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Essays on risk management applications to Appalachian grass -fed beef

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**ESSAYS ON RISK MANAGEMENT APPLICATIONS TO APPALACHIAN
GRASS-FED BEEF**

By
MAITREYI MANDAL

Dissertation submitted to the
Davis College of Agriculture, Natural Resources and Design
At West Virginia University
In partial fulfillment of the requirements for the degree of

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In
Natural Resource Economics

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ABSTRACT

ESSAYS ON RISK MANAGEMENT APPLICATIONS TO APPALACHIAN GRASS-FED BEEF

By

Maitreyi Mandal

The study area of this dissertation is the Appalachian state of West Virginia, where pasture-based livestock has traditionally dominated the state's agricultural production sector. Enhanced production risk has been identified as one of the key risk factors in grass fed beef production. This study aims to look into various risk management options that are available to grass-fed beef producers. One such management option is the various livestock insurance and rangeland, forage and grass land protection policies recently introduced and marketed by the Risk Management Agency (RMA) of USDA. The Livestock Risk Protection Plan (LRP) has been available to West Virginia cattle producers since summer 2006. This plan is uniquely aimed towards price protection. At the same time, two types of rangeland forage and pasture land protection policies have also been introduced by RMA, namely rainfall index and vegetation index based protection policies. These policies may help mitigate production related risk. A brief internet-based survey was conducted in early summer 2009 of various grass-fed beef producers who market their product electronically in neighboring states including West Virginia, Virginia, Pennsylvania, Kentucky, and Maryland to understand their perception of risk related to grass-fed production. It was found that drought or lack of rainfall is a major concern in their production related activities, an issue that further justified the need for this study. The latter consists of three distinct, but interrelated, essays, all oriented toward a better understanding of

the causes, effects, and management of production risk in pasture-beef production settings.

Stochastic dominance was the main tool used in the first and second essays to analyze various risky alternatives.

In the first essay, stochastic dominance analysis was used to understand LRP and price risk as may be faced by a grass-fed producer in West Virginia. It was found that in the current scenario, a high basis exists between the AMS 5 market selling price (on which the indemnity payouts are based) and the local cattle auction markets of Virginia and Pennsylvania. Due to this high basis, this LRP may not be suitable to these producers as offered currently.

The second essay deals with production risk and the rainfall index based protection policy of RMA. It was found that though this policy indeed helps to mitigate a certain part of production risk, managers of pastureland should have a thorough understanding of the nature of indemnity payouts. However, this insurance is not yet available in West Virginia. Hence, the study was conducted with Pennsylvania hay trial plots, using data provided by the WVU Agronomy Department.

As discussed earlier, in our e-mail based survey, it was found that drought or lack of rainfall is the major concern for most producers in Appalachia. Accordingly, in the third essay, a unique rainfall/precipitation based option contract was structured to assist businesses better manage rainfall/precipitation related risks. This unique precipitation based call/put option can be exploited by relevant businesses who suffer loss from either too little or too much precipitation. It was further found that there are indeed interested players in the capital market (e.g. Goldman Sachs commodity risk management; Phibro commodities trading firm; etc.) who are willing to underwrite the risk and provide such (rainfall call/put) risk management options to a broad range of businesses including grass-fed producers. This rainfall call/put, when made available through

the capital market (underwriter) either as over the counter (OTC) or exchange (CME) traded, would provide yet another weather related risk management option to businesses in West Virginia affected by too much or too little rain fall/precipitation.

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Sincere thanks also go to Dr. Chuck Moss, Professor, Food and Resource Economics Dept., University of Florida. It was his class in Risk Analysis (AEB 6182) that provided the idea of using stochastic dominance in this analysis. Similarly, special mention needs to be made of Haas School of Business, University of California at Berkeley (UCB). After attending a presentation by Weather Bill (www.weatherbill.com), a firm which provides weather related insurance coverage, at The Masters of Financial Engineering (MFE) lab, Haas/UCB on 2nd October, 2007, provided the inspiring idea to work on weather derivatives. Computational finance/Financial Engineering is the area I am highly interested to study further. Also, I am indebted to the following companies for providing derivatives-related data used in this analysis: Goldman Sachs (Commodities Desk, NYC/London); Travelers (Hartford, CT); Phibro (Westport, CT);

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RELATIONSHIP AMONG THE THREE ESSAYS

Risk management is defined (by the ISO 31000, for example) as the effect of uncertainty on objectives (whether positive or negative). Risk management can therefore be considered as the identification, assessment, and prioritization of risks followed by the coordinated and economical application of resources to minimize, monitor, and control the probability and/or impact of unfortunate events or to maximize the realization of opportunities. In this particular dissertation, a few aspects of risk, as perceived by grass-fed beef producers of Appalachia, have been identified, and the appropriateness of corresponding risk mitigation/reduction strategies through either purchase of government-offered insurance policies or unique market based instruments such as weather derivatives, have been evaluated. Grass-fed producers often have the dual role of both cattle-raiser and pasture/hay producer. In the first role, like any other producer, they face market/price risk. So, in the first essay, the role of the government-offered livestock risk plan which is a unique policy aimed towards protecting cattle producers from market risk, has been analyzed. The second essay analyzes the second role of these producers, which is as a hay producer. Finally, the third essay, examines the structuring of a unique financial product, i.e. a rainfall call/put/straddle based on local (West Virginia) weather station data. Weather-based contracts have been recently introduced in the Chicago Mercantile Exchange (CME) and have been growing in popularity, with rainfall contracts (obviously important to agriculturally-based settings) likely to be introduced in the not-too-distant future. In anticipation of this development, a hedging effectiveness strategy based on a structured rainfall contract is evaluated. It was very difficult to isolate the actual amount of revenue loss of these producers affected by too much or too little rainfall. Nonetheless, looking at rainfall-based

derivative pricing is a first step towards structuring a weather based contract which is becoming more and more important in agricultural settings.

CHAPTER 1

PRICE RISK AND LIVESTOCK PROTECTION PLAN (LRP) FROM USDA/RMA: A STOCHASTIC DOMINANCE ANALYSIS

If they give you ruled paper, write the other way
- Juan Ramon Jimenez

1.1 Introduction

Two types of livestock protection plans have been available to West Virginia cattle producers since summer of 2006. Due to the recent volatility in the cattle market, interest in price risk protection has increased. Traditionally, livestock producers have used either forward contracts or futures/options trading to manage this price risk. Livestock Risk Protection Plan (LRP) insurance provides another option that producers can now use to manage price risk. This essay is organized as follows: first, a brief description of both the LRP and Livestock Gross Margin (LGM) plans from the United States Department of Agriculture/Risk Management Agency (USDA/RMA) will be explained as supporting background perspective. Then an empirical model will be developed to determine the applicability of LRP for price risk management of grass-fed beef producers in West Virginia. Finally, we will examine the resulting industry and policy implications.

1.2 Basics of Grass -Fed Beef Production

In contrast to cattle produced via the conventional grain-intensive production system common here in the United States, grass-fed cattle are kept on natural pasture land for an extended period of time after the weaning period and spend no time in feedlots. Since forage-only diets typically contain less digestible energy and protein relative to grain diets, significantly longer periods are

required to produce finished cattle utilizing grass-based systems. Animal performance and, consequently, finish weights of grass-fed cattle are contingent upon the quality and quantity of the forage available. It should be noted that forage availability is directly subject to the vagaries of both weather and other external variables. Spiselman (2006) states that grass-fed cattle generally do not reach a slaughter weight of 750 lbs. and higher until they are 24 to 30 months of age. On the contrary, it is known that grain-finished cattle are generally slaughtered at 14 to 18 months of age weighing 1200 to 1250 lbs., with particularly heavy slaughter activity in September and October of each year.

As per USDA guidelines, cattle marketed as “grass-fed” must meet the following guidelines:

“Grass and forage shall be the feed source consumed for the lifetime of the ruminant animal, with the exception of milk consumed prior to weaning. The diet shall be derived solely from forage consisting of grass (annual and perennial), forbs (e.g., legumes, *Brassica*), browse, or cereal grain crops in the vegetative (pre-grain) state. Animals cannot be fed grain or grain byproducts and must have continuous access to pasture during the growing season. Hay, haylage, baleage, silage, crop residue without grain, and other roughage sources may also be included as acceptable feed sources. Routine mineral and vitamin supplementation may also be included in the feeding regimen. If incidental supplementation occurs due to inadvertent exposure to non-forage feedstuffs or to ensure the animal’s well being at all times during adverse environmental or physical conditions, the producer must fully document (e.g., receipts, ingredients, and tear tags) the supplementation that occurs including the amount, the frequency, and the supplements provided.” (ams.usda.gov)

Grass-fed production may have distinct advantages over conventional grain-based production in terms of market risk, given increased demand for corn from ethanol producers and uncertainty in feed prices. Further, live cattle market prices appear to be much more volatile than retail beef prices (Evans et al., 2007), indicating that producers who avoid marketing live cattle and instead sell harvested beef may experience less year-to-year revenue variability. Despite the apparent drawbacks of grass-finishing, namely lengthy growing periods and enhanced production risk, the resulting beef products have been shown to embody numerous relative benefits for human health, animal welfare, and the environment (Evans et al., 2007).

1.3 Livestock Protection Policies from USDA/RMA

Currently there are two types of insurance programs available.

1.3.1. Livestock Gross Margin (LGM)

The LGM for Cattle Insurance Policy provides protection against the loss of gross margin, which is the market value of livestock minus feeder cattle and feed costs associated with cattle. The indemnity at the end of the 11-month insurance period is the difference, if positive, between the gross margin guarantee and the actual gross margin. The LGM for Cattle Insurance Policy uses adjusted futures prices to determine the expected gross margin and the actual gross margin. Adjustments to futures prices are evaluated using both state- and month-specific basis levels. The price the producer receives at the local market is irrelevant in this price calculation (rma.usda.gov/livestock/). In this essay, we are not analyzing LGM, as typically a grass fed producer raises cattle in pasture and does not feed any grain based diets. So the corn future prices which are used to determine the expected gross margin and the actual gross margin are not applicable in our analysis.

