelling

Another general approach found in the agricultural economics literature that deals with risk analysis from an aggregate perspective, is the use of time series econometric modelling. Several sub-approaches to time series econometric modelling exist, namely: autoregressive integrated moving average (ARIMA); vector autoregression (VAR) models (Gujarati, 1995); Bayesian VAR, and flexible combination models (Colino, Irwin & Garcia, 2008).

Time series econometric modelling originated out of the need to understand and simulate aggregate economic systems, given that changes in underlying structures such as policy frameworks do take place. Hence, econometric regression modelling was found wanting due to changing structures underlying the aggregate economic systems that were modelled, and hence modellers adopted time series approaches to analyse these systems (Gujarati, 1995: 735).

Time series econometric techniques aim to analyse the stochastic component of an economic time series without imposing any significant economic theory. Hence, it is assumed that the outcome of the economic series analysed is a function of its own past behaviour, as well as a stochastic component (Gujarati, 1995: 735). Otherwise, as stated by Jordaan, Grové, Jooste and Alemu (2007: 306), analysis of such an economic series to determine volatility and therefore risk, needs to take into account both the predictable and the unpredictable components that cause the eventual economic outcome under study.

Examples of South African agricultural economic literature that use time series econometric techniques to analyse risk of a specific economic time series, include the works of: Jordaan *et al.* (2007), Jooste, Alemu, Botha and Van Schalkwyk (2003) and Ghebrechristos (2003). Jordaan *et al.* (2007) used the GARCH approach to analyse the price risk related to different crops traded on the South African Futures Exchange (SAFEX), namely, yellow maize, white maize, wheat, sunflower seed and soybeans. The reason for using the GARCH approach is that the researchers found that volatility of the stochastic component varied over time, implying that heteroskedasticity is present. The researchers found that the price volatility of white maize was the greatest, followed by yellow maize, sunflower seed, soybeans, and wheat. The researchers concluded that risk averse farmers would be better off farming wheat, sunflower and soybeans based on price risk, since the risk is much lower when compared to white and yellow maize. The researchers therefore recommend that farmers who farm white and yellow maize should use price risk management tools such as forward pricing or options in order to mitigate the price risk. They argue that the volatility in maize prices is difficult to predict and therefore the possibility of losing money if price risk management does not take place, is quite significant. Since the aim of the study was simply to quantify and compare the volatility of the respective crop prices, the cause of the variance in volatility levels over time is not analysed. The study concludes that further research needs to be done, since the underlying causalities of the economic system or series under study needs to be understood in order to support and facilitate policy and investment decision-making. (No indications are given by the authors on how and when such research will be conducted.)

In the international agricultural economic literature, time series econometric techniques have been used to analyse risk of an aggregate economic system by means of analysing an economic time series. Examples include the work of Colino *et al.* (2008), Ramírez and Fadiga (2003), Haigh & Bryant (2000), and Kroner, Kneafsey, Claessens (1993).

Colino *et al.* (2008) compare the accuracy of hog price forecasts released by Iowa State University with alternative market and time series forecast techniques such as univariate time series representation, VAR, Bayesian VAR, as well as other specifications designed to allow for instabilities in market relationships. Their findings indicate that VAR and Bayesian VAR do outperform the Iowa outlook estimates, but they indicate that forecasting success remains limited due to volatile markets. Ramírez & Fadiga (2003) compare the performance of an asymmetric-error GARCH model to that of normal-error and Student-t-GARCH model by applying the different models to forecast US soybean, sorghum, and wheat prices. Their findings indicate that the asymmetric-error GARCH and t-GARCH models perform better with the error term than GARCH, which appears as non-normal. Their findings indicate that although the t-GARCH and a-GARCH models do provide more reliable results, problems still occur in terms of capturing non-normality sufficiently, which could lead to incorrect forecasts.

Haigh & Bryant (2000) use a multivariate GARCH-M model to determine the impact of volatility in barge and ocean freight prices on international grain market prices. Their findings indicate that volatility in ocean freight prices influence volatility in international grain prices to a lesser extent than barge freight prices. The authors conclude by speculating that the possible reason for these findings is that no futures contracts exist for barge rates, while futures contracts do exist for ocean freight rates. Important to note is that through their research, some conclusions can be drawn on the impact of risk, but no underlying causality structures could be determined. The researchers could only speculate on what the underlying causes could be for the observed risk impacts. Kroner, Kneafsey, Claessens (1993) propose a combined approach to derive probability distributions for forecasting agricultural commodity prices, and advocate combining market expectations with options prices and time series modelling. Their findings indicate that some forecasting improvement does occur when their proposed combined approach is used.