1.3.2. Livestock Risk Protection (LRP)

Under LRP, both feeder and fed cattle are insured against declining market prices. Cattle producers may select from a variety of coverage levels and insurance periods to correspond with the time their feeder steers and fed cattle would normally be marketed. An LRP insurance policy for both the feeder and fed cattle may be purchased throughout the year from approved livestock insurance agents. Premium rates, coverage prices, and actual ending values are posted online daily as found on the USDA/RMA website.

1.4 Basics of LRP

Since this essay deals with LRP, it is pertinent to gain an understanding of how this insurance plan works. LRP is designed to provide producers downside price risk protection. It is also important to distinguish between two types of cattle for which this insurance protects, i.e. feeder or fed cattle.

1.4.1. LRP for Feeder Cattle

Feeder cattle are those within a weight range of 650-850 lbs that are destined for finishing in a feedlot. They are back-grounded on forage or a grain fed diet until they are transported to feedlots or slaughtered. LRP insurance payment or indemnity payments are based on an insured coverage price available at the RMA web site and the actual ending value reflected in the Chicago Mercantile Exchange (CME) feeder Cattle Cash Price Index (CPI). This CPI represents the 7-day weighted average price of 650-850 lb. steers in a 12 state area (CO, IA, KS, MO, MT, NE, NM, ND, OK, SD, TX and WY) (cmegroup.com/trading/commodities/). This CPI is again the same index which is used to cash-settle open CME feeder cattle contracts at expiration. It is believed that this index will generally be very close to CME feeder cattle futures prices. So, in effect, purchasing a LRP policy for feeder cattle is equivalent to buying an insurance policy that pays indemnity protection if the CME feeder cattle cash index (or the CPI) falls below the

insured coverage price. This insured coverage price is based on the expected ending value at the end of the policy as determined at the onset. It results in “nationalizing” the sale price of cattle as the indemnities are based on changes in the feeder cattle cash index, rather than actual changes at the local stockyard (e.g. local cattle auction markets) (McConnell, 2007). It is possible that the local market could drop the overall price, but the CME index stays constant since it is the average of the 12 market price. This is the way it offers price risk protection. However, it is generally observed that the local cattle market and the CME feeder cattle cash index travel in tandem. It is also assumed that the fundamental factors that affect cattle prices in one market should similarly affect cattle in the overall market represented by the CME Feeder Cattle Cash Index (i.e., the 12 state indexes as mentioned earlier). For example, when corn prices increase, downward pressure will occur on feeder cattle prices across all states, as corn is one of the main ingredients in cattle grain feed. However, after consulting with beef experts in the local region (Dr. Evans and Dr. Rayburn), it was found that there could be times when prices in West Virginia (WV) do not move perfectly with western cattle prices represented by the index. In an informal e-mail based survey it was found that, during the past few years local pasture beef producers had endured consecutive droughts. This may increase supply in WV markets as lack of forage pressurizes producers to sell their cattle early, causing downward pressure on local prices, while those from other regions could remain unaffected, given the relatively small size of the WV cattle market relative to the national market.

1.4.2. A Simple Example

Let us consider a producer who has purchased an insurance policy with a coverage price of \$105 per hundredweight (cwt). The producer would pay an insurance premium for this policy on the day it becomes effective, and the policy would remain in place until the specified ending date. If the CME feeder cattle cash index price was above \$105 per cwt on its ending day, then the

producer would not receive an indemnity payment. If the index is below \$105 per cwt on the ending date, then the producer would receive an indemnity for the difference. If the CME Feeder Cattle Cash Index Price was \$102 on the expiration date and the producer had insured 700 pound calves, then the indemnity payment would be \$21 per calf $[7 \text{ cwt} * (\$105 - \$102)]$.

1.4.3. Fed Cattle

Actual Ending Value–Fed Cattle

The price of fed cattle that was used is that calculated by the Agricultural Marketing Service (AMS). This report is released once a week. It is based on 5 area (Texas/Oklahoma/New Mexico; Kansas; Nebraska; Colorado; Iowa/Minnesota) market summary. The report used to calculate the actual ending value will be the report from the week that contains the end date for the endorsement. If there is no reported information, then the calculation will be based on the latest report made prior to the end date. This report/price will be refereed as AMS 5 Area market price later in this essay.

1.4.4. How to Purchase LRP?

LRP insurance can be purchased through licensed crop insurance agents. The first step is to fill out the necessary enrollment form. The next step is to fill out a “Specific Coverage Endorsement” form on the day the producer wants the policy to become effective. Eligibility requirements are fairly simple. Cattle must be held in the state that is specified by the insurance policy. Purchasers of insurance are also required to have at least 10% ownership in the cattle (and they can only insure their interest in the cattle). This product is not intended for speculation, so the purchaser could be asked to provide proof of ownership when purchasing the coverage at a later date. The minimum contract length, referred to as the endorsement length for LRP coverage, is approximately thirteen weeks (rma.gov). Thus, the LRP cannot be used to manage short term price risk due to a limited time period of less than 13 weeks. Ending dates are

available in four-week increments, although the availability of an ending date depends on the exchange traded option volume for deferred contracts traded on the CME that day.

LRP insurance is available for steers and heifers of different weights as well as different breed-types. Adjustments are made for lighter steers and heifers, as well as dairy-type and Brahman calves as shown in Table 1.1. This adjustment is made in order to bring the coverage price closer to the actual cash value of the cattle.

Table 1-1.: Adjustments in CME Feeder Cattle Index for Cattle Size and Type

Category	Steers	Heifers	Dairy	Brahman
Light: Less than 600 lbs	110%	100%	85%	100%
Heavy: 600 lbs to 900 lbs	100%	90%	80%	90%

(Data Source: rma.usda.gov/livestock/)

1.5. LRP Versus Cattle Put Options

Buying insurance coverage is similar to buying a put option. A put option is a financial contract that gives the holder the right to sell. A few very common, similar put options are car insurance or agricultural price supports. By purchasing car insurance, we actually buy a put option with the current market value of the car as the strike or exercise price. Similarly, an agricultural price support program is another example of a put option. In effect, the government actually writes a put option to farmers. If the market price goes down, farmers can sell the crop to the government at the set exercise or strike price; hence exercising the put option. If the market price for the crop is high, they do not need to exercise this option that the government has provided to them. Using a similar analogy, purchasing LRP insurance for feeder cattle is similar to purchasing a put-option at the CME, in that the coverage price works in a similar manner to a strike or exercise price. A put option contract moves into the money (i.e., makes profit) when the futures price falls below a strike price, resulting in a profit. This pay-off of a long put is described in section 3.8. Similarly, LRP insurance will pay an indemnity when the CME feeder cattle cash index is

below a certain coverage level on a specified ending date. There are several advantages with the LRP program over futures trading as follows. First, producers already have a working relationship established with an insurance agent who is selling the LRP insurance. Second, a commission is not paid by the producer for LRP insurance, whereas it would be paid to the broker when purchasing a put-option. Finally, the LRP program allows coverage for smaller cattle operations. This is in contrast to futures/options contracts that must be purchased in increments of 50,000 lbs, a size too large for most grass-fed producers. The flexibility of the LRP program allows producers to cover a much smaller number of cattle.

A major disadvantage of the LRP program is that there is no flexibility in closing the contract. Once purchased, LRP insurance cannot be sold back, unlike futures contracts. LRP insurance is like buying a put-option that can only be exercised on the last day. That is it works like a European option. LRP is also less flexible with respect to the actual sale of the cattle. If the cattle are sold more than 30 days prior to the end date, the insurance becomes void. This presents a potential problem in years of drought, when producers need to sell earlier than originally planned. Cattle may be sold anytime after the end date, but the indemnity is still figured into the value of the corresponding end date. So, the producers still run the risk of prices dropping after the ending date but before the calves are sold.

1.6. Empirical Model

1.6.1. Theory of Stochastic Dominance Analysis

This analysis can be initiated by a simple assumption that an individual's choice between actions or alternatives is made such that the outcome of the choice will maximize their expected utility. Axiomatically, this assumption is based on Bernoulli's principle which was expanded upon by Von Neumann and Morgenstern. Mathematically, this principle is based on three axioms (Anderson, Dillon and Hardeker, p. 66-69):

1. Ordering and transitivity: A person either prefers one of the two prospects a_1 and a_2 or is indifferent between them. Further, if the individual prefers a_1 to a_2 and a_2 to a_3 then he prefers a_1 to a_3 .
2. Continuity: If a person prefers a_1 to a_2 to a_3 , then there exists some subjective probability level $\Pr [a_1]$ such that s/he is indifferent between the gamble paying a_1 with probability $\Pr [a_1]$ and a_3 with probability $1 - \Pr [a_1]$ which leaves him/her indifferent with a_2 .
3. Independence: If a_1 is preferred to a_2 and a_3 is any other risky prospect, a lottery with a_1 and a_3 outcomes will be preferred to a lottery with a_2 and a_3 outcomes when $\Pr [a_1] = \Pr [a_2]$. In other words, preference between a_1 and a_2 is independent of a_3 .

There is some literature questioning these assumptions. For example, May (1954) and Tversky (1969) questioned the transitivity of preferences. These studies question whether preferences under uncertainty are adequately described by the traditional expected utility framework. One alternative is to develop risk efficiency criteria rather than expected utility axioms. Risk efficiency criteria are an attempt to reduce the collection of all possible alternatives to a smaller collection of risky alternatives that contain the optimum choice. One example is the mean-variance derivation of optimum portfolios. The efficient frontier, a result of mean-variance optimization, contains the set of possible portfolios, such that no other portfolio could be constructed with a higher return with the same risk (measured by the variance of that particular portfolio). It was the general contention that this efficient set contained the utility maximizing portfolio. Instead of expected utility justifying risk efficiency, we are interested in the derivation of risk efficiency measures per se. An alternative justification of

risk efficiency measures involves the scenario where the individual's risk preferences are difficult to elicit.

The concept of efficiency criteria can be developed as follows. According to Meyer 1977, an efficiency criterion is a decision rule for dividing alternatives into two mutually exclusive groups: efficient and inefficient. If an alternative is in the efficient group, then it is one that an investor may choose. An inefficient investment will not be chosen by any investor regardless of individual risk preference. From an economic standpoint, the criteria should be related to general notions of utility or preferences. In general, the more global the preference, the less discerning the criteria (i.e. the fewer alternatives eliminated). A smaller efficient set requires more stringent requirements on preferences. One of the most frequently used risk efficiency approaches is analyzed using stochastic dominance. To demonstrate the concept of stochastic dominance, let's examine two forms of stochastic dominance: first and second order stochastic dominance rules (collectively FSD and SSD).

To develop **first order stochastic dominance** (Moss, 2005), let us assume that the decision maker is faced with two alternative investments, a and b . Assume that the probability density function for alternative a can be characterized by the probability density function $f(x)$. Similarly, assume that the return on investment b is associated with the probability density function $g(x)$. Investment a is said to be first order dominant over investment b if and only if

$$\int_{-\infty}^x g(x)dx \geq \int_{-\infty}^x f(x)dx \quad (1)$$

Figure 1-1.: CDFs to illustrate stochastic dominance.

Thus, investment a is always more likely to yield a higher return. Intuitively, one investment is going to dominate the other investment if their cumulative distribution functions do not cross.

Economically, the only axiom required for first degree stochastic dominance is that the individual prefers more to less, or is non-satiated in consumption.

Mathematically, FSD is dependent on the integrals of the utility function times each alternative distribution function:

$$E_F U(x) = \int_a^b U(x) f(x) dx \quad \text{Against} \quad E_G U(x) = \int_a^b U(x) g(x) dx \quad (2)$$

Note that the utility function is the same for each investment alternative, but the distribution function changes. If investment F dominates investment G, then the investment, Δ , defined as

$$\Delta = E_F U(x) - E_G U(x) = \int_a^b [f(x) - g(x)] U(x) dx \quad (3)$$

must be greater than or equal to zero for all x with at least one strict inequality.

1.6.2. Second Degree Stochastic Dominance

As noted in the preceding section, the only requirement for FSD to be valid is that the decision maker prefers more to less. Building on this concept, second order stochastic dominance (SSD) invokes risk aversion by inferring that the utility function is concave, implying that the second derivative of the utility function is negative.

The SSD rule can be described as follows. A necessary and sufficient condition for an alternative F to be preferred to a second alternative G, by all risk adverse decision makers is that

$$\int_{-\infty}^x F(z)dz \leq \int_{-\infty}^x G(z)dz \text{ For all } x, \text{ or } \int_{-\infty}^x [G(z) - F(z)]dz \geq 0 \text{ With at least one inequality.}$$

Mathematically, building on first degree stochastic dominance:

$$\Delta = \int_a^b [G(x) - F(x)]U'(x)dx \quad (4)$$

Which is positive if $\int_a^x [G(z) - F(z)]dz \leq 0$ for all x with a strict inequality for at least one x.

The theory of utility, expected utility, risk preferences, and decision making under uncertainty in general, upon which the analysis in this chapter is based, has a rich heritage in the applied economics profession, as evidenced by the following works: Borch (1968); Tisdell (1968); Hey (1979); Karni (1985); and Laffont (1989).

1.7. The Empirical Model

An empirical model was developed to measure the price risk associated with grass-fed beef production and also to evaluate how these producers would respond to the LRP of USDA/RMA. The distribution of payoffs from this model was evaluated using FSD or First Degree Stochastic Dominance Rule. There are quite a few empirical studies which show that the properties of FSD and SSD as described in previous sections hold for most individuals (Anderson, 1974; Antle, 1987; Chavas and Holt, 1996). Similarly, stochastic dominance (SD) analysis has been used in a wide variety of farm studies. Some of them, including Hien et al. (1997) used SD analysis to estimate the riskiness of alternative phosphate sources for African farmers. Hallman and Lowenberg-DeBoer (1999) used SD techniques to assess the economic advantages of switching to narrow row corn. There are also other studies (e.g. Ribera, Hons and Richardson 2004; Sangtaek, Mitchell and Leatham 2005) which build upon using stochastic dominance to evaluate risks and cropping decisions.

The **model of this study** can be described as:

$$\text{Net Return} = \text{Net Revenue} + \text{Indemnity Paid Out} - \text{Premium Paid} + \text{Production Cost} \quad (5);$$

We are omitting the production cost from our study as we assume that it is fixed or constant across all the cases. Hence our model reduces to:

$$\text{Net Return} = \text{Net Revenue} + \text{Indemnity Paid Out} - \text{Premium Paid} \quad (6);$$

Net Revenue is calculated from the parent project data base of the Pasture-beef project consortium. This data base maintains record of cattle finished at the Beaver project trial center of the USDA Agriculture Research Service (ARS). Currently this data base consists of the last 5 years of pasture raised cattle data (of about 200 animals; since 2004). The software @Risk was used to get the best fit distribution of the weights of these animals. A Monte Carlo simulation was carried out to generate 1,000 observations using the best fit distribution reported by @Risk. Beef revenue was then calculated by using the West Virginia sales price as applicable in October 2008 from the USDA National Agriculture Statistics Service (NASS). These steps are presented in the flow chart of figure 1.7. Indemnity is calculated by:

$$\text{Rounded Total Premium} = (\# \text{ of head} * \text{target weight} * \text{coverage price} * \text{insured share} * \text{rate}) \quad (7);$$

USDA/RMA subsidizes the premium by 13%, so the actual producer premium is:

$$\text{Producer Premium} = (\text{Rounded Total Premium} * 0.87) \quad (8);$$

The producer premium is calculated by:

$$\text{Indemnity} = (\# \text{ of head} * \text{target weight} * (\text{coverage price} - \text{ending value}) * \text{insured share}) \quad (9);$$

1.8. Model Assumptions

Table 1-2.: Model Assumptions for Essay I

Model Parameters	Description
Shipping Date	After consulting with industry experts and practioners, the optimal cattle shipping date has been fixed as 15th September, i.e., 09/15/2008.
Model	$\text{Net Return} = \text{Net Sale Price} + \text{Indemnity Received} - \text{Premiums Paid}$
Type of Costs Considered	We have eliminated production costs from the model and only included the cost of the insurance premium.
Best Fit Distribution	Beta General (11.939, 91.517, 313.1423) as reported by @Risk. Numbers in parenthesis indicate the distribution parameters of the finish weight.
Coverage Lengths	17 different choices with minimum length of 13 to maximum 26 weeks.
Price Scenarios	Scenarios: Base Price; a 5% discount; and premiums of 5%, 10%, 15% and 20%. It was important to generate these price scenarios as the direct marketers' charge a premium or discount over the market beef price as found in an earlier survey conducted by WVU Extension dept. This survey is located at: http://www.caf.wvu.edu/~forage/PFBSSurvey.pdf . These price scenarios also deemed to be exact by Dr. Jason Evans, SUNY who has worked extensively in grass fed production systems.
Case Studies	A: Indemnity, paid as of 09/15/08. B: Selecting two end values after examining the actual daily LRP end values of 15 th Sep-15 th Oct, 2005-2009.

Methodology flowchart

Figure 1-2.: Methodology Flowchart of Essay I.

Stochastic dominance analysis was carried out using Simetar software [<http://simetar.com/>]. It is an Excel add-in, developed at Texas A&M University. This is a simple but powerful tool to conduct risk analysis. Once the net return scenarios are compiled, these can be inputted into Simetar to build up the cumulative distribution functions (CDFs). The risk rankings are also reported. Simetar makes use of exponential and power utility functions to generate stochastic dominance with respect to a function (SDRF) CDFs. Use of an exponential utility function gives rise to a constant absolute risk aversion coefficient (CARA), whereas use of a power utility function gives rise to a constant relative risk aversion coefficient (CRRA).

Table 1-3 shows the 17 possible choices and table 1-4 shows the associated return scenarios for these 17 risky outcomes.

Table 1-3.: Various LRP Insurance choices with 10/15/2008 as the end date

Choice(s)	State	County	Endorsement Length	Commodity	Type	Exp. End Value (\$)	Coverage Price (\$)	Coverage Level	End Date	Actual End Value (\$)
I.	WV	ALL	13weeks	0802 Fed Cattle	Steer /heifers	105.807	91.23	0.8622	09/15/08	98.59
II.	WV	ALL	13 weeks	0802 Fed Cattle	„	105.807	87.23	0.8244	09/15/08	98.59
III.	WV	ALL	13 weeks	0802 Fed Cattle	„	105.807	81.23	0.7677	09/15/08	98.59
IV.	WV	ALL	13 weeks	0802 Fed Cattle	„	105.807	79.23	0.7488	09/15/08	98.59
V.	WV	ALL	17 weeks	0802 Fed Cattle	„	99.956	93.66	0.937	09/15/08	98.59
VI.	WV	ALL	17 weeks	0802 Fed Cattle	„	99.956	91.66	0.917	09/15/08	98.59
VII.	WV	ALL	17 weeks	0802 Fed Cattle	„	99.956	89.66	0.897	09/15/08	98.59
VIII.	WV	ALL	17 weeks	0802 Fed Cattle	„	99.956	87.66	0.877	09/15/08	98.59
IX.	WV	ALL	17 weeks	0802 Fed Cattle	„	99.956	81.66	0.817	09/15/08	98.59
X.	WV	ALL	21 weeks	0802 Fed	„	98.994	94.34	0.953	09/15/08	98.59