From the overview of the literature, two major shortcomings were identified. The first is that the model structures specify that future variance is a function of the weighted long-run average variance; the variance predicted for the current period of estimation and new information that is captured by the most recent squared residual (Engle, 2001), implies that the outcome of the model should mostly be a function of past and present data. This is confirmed by Engle (2001: 160) who states that with a long-run forecast, a GARCH model is mean reverting, conditionally heteroskedastic, and has a constant unconditional variance. The problem with this is that in a fast-changing and turbulent environment, a structural shift often occurs in the long-run, implying that the long-run average up till present is not applicable any more in terms of the newly formed future environment. This is endorsed by Nwogugu (2006: 1736). The author argues that these types of models are based on the assumption of conditionality that stipulates that all conditions and causal factors that existed in period *t* are present in period *t+1*, which is often not the case. In addition, even when the same conditions and causal factors do exist, the intensity, duration, impact and correlation is likely to differ from period *t* to period *t+1*. Thus, a model that reverts to the mean is likely to give an incorrect result in terms of future trends, and since heteroskedasticity is assumed to be constant, the forecasted volatility of the model is also likely to be incorrect when compared to reality. Colino *et al.* (2008) also confirms this point when indicating that published research on price forecasting has decreased significantly during the period 1993 to 2008, due to the fact that the agricultural environment has become much more turbulent and the magnitude and frequency of changes has increased significantly. They argue that this makes accurate forecasting much more challenging as underlying structural changes occur.

The second major shortfall identified in using time series econometrics is that the underlying factors that cause the observed volatility in the economic series are difficult to deduce from the modelling results. This is also confirmed in the writing of Nwogugu (2006: 1740) when the author argues that, due to the under-specification of these types of models, and therefore the limited use of a number of parameters, the error terms cannot be decomposed into causal elements. Hence, the analyst and decision-maker are able to understand the past and present volatility and therefore risk of the analysed economic series, but are often not in a position to understand and deduce the underlying causality structures causing the observed trends and volatility. This point is further confirmed, although indirectly, by Jordaan *et al.* (2007: 321) in the concluding paragraph when addressing potential sources of the observed price volatility, namely: supply and demand; weather conditions; changes in trade volumes; terms of trade shocks, and exchange rates with respect to the commodity prices analysed in their article (done without supplying quantified evidence from the modelling results).

Time series econometrics offer valuable approaches when quantifying risk (in terms of magnitude of economic time series from an aggregate perspective) but is limiting in that it does not inform the analyst and decision-maker about the underlying causality structures that cause the observed risk. Good decision-making not only depends on understanding the magnitude of the risk faced, but also the underlying causality structures that cause the risk. Correctly understanding the potential impact of the risk of a decision, requires more than just time series econometrics.

2.4.3.3 Mathematical programming

Mathematical programming consists of various methods that can be used to solve optimisation problems. An optimisation problem is normally described as a problem wherein an objective function has to be optimised, dependent on a set of constraints. Mathematical programming is often used to analyse on-farm or whole-farm optimisation problems, but also to simulate aggregate market systems in terms of supply, demand, and prices. In such cases, an objective function is described, and then, using the constraints faced by the farm or market such as land availability, soil potential, water availability, labour availability and capital availability, an optimal solution for the system is found.

The problem with finding an optimal solution is often that one does not take risk into account and therefore one might, in actual fact, not have the optimal solution, given that external conditions can change and variability in the constraints can occur. To solve this problem, mathematical programming techniques have been developed to include the impact of risk. Hardaker *et al.* describe two main approaches to include risk in the optimisation problem, namely, risk programming and stochastic programming. Risk programming techniques are used to include non-embedded risk, while stochastic programming is used to include embedded risk (Hardaker *et al.*, 2004: 187). Non-embedded risk is defined by Hardaker *et al.* as arising when a decision is not dependent on previous decisions and resulting uncertain events; embedded risk is opposingly defined i.e. when a decision does depend on both previous decisions as well as outcomes of uncertain events. Hence, to decide which main approach to follow, one has to decide on the nature of the risk faced by the entity, and how it impacts on decisions.

Various methods exist within each of the two main approaches described in the preceding paragraph. Methods included in risk programming are: linear risk programming; quadratic risk programming; MOTAD programming; Target MOTAD programming, and Mean-Gini Programming. Stochastic risk programming includes the technique of discrete risk programming (DSP). Discrete risk programming is used when a decision depends on previous decisions as well as outcomes of uncertain events. To solve a problem such as this, the decision problem is set up in stages that are similar to those of a decision tree, after which each stage is solved in order to get to an optimum. The problem with DSP, as described in Hardaker *et al.*(2004: 203) by Raiffa, is that the problem tends to evolve into too many stages, causing the problem to become too complicated and therefore creating confusion as to what the optimal solution is, given the risks faced.