				Cattle						
Choice(s)	State	County	Endorsement Length	Commodity	Type	Exp. End Value (\$)	Coverage Price (\$)	Coverage Level	End Date	Actual End Value (\$)
XI.	WV	ALL	21 weeks	0802 Fed Cattle	„	98.994	92.34	0.9328	09/15/08	98.59
XII.	WV	ALL	21 weeks	0802 Fed Cattle	„	98.994	90.34	0.9126	09/15/08	98.59
XIII.	WV	ALL	21 weeks	0802 Fed Cattle	„	98.994	86.34	0.8722	09/15/08	98.59
XIV.	WV	ALL	26 weeks	0802 Fed Cattle	„	95.341	93.97	0.9856	09/15/08	98.59
XV.	WV	ALL	26 weeks	0802 Fed Cattle	„	95.341	87.97	0.9227	09/15/08	98.59
XVI.	WV	ALL	26 weeks	0802 Fed Cattle	„	95.341	81.97	0.8588	09/15/08	98.59
XVII.	NO INSURANCE									

Table 1-4.: Various Return Scenarios

Choice	Coverage Price (\$per cwt)	Coverage Level	Premium without Subsidy (\$ per cwt)	Premium with subsidy (\$ per cwt)
I.	91.23	0.8622	0.538	0.24
II.	87.23	0.8244	0.279	0.24
III.	81.23	0.7677	0.094	0.081
IV.	79.23	0.7488	0.060	0.05
V.	93.66	0.937	2.510	2.18
VI.	91.66	0.917	1.823	1.58
VII.	89.66	0.897	1.268	1.10
VIII.	87.66	0.877	0.865	0.75
IX.	81.66	0.817	0.242	0.21
X.	94.34	0.953	3.297	2.87
XI.	92.34	0.9328	2.437	2.12
XII.	90.34	0.9126	1.781	1.55
XIII.	86.34	0.8722	0.911	0.79
XIV.	93.97	0.9856	4.699	4.09
XV.	87.97	0.9227	2.066	1.79
XVI.	81.97	0.8588	0.736	0.64
XVII.	91.23	0.8622	0	0

1.9. Data Sources

Data used in the simulation was obtained from the parent project database. The following table explains the different data sources used in this study.

Table 1-5.: Data Sources for essay I

Variable	Data Source
Hard Carcass Weight /Cattle Weight	Project Data base
Beef Revenue	West Virginia Beef price by cwt [USDA-WV market news] and NASS Price as pertinent of 08.15.2008.
LRP Premium/Indemnity	USDA, AMS http://www3.rma.usda.gov/apps/livestock_reports/main.aspx
Basis Risk	National Agricultural Statistics Service (NASS) and USDA-PA/USDA-VA Dept of Agriculture Market News

1.10. Basis in Local Cattle Market

Basis refers to the difference in prices realized in different markets with regard to risk. The main purpose of LRP is to protect producers with the price differential between the local and national market. WV grass fed producers typically sell their cattle at cattle auction markets in Virginia (located in Winchester) and Pennsylvania (located in New Holland, Lancaster). It was important to examine if any basis exists between the auction markets in VA/PA and AMS 5 market prices. The graph below shows the historical basis that exists in these three markets. Data was collected from the National Agricultural Statistics Service (NASS) and USDA-PA/USDA-VA Dept of Agriculture Market News.

Figure 1-9.: Basis in Local Cattle Market (Data Source: NASS/Market News).

From the above graph, it can be seen that indeed a basis exists, between the local cattle and the AMS 5 area markets. It can also be seen that, on average, there is a basis of \$11.21 for the VA/Winchester auction market and \$13.01 for the PA/Lancaster auction market based on the last 5 years of NASS data.

1.11. Estimation and Results

After studying the existing basis, stochastic dominance analysis was subsequently used to analyze 17 scenarios of the model described earlier. In addition, two case studies were created, as follows: Case A is actual indemnities/premium as paid out as of 09/15/08. For Case B I chose two actual end values after examining 5 years of actual end values for LRP which are \$84 and \$89 respectively..

Case A: Actual End Value as of 09/15/2008 (Actual End Value: \$98.59)

Table 1-6.: Descriptive Statistics of Net Return Distributions of 17 different insurance choices with Actual End Value as of 09/15/2008 (Values in \$).

Base Price Scenario:

Type	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII	XII	XIV	XV	XVI	XVII
Mean	1390.94	1393.19	1394.80	1395.10	1373.78	1379.76	1384.59	1388.09	1393.51	1366.94	1374.11	1380.13	1387.69	1354.74	1377.65	1389.22	1395.62
Std.Dev	183.46	183.46	183.46	183.46	183.46	183.46	183.46	183.46	183.46	183.46	183.46	183.46	183.46	183.46	183.46	183.46	183.45
Min.	917.02	919.27	920.88	921.18	899.86	905.84	910.67	914.17	919.59	893.02	900.18	906.20	913.77	880.82	903.73	915.30	921.70
Max.	2012.27	2014.53	2016.14	2016.43	1995.12	2001.09	2005.92	2009.43	2014.85	1988.27	1995.44	2001.46	2009.03	1976.07	1998.98	2010.55	2016.95

Discounted Price Scenario:

Type	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII	XII	XIV	XV	XVI	XVII
Mean	1321.16	1323.41	1325.02	1325.32	1304.00	1309.98	1314.81	1318.31	1323.73	1297.16	1304.32	1310.34	1317.91	1284.96	1307.87	1321.16	1325.84
Std.Dev	174.28	174.28	174.28	174.28	174.28	174.28	174.28	174.28	174.28	174.28	174.28	174.28	174.28	174.28	174.28	174.28	174.28
Min.	870.93	873.19	874.80	875.09	853.78	859.75	864.58	868.09	873.51	846.93	854.10	860.12	867.69	834.73	857.64	870.93	875.61

Type	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII	XII	XIV	XV	XVI	XVII
Max.	1911.43	1913.68	1915.29	1915.58	1894.27	1900.25	1905.07	1908.58	1914.00	1887.42	1894.59	1900.61	1908.18	1875.23	1898.13	1911.43	1916.11

5% Premium

Type	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII	XII	XIV	XV	XVI	XVII
Mean	1321.16	1323.41	1254.87	1257.12	1258.73	1259.03	1237.71	1243.69	1248.52	1252.02	1257.44	1254.87	1257.12	1258.73	1259.03	1237.71	1259.55
Std.Dev	174.28	174.28	165.57	165.57	165.57	165.57	165.57	165.57	165.57	165.57	165.57	165.57	165.57	165.57	165.57	165.57	165.57
Min.	870.93	873.19	827.15	829.41	831.02	831.31	810.00	815.97	820.80	824.31	829.73	827.15	829.41	831.02	831.31	810.00	831.83
Max.	1911.43	1913.68	1815.62	1817.87	1819.48	1819.78	1798.46	1804.44	1809.27	1812.77	1818.19	1815.62	1817.87	1819.48	1819.78	1798.46	1820.30

10% Premium

Type	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII	XII	XIV	XV	XVI	XVII
Mean	1191.89	1194.14	1195.75	1196.05	1174.73	1180.71	1185.54	1189.04	1194.46	1167.89	1175.06	1181.08	1191.89	1194.14	1195.75	1196.05	1196.57
Std.Dev	157.29	157.29	157.29	157.29	157.29	157.29	157.29	157.29	157.29	157.29	157.29	157.29	157.29	157.29	157.29	157.29	157.29
Min.	785.56	787.81	789.42	789.72	768.40	774.38	779.21	782.72	788.14	761.56	768.73	774.75	785.56	787.81	789.42	789.72	790.24

Type	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII	XII	XIV	XV	XVI	XVII
Max.	1724.61	1726.86	1728.47	1728.76	1707.45	1713.43	1718.25	1721.76	1727.18	1700.60	1707.77	1713.7 9	1724.61	1726.86	1728.47	1728.76	1729.29

15% Premium

Type	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII	XII	XIV	XV	XVI	XVII
Mean	1132.06	1134.31	1135.92	1136.22	1114.90	1120.88	1125.71	1129.22	1134.64	1108.06	1115.23	1121.25	1132.06	1134.31	1135.92	1136.22	1136.74
Std.Dev	149.43	149.43	149.43	149.43	149.43	149.43	149.43	149.43	149.43	149.43	149.43	149.43	149.43	149.43	149.43	149.43	149.43
Min.	746.05	748.30	749.91	750.21	728.89	734.87	739.70	743.20	748.62	722.05	729.21	735.24	746.05	748.30	749.91	750.21	750.73
Max.	1638.14	1640.39	1642.00	1642.30	1620.98	1626.96	1631.79	1635.30	1640.72	1614.14	1621.31	1627.33	1638.14	1640.39	1642.00	1642.30	1642.82

20% Premium

Type	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII	XII	XIV	XV	XVI	XVII
Mean	1068.87	1072.38	1077.80	1051.22	1058.39	1064.41	1071.98	1039.02	1061.93	1073.50	1068.87	1072.38	1077.80	1051.22	1058.39	1064.41	1079.90
Std.Dev	141.96	141.96	141.96	141.96	141.96	141.96	141.96	141.96	141.96	141.96	141.96	141.96	141.96	141.96	141.96	141.96	141.96

Type	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII	XII	XIV	XV	XVI	XVII
Min.	702.16	705.67	711.09	684.51	691.68	697.70	705.27	672.31	695.22	706.79	702.16	705.67	711.09	684.51	691.68	697.70	713.19
Max.	1549.65	1553.15	1558.57	1532.00	1539.17	1545.19	1552.75	1519.80	1542.71	1554.28	1549.65	1553.15	1558.57	1532.00	1539.17	1545.19	1542.78

Case B: Introducing Randomness in Actual End Value

Case B introduces some randomness into the calculation by changing the actual end value. After close inspection of AMS price reporting, the actual end value has a range between \$84.11 per cwt and \$89.79 per cwt; indemnity will be paid out in both cases, depending on insurance choices. The actual end values of LRP between 15th Sept. to 15th Oct., 2005-2009 are reported in Appendix D.

Table 1-7.: Descriptive Statistics of Net Distribution Returns (End Value: \$84.11). All Values are in \$.

Base Price Scenario:

Type	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII	XII	XIV	XV	XVI	XVII
Mean	1452.14	1406.39	1394.80	1395.10	1469.28	1437.26	1422.09	1405.59	1393.51	1451.24	1438.41	1424.43	1391.99	1435.34	1398.25	1452.14	1395.62
Std.Dev	183.46	183.46	183.46	183.46	183.46	183.46	183.46	183.46	183.46	183.46	183.46	183.46	183.46	183.46	183.46	183.46	183.46
Min.	978.22	932.47	920.88	921.18	995.36	963.34	948.17	931.67	919.59	977.32	964.48	950.50	918.07	961.42	924.33	978.22	921.70
Max.	2073.47	2027.73	2016.14	2016.43	2090.62	2058.59	2043.42	2026.93	2014.85	2072.57	2059.74	2045.76	2013.33	2056.67	2019.58	2073.47	2016.95

Discounted Price Scenario:

Type	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII	XII	XIV	XV	XVI	XVII
Mean	1374.36	1336.61	1325.02	1325.32	1381.50	1367.48	1352.31	1335.81	1323.73	1381.46	1368.62	1354.64	1322.21	1365.56	1328.47	1319.44	1325.84
Std.Dev	174.28	174.28	174.28	174.28	174.28	174.28	174.28	174.28	174.28	174.28	174.28	174.28	174.28	174.28	174.28	174.28	174.28
Min.	924.13	886.39	874.80	875.09	931.28	917.25	902.08	885.59	873.51	931.23	918.40	904.42	871.99	915.33	878.24	869.21	875.61
Max.	1964.63	1926.88	1915.29	1915.58	1971.77	1957.75	1942.57	1926.08	1914.00	1971.72	1958.89	1944.91	1912.48	1955.83	1918.73	1909.70	1916.11

5% Premium

Type	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII	XII	XIV	XV	XVI	XVII
Mean	1258.73	1259.03	1315.21	1301.19	1286.02	1269.52	1257.44	1315.16	1302.33	1288.35	1255.92	1299.27	1262.17	1253.14	1258.73	1259.03	1259.55
Std.Dev	165.57	165.57	165.57	165.57	165.57	165.57	165.57	165.57	165.57	165.57	165.57	165.57	165.57	165.57	165.57	165.57	165.57
Min.	831.02	831.31	887.50	873.47	858.30	841.81	829.73	887.45	874.62	860.64	828.21	871.55	834.46	825.43	831.02	831.31	831.83
Max.	1819.48	1819.78	1875.96	1861.94	1846.77	1830.27	1818.19	1875.92	1863.09	1849.11	1816.68	1860.02	1822.93	1813.90	1819.48	1819.78	1820.30

10% Premium

Type	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII	XII	XIV	XV	XVI	XVII
Mean	1245.09	1207.34	1195.75	1196.05	1252.23	1238.21	1223.04	1206.54	1194.46	1252.19	1239.36	1225.38	1192.94	1236.29	1199.20	1190.17	1196.57
Std.Dev	157.29	157.29	157.29	157.29	157.29	157.29	157.29	157.29	157.29	157.29	157.29	157.29	157.29	157.29	157.29	157.29	157.29

Type	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII	XII	XIV	XV	XVI	XVII
Min.	838.76	801.01	789.42	789.72	845.90	831.88	816.71	800.22	788.14	845.86	833.03	819.05	786.62	829.96	792.87	783.84	790.24
Max.	1777.81	1740.06	1728.47	1728.76	1784.95	1770.93	1755.75	1739.26	1727.18	1784.90	1772.07	1758.09	1725.66	1769.00	1731.91	1722.88	1729.29

15% Premium

Type	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII	XII	XIV	XV	XVI	XVII
Mean	1185.26	1147.51	1135.92	1136.22	1192.40	1178.38	1163.21	1146.72	1134.64	1192.36	1179.53	1165.55	1133.12	1176.46	1139.37	1130.34	1136.74
Std.Dev	149.43	149.43	149.43	149.43	149.43	149.43	149.43	149.43	149.43	149.43	149.43	149.43	149.43	149.43	149.43	149.43	149.43
Min.	799.25	761.50	749.91	750.21	806.39	792.37	777.20	760.70	748.62	806.35	793.51	779.54	747.10	790.45	753.36	744.33	750.73
Max.	1691.34	1653.59	1642.00	1642.30	1698.48	1684.46	1669.29	1652.80	1640.72	1698.44	1685.61	1671.63	1639.20	1682.54	1645.45	1636.42	1642.82

20% Premium

Type	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII	XII	XIV	XV	XVI	XVII
Mean	1128.42	1090.68	1079.09	1079.38	1135.57	1121.54	1106.37	1089.88	1077.80	1135.52	1122.69	1108.71	1076.28	1119.62	1082.53	1073.50	1079.90
Std.Dev	141.96	141.96	141.96	141.96	141.96	141.96	141.96	141.96	141.96	141.96	141.96	141.96	141.96	141.96	141.96	141.96	141.96
Min.	761.71	723.97	712.38	712.67	768.86	754.83	739.66	723.17	711.09	768.81	755.98	742.00	709.57	752.91	715.82	706.79	713.19
Max.	1609.20	1571.45	1559.86	1560.16	1616.34	1602.32	1587.15	1570.65	1558.57	1616.30	1603.47	1589.49	1557.05	1600.40	1563.31	1554.28	1560.68

Case B: Descriptive Statistics of Net Distribution Returns (\$) (Actual End Value: \$89.79).

Table 1-8.: Descriptive Statistics of Net Return Distributions of 17 different insurances choices (Actual End Value: \$89.79).

Base Price Scenario:

Type	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII	XII	XIV	XV	XVI	XVII
Mean	1401.54	1393.19	1394.80	1395.10	1408.68	1394.66	1384.59	1388.09	1393.51	1408.64	1395.81	1381.83	1387.69	1392.74	1377.65	1389.22	1395.62
Std.Dev	183.46	183.46	183.46	183.46	183.46	183.46	183.46	183.46	183.46	183.46	183.46	183.46	183.46	183.46	183.46	183.46	183.46
Min.	927.62	919.27	920.88	921.18	934.76	920.74	910.67	914.17	919.59	934.72	921.88	907.90	913.77	918.82	903.73	915.30	921.70
Max.	2022.87	2014.53	2016.14	2016.43	2030.02	2015.99	2005.92	2009.43	2014.85	2029.97	2017.14	2003.16	2009.03	2014.07	1998.98	2010.55	2016.95

Discounted Price Scenario:

Type	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII	XII	XIV	XV	XVI	XVII
Mean	1331.17	1322.82	1324.43	1324.73	1338.31	1324.29	1314.22	1317.72	1323.14	1338.26	1325.43	1311.45	1317.32	1322.37	1307.27	1318.85	1325.84
Std.Dev	173.37	173.37	173.37	173.37	173.37	173.37	173.37	173.37	173.37	173.37	173.37	173.37	173.37	173.37	173.37	173.37	174.28
Min.	881.53	873.19	874.80	875.09	888.68	874.65	864.58	868.09	873.51	888.63	875.80	861.82	867.69	872.73	857.64	869.21	875.61
Max.	1918.00	1909.65	1911.26	1911.56	1925.14	1911.12	1901.05	1904.55	1909.97	1925.09	1912.26	1898.28	1904.15	1909.20	1894.10	1905.67	1916.11

5% Premium

Type	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII	XII	XIV	XV	XVI	XVII
Mean	1264.91	1256.56	1258.17	1258.46	1272.05	1258.03	1247.95	1251.46	1256.88	1272.00	1259.17	1245.19	1251.06	1256.10	1241.01	1252.58	1259.55
Std.Dev	164.70	164.70	164.70	164.70	164.70	164.70	164.70	164.70	164.70	164.70	164.70	164.70	164.70	164.70	164.70	164.70	165.57
Min.	837.75	829.41	831.02	831.31	844.90	830.87	820.80	824.31	829.73	844.85	832.02	818.04	823.91	828.95	813.86	825.43	831.83
Max.	1822.39	1814.05	1815.66	1815.95	1829.54	1815.51	1805.44	1808.95	1814.37	1829.49	1816.66	1802.68	1808.55	1813.59	1798.50	1810.07	1820.30

10% Premium

Type	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII	XII	XIV	XV	XVI	XVII
Mean	1201.96	1193.61	1195.22	1195.51	1209.10	1195.08	1185.01	1188.51	1193.93	1209.05	1196.22	1182.24	1188.11	1193.16	1178.06	1189.63	1196.57
Std.Dev	156.46	156.46	156.46	156.46	156.46	156.46	156.46	156.46	156.46	156.46	156.46	156.46	156.46	156.46	156.46	156.46	157.29
Min.	796.16	787.81	789.42	789.72	803.30	789.28	779.21	782.72	788.14	803.26	790.43	776.45	782.32	787.36	772.27	783.84	790.24
Max.	1731.57	1723.22	1724.83	1725.13	1738.71	1724.69	1714.62	1718.12	1723.54	1738.67	1725.84	1711.86	1717.73	1722.77	1707.68	1719.25	1729.29

15% Premium

Type	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII	XII	XIV	XV	XVI	XVII
Mean	1142.15	1133.81	1135.42	1135.71	1149.30	1135.27	1125.20	1128.71	1134.13	1149.25	1136.42	1122.44	1128.31	1133.35	1118.26	1129.83	1136.74
Std.Dev	148.64	148.64	148.64	148.64	148.64	148.64	148.64	148.64	148.64	148.64	148.64	148.64	148.64	148.64	148.64	148.64	149.43
Min.	756.65	748.30	749.91	750.21	763.79	749.77	739.70	743.20	748.62	763.75	750.91	736.94	742.80	747.85	732.76	744.33	750.73

Type	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII	XII	XIV	XV	XVI	XVII
Max.	1645.29	1636.94	1638.55	1638.85	1652.43	1638.41	1628.34	1631.84	1637.26	1652.38	1639.55	1625.57	1631.44	1636.49	1621.39	1632.96	1642.82

20% Premium

Type	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII	XII	XIV	XV	XVI	XVII
Mean	1085.34	1077.00	1078.61	1078.90	1092.49	1078.46	1068.39	1071.90	1077.32	1092.44	1079.61	1065.63	1071.50	1076.54	1061.45	1073.02	1079.90
Std.Dev	141.21	141.21	141.21	141.21	141.21	141.21	141.21	141.21	141.21	141.21	141.21	141.21	141.21	141.21	141.21	141.21	141.96
Min.	719.11	710.77	712.38	712.67	726.26	712.23	702.16	705.67	711.09	726.21	713.38	699.40	705.27	710.31	695.22	706.79	713.19
Max.	1563.32	1554.97	1556.58	1556.88	1570.46	1556.44	1546.37	1549.87	1555.29	1570.42	1557.58	1543.61	1549.47	1554.52	1539.43	1551.00	1560.68

In case A, where the actual LRP end values were used, no indemnity was paid in any price scenario. So, in our stochastic dominance analysis in Simetar, no insurance (Choice XVII) was picked as the most preferred option. The net return distributions were used in Case B to analyze the stochastic dominance. Results are reported in the following graphs.