In terms of risk programming techniques, linear programming is most often used in optimisation problems, and can take cognisance of non-embedded risk quite successfully. The limitation, as indicated by Hardaker *et al.*, is that linear programming does not take account of the situation where the decision-maker is not risk neutral. To mitigate this problem, quadratic risk programming (QRP) has been developed to include the risk aversion coefficient, which represents the decision-maker’s attitude towards the risks faced. To solve models such as these, different types of programming software can be used to solve the non-linear relationships. Examples of such software are the General Algebraic Modelling System (GAMS), and Lingo. The assumptions underlying QRP, according to Hardaker *et al.*, is that the decision-maker's utility function is quadratic, or the distribution of total net revenue is normal. As argued by Hardaker *et al.*, these assumptions do not always hold, since total net revenue is seldom distributed normally, and quadratic utility functions are not increasing at all points. In addition, using it implies absolute risk aversion is increasing. This is not always the case.

A number of examples exist in the South African agricultural economics literature where mathematical programming that includes risk, has been used to analyse an aggregate market system. This includes the work of Ortmann (1988), Van Zyl, Vink, Townsend and Kirsten (1998) and Esterhuizen, Van Zyl, and Kirsten (1999).

Ortmann (1988) developed a linear programming model that included negative-sloping demand functions for crops, and positive-sloping supply functions for labour and production risk, by means of using variance-covariance matrices. The model was developed for the South African sugar industry, and regions included the Eastern Transvaal/KaNgwane (now Mpumalanga province), Pongola/Jozini/Makatini, Zululand, and Natal (now Kwazulu-Natal province). In the model, the regional demand curves for tomatoes, cucumbers, green beans, gem squash, hubbard squash, bananas, pawpaws, mangos, litchis, guavas, dry beans, and cotton were estimated. Regional labour supply curves were also estimated. Risk was included by using the mean absolute deviation method. This was done by relating enterprise price elasticity and yield variability to income variability, and including that in the objective function under the assumption that distributions are normally distributed, and that the objective function is linear. Modelling results were compared to actual cropping patterns, actual land rentals, and actual crop prices to validate the model. Results indicated that the model accurately simulated all three of the above-mentioned aspects in the comparison.

Van Zyl *et al.* (1998) also developed a linear programming model based on the model structure used by Ortmann (1988), in order to estimate the effect of market liberalisation on production, employment, price, and welfare impacts in the agricultural sector of the Western Cape province of South Africa. Risk was included in the model by using Minimisation of Total Absolute Deviations (MOTAD), which is similar to the technique used by Ortmann. Six years of historical data, namely, 1983 to 1988 were used as a basis for deriving probability distributions for prices and yields in order to simulate production risk. The model was validated by comparing production levels of crops (in terms of hectares or livestock numbers), with simulation results from the model. It was found that the modelling results compare relatively accurately with actual numbers for the year 1988, which is the base year for the model. The year 1988 was selected as the base year because the researchers argued that it was a fairly 'normal' year. (No reasons are given by the authors as to why they thought it was a 'normal' year.) Results indicated that market liberalisation could have a significant impact on prices, especially where extensive market intervention takes place, namely, with grain and livestock. In the case of vegetables and fruit, it was found that market liberalisation does not have such a significant impact, since these industries were not influenced by market intervention to the same extent as grain and livestock. Hence, the vegetable and fruit industries were perceived as being much more globally competitive in agricultural markets.

The model developed by Esterhuizen *et al.* (1999) was used to analyse the operation of the most important stockfeed proteins in South Africa, with regards to demand and supply. This included products such as maize, wheat, sorghum, oilseeds and fishmeal. The model developed and used by the researchers was similar to that developed by Ortmann (1988) and Van Zyl *et al.* (1998), and also made use of MOTAD to include risk in the modelling exercise. The model covered the nine provinces of South Africa, and the assumed base year for the model was the 1995/96 production year. Time series data for the period 1990/91 to 1995/96 was used to set up the risk distribution functions, while cross-sectional data was used to set up the structure of the model. Validation of the model was done by means of comparing modelling results to actual data for specified variables such as production and prices. The model was used to simulate different outcomes of various selected factors such as: a drought; a general increase in production costs; an increase in transport costs; a change in the yield and production costs of yellow maize, and an increase in the yield and price of soybeans. Each of these situations that were analysed was called a 'scenario.' Results indicated that the model is quite useful in understanding the impacts of exogenous variables on the aggregate system being studied.