A. CDFs of Case B:

Figure 1-10.: CDFs of 17 different choices of various price scenarios of Case B.

B. Risk Rankings Using FSD

Table 1-9.: Risk Ranking of Case B with Actual End Value of \$84.11

	Actual End Value: \$84.11	
Risk Rank	Insurance Choice	Level of Preference as determined by FSD
1	V	Most Preferred
2	X	2nd Most Preferred
3	I	3rd Most Preferred
4	XI	4th Most Preferred
5	VI	5th Most Preferred
6	XIV	6th Most Preferred
7	XVII	7th Most Preferred
8	IV	8th Most Preferred
9	III	9th Most Preferred
10	IX	10th Most Preferred
11	II	11th Most Preferred
12	XVI	12th Most Preferred
13	VIII	13th Most Preferred
14	XIII	14th Most Preferred
15	XII	15th Most Preferred
16	VII	16th Most Preferred
17	XV	Least Preferred

Table 1-10.: Risk Ranking of Case B with Actual End Value of \$89.79

Actual End Value: \$89.79		
Risk Rank	Name	Level of Preference as determined by FSD
1	VI	Most Preferred
2	XI	2nd Most Preferred
3	I	3rd Most Preferred
4	X	4th Most Preferred
5	V	5th Most Preferred
6	XIV	6th Most Preferred
7	XVII	7th Most Preferred
8	IV	8th Most Preferred
9	III	9th Most Preferred
10	IX	10th Most Preferred
11	II	11th Most Preferred
12	XVI	12th Most Preferred
13	VIII	13th Most Preferred
14	XIII	14th Most Preferred
15	XII	15th Most Preferred
16	VII	16th Most Preferred
17	XV	Least Preferred

Analyzing the Cumulative Distribution Functions (collectively CDFs) and the risk rankings as determined using Simetar, it can be seen that individual rankings and CDFs for different price scenarios remain unchanged. There is little difference in the individual rankings of two LRP end values. Choice V and VI have been selected as the most preferred insurance option for the producers for end values of \$84.xx and \$89.xx, respectively. They correspond to 17 weeks coverage, with a coverage price of \$93.66 and \$91.66, respectively, for choices V and VI. A recommendation to these producers would be to go for the 17 weeks coverage option. However, due to the basis that exists between the local cattle markets vs. AMS 5 area market; this insurance policy may not be useful to WV producers, due to the fact that an indemnity will not be paid out. The basis is reported in figure 1.3. It is obvious from 5 years of historical data that the local cattle auction markets operate at a much lower price as compared to the AMS 5 area market at least for the heavy steer/heifer (500+ lbs) category. Since the indemnity payout is typically tied to the AMS price, these producers may not be able to receive any indemnity at all.

1.12. Black's (1976) Model to Price the LRP Premium

After starting the initial work in April 2009, it was difficult to understand how USDA/RMA calculates the premium and coverage levels of LRP. Subsequently, after contact, USDA/RMA declined to give any insight as to how LRP premiums are priced. However, the reported LRP premium prices can be evaluated using Black's (1976) model, which is actually an approximation of the Black-Scholes model for option pricing. Here the stock price needs to be replaced by the futures price. The Black model can be written as [Hull, 2007]:

Price of a put option on futures is given by:

$$p = e^{-rT} [KN(-d_2) - FN(-d_1)]$$

$$d_1 = \frac{[\ln(\frac{F}{K}) + \sigma^2 \frac{T}{2}]}{\sigma\sqrt{T}};$$

$$d_2 = \frac{[\ln(\frac{F}{K}) - \sigma^2 \frac{T}{2}]}{\sigma\sqrt{T}} \quad (10)$$

Where, r is the risk-free interest rate, T is the time to maturity; K is the strike/exercise rate, F is the futures (or forward) price, σ is the unknown price volatility and $N(x)$ is the cumulative probability or area under the normal curve.

The derivation of the pricing formulas in the model follows that of the Black-Scholes model almost exactly. The assumption that the spot price follows a log-normal process (in Black-Scholes model) is replaced by the assumption that the forward price at maturity of the option is log-normally distributed (in Black Model). From there, the derivation is identical, and so the final formula is the same except that the spot price is replaced by the forward - the forward price represents the undiscounted expected future value.

An example of using the Black-Model: The following example will make the above discussion clear. Take us for an example of a Put option which had been traded over CME on Oct. 15, 2008, with a delivery date of 24th March, 2009. The features of this put contract is the Future price (F) is \$104.08. Strike rate is \$88. Price of this put option p is \$0.75/cwt before brokerage commission. A Similar LRP with end date March 11, 2009 cost is \$0.78/cwt before subsidy. USDA/RMA provides 13% subsidy to LRP coverage. So the effective price after subsidy is \$0.68/cwt. Black Model can be used successfully to show that these two hedging mechanism (put and LRP) are actually cost almost the same. I used the Black Model

to calculate volatility from traded put and when put terms adjusted according to LRP, put price=\$0.64+\$0.12 (broker commission) = \$0.76. Put terms (length) needs to be adjusted to reflect the similar LRP features.

LRP and put options are similar, but not identical. LRP premiums receive a federal price subsidy. A brokerage commission adds to the quoted cost of a put option. LRP contracts are written on underlying forward prices, called the “expected ending value” in the policy endorsement. For feeder cattle and swine LRP endorsements, the forward and futures prices settle to the same cash prices. For the fed cattle LRP endorsement, the forward prices are similar to the cash price used to settle live cattle futures contracts. LRP coverage is available daily with ending dates a fixed number of weeks in the future. Put options have set expiration dates and set strike prices. LRP coverage is available at fixed percentages of the expected ending value, in essence becoming strike prices.

1.13. Conclusion

LRP offers livestock producers the opportunity to manage a portion of their price risk by buying insurance coverage for cattle. The decision to manage price risk is very attractive in today’s environment where grain and input prices, international trade, and the U.S. economy have added to the volatility and uncertainty in feeder/fed cattle prices. However, LRP’s usefulness remains doubtful particularly to grass fed beef producers in West Virginia. This insurance program may work well to reduce the market risk of feeder cattle, but is not very effective for the heavy cattle (i.e. fed cattle) category. This program adds one more option in the arsenal of risk management strategies of grass fed producers who have historically purchased CME traded futures and puts on those futures. Future research needs to be conducted on the stochastic dominance analysis of the equivalent LRP and CME traded put options to determine which strategy works better for these producers. Either of them have

their unique advantages and disadvantages. So, advanced risk managers need to identify which one will work better for them. But it is to be kept in mind that none of these risk management strategies absolutely guarantees a profit over production cost as both of them are tied to market movement.

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CHAPTER 2
PRODUCTION RISK AND RAINFALL INSURANCE FROM USDA/RMA: A
STOCHASTIC DOMINANCE ANALYSIS

*Remember, when discoursing about water,
to induce first experience, then reason.
- Leonardo Da Vinci*

2. 1. Introduction

Crop insurance is purchased by agricultural producers, including farmers, ranchers, and others to protect themselves against the loss of their crops due to natural disasters. These natural disasters include hail, drought, and even floods. The two general categories of crop insurance are: crop-yield insurance and crop-revenue insurance.

2.1.1. Crop-Yield Insurance

There are two main classes of crop-yield insurance: the first class is hail insurance, which is generally available from private insurers because hail damage is limited in the manner by which it occurs, and it is localized. The accumulated losses accrued from hail damage being small in compensatory amount tend not to overwhelm the capital reserves of private insurers. The earliest crop-hail programs were the result of farmers' cooperatives in France and Germany in the 1820s (Fact sheet, European Commission on Agriculture, 2009).

Multi-peril crop insurance covers the broad perils of drought, flood, insects, disease, etc., which may affect farmers insured simultaneously. This crop insurance protects the insurer with excessive losses. To make this class of insurance, the perils are often bundled together in a single policy, called a multi-peril crop insurance (MPCI) policy. MPCI coverage is normally offered by a government insurer and premiums are usually partially subsidized by the government. The earliest MPCI program was implemented by the Federal

Crop Insurance Corporation (FCIC), an agency of the U.S. Department of Agriculture (USDA), in 1938. The FCIC program has been managed by the Risk Management Agency (RMA) since 1996.

2.1.2. Crop-Revenue Insurance:

This insurance is a combination of both crop-yield insurance and price insurance. RMA establishes crop-revenue insurance guarantees on corn by multiplying each farmer's corn-yield guarantee, which is based on the farmer's own production history, times the harvest-time futures price discovered at a commodity exchange before the policy is sold and the crop planted. There is a single guarantee for a certain number of dollars. The policy pays an indemnity if the combination of the actual yield and the cash settlement price in the futures market (as determined by trading at CME) is less than the guarantee. In the United States, the program is called Crop Revenue Coverage according to information available from USDA/RMA. Crop-revenue insurance covers the decline in price that occurs during that specific insured growing season. The insurance does not cover declines that may occur from one growing season to another.

2.2. Insurance for Pasture/Rangeland Management: Rainfall/Vegetation Index Based Insurance

The United States currently comprises about 588 million acres of pasture and rangeland and 61.5 million acres of hay land. RMA has developed programs for pasture, rangeland, forage, and hay to provide a safety net for farmers who face drought conditions (USDA/RMA, 2008). This safety net is currently comprised of two programs: the Rainfall Index program and the Vegetation Index program. Both programs use indexes and grids that are smaller in

size than counties to determine expected losses. The Rainfall program is based on accumulated rainfall and the Vegetation program relies on satellite imagery to measure departures from expected losses for a given grid area. As of January 2009, the Rainfall Index is available for at least 10 states and the vegetation index for at least 13 states. So far, they have been highly successful due to the participation levels occurring in excess of expectations. Together, these programs ultimately will be available for areas that represent about 25 percent of the nation's grazing and hay land. The RMA's long-range goals call for crop insurance to be available that covers 98 percent of the value of U.S. commercial crops by crop year 2012.

Figure 2-1.: Pasture, Rangeland and Forage Program 2008 Crop Year.

2.3. Rainfall Insurance

In this section, various elements of the rainfall insurance, which has been marketed by RMA since 2009, will be discussed. These definitions were collected from policy and actuarial documents maintained at RMA website.

1. Grid – Acreage within each 0.25 degree gridded area established by National Oceanic and Atmospheric Administration (NOAA) and identified by longitude and latitude.

The grid is used to determine the expected grid index, premium, final grid index, and indemnity.
2. Grid identification number (grid ID) – A specific number code associated with each grid contained in the actuarial documents. The applicable grid ID is determined based on a point of reference selected by the farmer, which must be established by the acreage reporting date.
3. Index interval – A period of time during which precipitation data is collected that is used to calculate the expected grid index and final grid index, which is designated on the Special Provisions.
4. Insurable acres – The total number of acres planted or established, as applicable to the insured crop and eligible for insurance under the applicable Crop Provisions. Insurable acres include both insured acres and acres of the crop that are not insured (if allowed by the Crop Provisions) in the county.
5. Coverage Level – The coverage level is the percentage of the county base value selected by a producer for insurance coverage. A producer can chose a coverage level of 70, 75, 80, 85, or 90 percent of the county base value for the crop type being insured. Producers are required to insure all grids in a county at the same coverage level.
6. Productivity Factor – The productivity factor is a factor between 60 and 150 percent that a producer selects to reflect his/her operation's forage productivity. Producers often select coverage levels and productivity factors to reflect the forage production

- value on the acreage they are insuring. For instance, if the producer realizes that his/her value of production is similar to the county base value, the producer may select a coverage value/productivity factor combination to provide a level of protection similar to the county base value for the crop type that is being insured.
7. **Producer Share** – The producer share is the operator's share of forage production on the insured acreage. If a producer is an owner/operator, his/her share is likely to be 100 percent. But if a producer has acreage on a 50/50 crop share basis, his/her share is 50 percent.
 8. **Premium Calculations:** Premium calculations for a Pasture, Rangeland and Forage PRF Rainfall Index Insurance contract are similar to those of other group risk insurance products. The premium rate is quoted as a dollar amount per \$100 of insurance liability (the maximum indemnity payment under the provisions of the contract which equals the dollar protection per acre chosen by the producer). The premium rate is multiplied by an adjustment factor of 0.01 to express the premium rate on a per dollar of protection basis. Premium subsidy rates are similar to those for other group risk products and subsidy rates decrease as coverage levels increase.
 9. **PRF Rainfall Index Insurance Indemnities:** Indemnities are paid to a producer when the rainfall final grid index falls below the trigger grid index established by the producer.

$$\text{Trigger Grid Index} = (\text{Expected Grid Index}) \times (\text{Coverage Level}) \quad (11)$$

If an insured producer wants a relatively high Trigger Grid Index, they will choose a relatively high coverage level. The amount of the indemnity is determined by a payment calculation factor, defined as $\frac{(\text{Trigger Grid Index} - \text{Final Grid Index})}{(\text{Trigger Grid Index})}$ (12).

An insurance payment (indemnity) is due if the Final Grid Index is less than the Trigger Grid Index. The indemnity per unit is: Policy Protection per Unit x Payment Calculation Factor.

The Final Grid Index values are calculated soon after the close of each index interval so that insurance payments can be made in time.

The website maintained by RMA has a decision support tool (Appendix B) which gives the entire premium and indemnity related information and the data were collected from this decision tool only.

2.4. Empirical Model

An empirical model has been developed to measure risk in grass fed beef production and to evaluate how these producers would respond to the livestock risk protection plan of USDA/RMA. The distribution of payoffs from this model was evaluated using First Degree Dominance or FSD, similar to the previous essay. The analysis again builds upon other recent studies using stochastic dominance to evaluate risks and cropping decisions as have been discussed in the previous essay. The framework underlying the economics of insurance is outlined in Dionne and Harrington (1992) and Jewson and Brix (2005).

The net return is given by:

$$\text{Net Return} = \text{Net Revenue} + \text{Indemnity Paid Out} - \text{Premium Paid} + \text{Production Cost} \quad (13)$$

Production cost is not included as we assume that it is fixed or constant for all the cases.

Hence, our model reduces to:

$$\text{Net Return} = \text{Net Revenue} + \text{Indemnity Paid Out} - \text{Premium Paid} \quad (14)$$

Methodology Flowchart to Carry Out Stochastic Dominance Analysis of Rainfall Insurance

Figure 2-2. Methodology Flowchart of Essay II

2.5. Model Assumptions for Stochastic Dominance Analysis of Essay II:

Table 2-1. illustrates the model assumptions to carry out stochastic dominance analysis in Essay II.

Table 2-1.: Model Assumptions for Essay II

Model Parameter(s)	Description(s)
Area to be insured	25 acres
Interval(s)	III and IV, correspond to Day of the Year (DOY) of 151-243 (June-September), as this is the critical back grounding period for Grass fed producers of West Virginia. This period falls in two intervals of Rainfall insurance as marketed by RMA. Interval III: June-July Interval IV: August-September
Productivity Factor	100%, this factor has been determined by WVU Extension as the preferred productivity level
Location	Allegheny County of PA, Grid 24500 and 24800, this insurance has not been introduced in WV as of yet, Allegheny county is nearest to WV where this insurance being offered as part of the pilot program.
Distribution	Hay yield distribution follows a Triangular Distribution as reported by Best Fit.
Coverage Level	70%, 75%, 80%, 85% and 90%.
Hay Price	Hay price varies depending on quality, to capture this variability 2 scenarios: \$110/ton and \$200/ton have been assumed which will take care of this price variability and also this deems to be perfect with people associated with hay business in West Virginia.
Type of Cost Considered	Production cost has been eliminated from the model
Case Studies	A: Average Positive Payout B: Average Negative Payout It was important to build out these two scenarios, as this insurance will not offer pay out every year. Positive and Negative pay outs are the averaged positive and negative pay outs (indemnity minus premium) as calculated using 60 years of cumulative data from USDA/RMA Rainfall Insurance calculator web page.

2.6. Data and Data Analysis

Figure 2-3.: PA Counties

The following table reports various sources of data used in this study.

Table 2-2: Data Sources for Essay II

Variable	Data Source
Hay Yield	Since Rainfall Insurance is still not available for West Virginia, hence Pennsylvania Project Trial data of Allegheny county (since it is nearest to WV) of WVU Extension Dept. was used.
Hay Price	Expert Consultation with Dr. Ed Rayburn of WVU Extension Dept.
Rain fall Insurance Indemnity/Premium	http://agforceusa.com/rma/ri/prf/dst
Grid Locator	http://prfri-rma-map.tamu.edu/getGridId.aspx

Table 2-3.: Different Rainfall Insurance Choices available

Choice(s)	Type	Significance
I	No_Insur_PriceI	No Insurance, Price \$200/ton
II	PriceI_I	70% Coverage, Price \$200/ton
III	PriceI_II	75% Coverage, Price \$200/ton
IV	PriceI_III	80% Coverage, Price \$200/ton
V	PriceI_IV	85% Coverage, Price \$200/ton
VI	PriceI_V	90% Coverage, Price \$200/ton
VII	No_Insur_PriceII	No Insurance, Price \$110/ton
VII	PriceII_I	70% Coverage, Price \$110/ton
IX	PriceII_II	75% Coverage, Price \$110/ton
X	PriceII_III	80% Coverage, Price \$110/ton
XI	PriceII_IV	85% Coverage, Price \$110/ton
XII	PriceII_V	90% Coverage, Price \$110/ton

Table 2-4.: Net Indemnity Received after Paying Premiums for Rainfall Insurance for Pastures for Interval III of Grid 24500(Grid I)

Coverage Level	70%	75%	80%	85%	90%
Average net indemnity ¹	\$1.87	\$1.59	\$1.23	\$1.01	\$0.75
Average Positive Payout	\$7.71	\$7.63	\$7.19	\$6.99	\$5.61
Probability Positive Payout	37%	31%	25%	20%	19%
Average Negative Payout	-\$1.60	-\$1.60	-\$0.80	-\$0.51	-\$0.36
Probability Negative Payout	63%	69%	75%	80%	81%
Maximum Net Indemnity	\$21.53	\$19.98	\$18.23	\$16.49	\$14.61
Minimum Net Indemnity	-\$1.61	-\$1.12	-\$0.82	-\$0.52	-\$0.36

Where

Average net indemnity: The average indemnity less premium.