In international literature, various examples exist where mathematical programming models have been used to analyse an aggregate market system. Examples include the work of Butt & Mccarl (2005), which has already been reviewed and discussed in chapter one of this thesis, and Olubode-Awosola, Van Schalkwyk, and Jooste (2008). Olubode-Awosola *et al.* use an extended version of the standard Positive Mathematical Programming (PMP) model calibration approach to analyse the potential impact of land redistribution on the production of crops and animal products. The study uses the Free State province of South Africa as a case study. The data and model is validated by means of using expert opinion, as well as comparing model results with actual data on specified variables. The researchers found that the model simulates the actual economic system accurately. Findings indicate that as the number of large farm units decrease, the number of small farm units increase, as a result of the assumed land redistribution policy modelled. This resulted in a general decline in total production levels of crops and livestock products - the decline in production due to the decline in large farm units overshadowed the increase in production attributed to the increased small farm units. This effect is especially apparent in the case of capital-intensive production activities such as soybeans, wheat, sorghum, sunflower seed, broiler operations and layer operations. The researchers conclude that the South African government needs to balance equity with efficiency in a free market economy when designing a land redistribution policy.

The overview of the different mathematical programming models show that mathematical programming is useful in analysing the impact of demand, supply and prices on an aggregate market. Mathematical programming models tend to have extensive range in terms of the number of inter-relationships and equations that can be included. This makes mathematical programming very useful in the sense that underlying causality structures can be captured accurately and with a lot of detail, making it an ideal technique to study the impact of risk on aggregate market systems (Van Zyl *et al.*,1998:83). However, this means that mathematical programming models can be very demanding – many data inputs are needed to estimate the various parameter values. Also, in many instances, assumptions need to be made on causality structures simply due to a lack of accurate or timely data. This causes the modelling exercise to be highly reliant on expert opinion and other sources to ensure that modelling results accurately reflect reality (Van Zyl *et al.*, 1998: 83; Olubode-Awosola *et al.*, 2008: 847 - 848).

2.5 Conclusion

The discussion of the various methods of formal risk analyses clearly highlights, in broad terms, the various advantages and disadvantages of each method. As clearly illustrated in chapter one, the environment into which the agricultural sector is moving, is one of increasing volatility and therefore risk. However, given the potential increase in volatility, underlying structures and inter-relationships between factors are likely to change over time and possibly at irregular intervals. This implies that the method or combination of methods used to analyse risk needs to be flexible and adaptable in order to keep up with these structural changes.

Decision-makers need tools that can map changes in inter-relationships and structures as they happen. From the description of the various decision analysis techniques, it is clear that regression modelling offers this capability. It provides flexible and mathematically and economically rigorous analysis, that is virtually independent of intuition. However, it is not as structured as mathematical programming in the sense that it relies on very specific assumptions about functional form, and linearity or non-linearity in inter-relationships, which makes it a bit more flexible (but less rigorous) than mathematical programming. Regression is also more structured with regards to revealing the underlying causality structures compared to time series econometric analysis, making it more useful when analysing risk. Therefore, regression modelling, and specifically the model of Meyer *et al.* (2006) will be used in the remainder of this thesis to test the hypothesis. Other reasons for selecting the model of Meyer *et al.* (2006) is because it simulates the South African yellow maize price from a national perspective which is needed for presenting the case studies in chapters five and six, and also includes interaction with other grain crops, livestock sectors, the macro-economy, the policy environment and the natural environment. It has also been shown that the model of Meyer *et al.* is based on the model typology presented by Just (2001) and is significantly advanced in relation to other regression models in South African literature. Hence it is quite suitable to do risk analysis in the South African agricultural commodity market.

A major shortcoming, however, as indicated throughout this chapter, is that all types of models used in agricultural economic risk analysis, use historical data to derive underlying causality structures or to understand risk. Risk is also included by means of objective or subjective probabilities, as explained. In the case where subjective probabilities are used, agricultural economists tend to argue that both risk and uncertainty are included in the analysis. This links up to the argument made by Valsamakis *et al.* (1996: 24) which proposes that when considering the definitions of risk and uncertainty, one should rather focus on the similarities between the two concepts. Valsamakis further argues that the interpretation of risk and uncertainty should rather be based on a situation in which certainty is absent.

This argument is, however, flawed, since a fundamental part of decision-making lies in correctly identifying and analysing risk AND uncertainty. In order to identify and analyse both risk and uncertainty effectively, one needs to use the correct approaches or tools. However, using the correct tool depends on whether one is working with risk or uncertainty. A clear distinction should be made between risk and uncertainty, and it should be based on whether causality can be determined and is still relevant or not, and therefore whether probabilities (subjective or objective) can be assigned to different outcomes. In the case where probabilities can't be assigned, and causality can't be determined nor understood, uncertainty per definition does exist. Consequently, different tools need to be used to understand and manage uncertainty. The following chapter defines and discusses uncertainty, and presents a tool that can be used to analyse uncertainty in a fundamentally more correct and comprehensive fashion than by just assigning subjective probabilities.