Average Positive Payout: The average indemnity less premium when the net indemnity is greater than zero.

Probability Positive Payout: The probability of receiving a net indemnity that is greater than zero for 60 years of weather data.

Average Negative Payout: The average indemnity less premium when the net indemnity is less than zero for 60 years of weather data.

Probability Negative Payout: The probability of receiving a net indemnity that is less than zero for 60 years of weather data.

Maximum Net Indemnity: The largest indemnity less premium for 60 years of weather data.

Minimum Net Indemnity: The smallest indemnity less premium for the 60 years of weather data.

Data Source for table 2.3-2.6 is the USDA/RMA online decision support system available at: [rma.usda.gov/policies/pasture range forage](http://rma.usda.gov/policies/pasture_range_forage).

Table 2-5.: Net Indemnity Received after Paying Premiums for Rainfall Insurance for Pastures for Interval IV of Grid 24500 (Grid I)

Coverage Level	70%	75%	80%	85%	90%
Average net indemnity	\$2.12	\$1.85	\$1.46	\$1.18	\$0.78
Average Positive Payout	\$8.99	\$8.32	\$6.61	\$4.97	\$4.27
Probability Positive Payout	37%	34%	34%	34%	27%
Average Negative Payout	-\$1.96	-\$1.47	-\$1.18	-\$0.77	-\$0.52
Probability Negative Payout	63%	66%	66%	66%	73%
Maximum Net Indemnity	\$16.33	\$14.85	\$13.13	\$11.50	\$9.70
Minimum Net Indemnity	-\$2.07	-\$1.51	-\$1.18	-\$0.77	-\$0.52

Table 2-6.: Net Indemnity Received after Paying Premiums for Rainfall Insurance for Pastures for Interval III of Grid 24800 (Grid II)

Coverage Level	70%	75%	80%	85%	90%
Average net indemnity	\$1.94	\$1.72	\$1.38	\$1.17	\$0.82
Average Positive Payout	\$9.60	\$9.12	\$7.38	\$5.75	\$4.99
Probability Positive Payout	34%	31%	31%	31%	25%
Average Negative Payout	-\$1.99	-\$1.53	-\$1.25	-\$0.84	-\$0.60
Probability Negative Payout	66%	69%	69%	69%	75%
Maximum Net Indemnity	\$22.25	\$20.77	\$19.03	\$17.40	\$15.59
Minimum Net Indemnity	-\$2.12	-\$1.56	-\$1.25	-\$0.84	-\$0.60

Table 2-7.: Net Indemnity Received after Paying Premiums for Rainfall Insurance for Pastures for Interval IV of Grid 24800 (Grid II)

Coverage Level	70%	75%	80%	85%	90%
Average net indemnity	\$2.35	\$1.95	\$1.34	\$1.08	\$0.78
Average Positive Payout	\$10.16	\$8.32	\$6.61	\$4.97	\$3.60
Probability Positive Payout	38%	33%	33%	33%	25%
Average Negative Payout	-\$1.96	-\$1.47	-\$1.18	-\$0.77	-\$0.52
Probability Negative Payout	64%	67%	67%	67%	75%
Maximum Net Indemnity	\$16.33	\$14.85	\$13.13	\$11.50	\$9.70
Minimum Net Indemnity	-\$2.07	-\$1.51	-\$1.18	-\$0.77	-\$0.52

Table 2-8.: Descriptive Statistics of Net Return Distribution Grid 24500

Average Positive Payout

Choice(s)	I	II	III	IV	V	VI	VII	VII	IX	X	XI	XII
Average(\$)	346.26	342.96	362.21	360.06	358.22	356.14	629.56	646.26	645.51	643.36	641.52	639.44
Std.Dev(\$)	62.81	62.81	62.81	62.81	62.81	62.81	114.20	114.20	114.20	114.20	114.20	114.20
Min.(\$)	195.60	212.30	211.55	209.40	207.56	205.48	355.64	372.34	371.59	369.44	367.60	365.52
Max.(\$)	492.09	508.79	508.04	505.89	504.05	501.97	894.71	911.41	910.66	908.51	906.67	904.59

Average Negative Payout

Choice(s)	I	II	III	IV	V	VI	VII	VII	IX	X	XI	XII
Average(\$)	346.26	342.70	343.19	344.28	344.98	345.38	629.22	626.00	626.49	627.58	628.28	628.68
Std.Dev(\$)	62.81	62.81	62.81	62.81	62.81	62.81	114.49	114.20	114.20	114.20	114.20	114.20
Min.(\$)	195.60	192.04	192.53	193.62	194.32	194.72	355.64	352.08	352.57	353.66	354.36	354.76
Max.(\$)	492.09	488.53	489.02	490.11	490.81	491.21	894.71	891.15	891.64	892.73	893.43	893.83

Table 2-9.: Descriptive Statistics of Net Return Distribution Grid 24800

Average Positive Payout

Choice(s)	I	II	III	IV	V	VI	VII	VII	IX	X	XI	XII
Average(\$)	346.26	364.85	363.70	360.25	356.98	355.52	629.59	648.15	647.00	643.55	640.28	638.82
Std.Dev(\$)	62.81	62.81	62.81	62.81	62.81	62.81	114.19	114.20	114.20	114.20	114.20	114.20
Min.(\$)	195.60	214.19	213.04	209.59	206.32	204.86	355.64	374.23	373.08	369.63	366.36	364.90
Max.(\$)	492.09	510.68	509.53	506.08	502.81	501.35	894.71	913.30	912.15	908.70	905.43	903.97

Average Negative Payout

Choice(s)	I	II	III	IV	V	VI	VII	VII	IX	X	XI	XII
Average(\$)	346.26	342.31	343.26	343.83	344.65	345.14	629.59	625.61	626.56	627.13	627.95	628.44
Std.Dev(\$)	62.81	62.81	62.81	62.81	62.81	62.81	114.19	114.20	114.20	114.20	114.20	114.20
Min.(\$)	195.60	191.65	192.60	193.17	193.99	194.48	355.64	351.69	352.64	353.21	354.03	354.52
Max.(\$)	492.09	488.14	489.09	489.66	490.48	490.97	894.71	890.76	891.71	892.28	893.10	893.59

2.7. Estimation and Results

2.7.1. Grid 24500

Table 2-10.: Risk Ranking for Grid 24500

Average Positive Payout			Average Negative Payout		
Risk Ranking	Insurance Choice	Level of Preference by FSD	Risk Ranking	Insurance Choice	Level of Preference by FSD
1	70%_PII	Most Preferred	1	No_Insur_PII	Most Preferred
2	75%_PII	2nd Most Preferred	2	90%_PII	2nd Most Preferred
3	80%_PII	3rd Most Preferred	3	85%_PII	3rd Most Preferred
4	85%_PII	4th Most Preferred	4	80%_PII	4th Most Preferred
5	90%_PII	5th Most Preferred	5	75%_PII	5th Most Preferred
6	No_Insur_PII	6th Most Preferred	6	70%_PII	6th Most Preferred
7	70%_PI	7th Most Preferred	7	No_Insur_PI	7th Most Preferred
8	75%_PI	8th Most Preferred	8	90%_PI	8th Most Preferred
9	80%_PI	9th Most Preferred	9	85%_PI	9th Most Preferred
10	85%_PI	10th Most Preferred	10	80%_PI	10th Most Preferred
11	90%_PI	11th Most Preferred	11	75%_PI	11th Most Preferred
12	No_Insur_PI	12th Most Preferred	12	70%_PI	12th Most Preferred

2.7.2. Grid 24800

Average Positive Payout

Average Negative Payout

Figure 2-5.: CDF's for Grid 24800

Table 2-11.: FSD Risk Rankings for Grid 24500

Average Positive Payout			Average Negative Payout		
Risk Ranking	Insurance Choice	Level of Preference by FSD	Risk Ranking	Insurance Choice	Level of Preference by FSD
1	70%_PII	Most Preferred	1	No_Insur_PII	Most Preferred
2	75%_PII	2nd Most Preferred	2	90%_PII	2nd Most Preferred
3	80%_PII	3rd Most Preferred	3	85%_PII	3rd Most Preferred
4	85%_PII	4th Most Preferred	4	80%_PII	4th Most Preferred
5	90%_PII	5th Most Preferred	5	75%_PII	5th Most Preferred
6	No_Insur_PII	6th Most Preferred	6	70%_PII	6th Most Preferred
7	70%_PI	7th Most Preferred	7	No_Insur_PI	7th Most Preferred
8	75%_PI	8th Most Preferred	8	90%_PI	8th Most Preferred
9	80%_PI	9th Most Preferred	9	85%_PI	9th Most Preferred
10	85%_PI	10th Most Preferred	10	80%_PI	10th Most Preferred
11	90%_PI	11th Most Preferred	11	75%_PI	11th Most Preferred
12	No_Insur_PI	12th Most Preferred	12	70%_PI	12th Most Preferred

2.8. Climate Effects and Rainfall Index Insurance Purchase Decision

As we have seen in the previous sections, the rainfall insurance premiums and estimates of potential indemnity payments are based on past averages of rainfall as determined for two month intervals under all climatic conditions. However, indemnifying 2-month intervals based on alternative climate phases, in particular those associated with the El Nino Southern Oscillation (ENSO, described in detail in Essay III), may change the bimonthly intervals that, if insured, would provide the largest potential insurance protection level to the farm operation. The ENSO impact on the bi-monthly rainfall insurance is likely to be more pronounced than the impact on

annual yield/revenue insurance (1) because of the nature of the insured variable and (2) because ENSO phases, particularly in the Southeastern U.S., affect regional climate most strongly in late fall and winter (Jewson, 2002) . Rainfall Index (RI) insurance actuarial rates are set by RMA/USDA and are based on pooled climate data going back to 1948. The ENSO is not currently considered in setting insurance premium rates. ENSO/El Niño will be discussed in detail in section 3.13. A study by Novak et al. (2008) analyzes the expected payoff of the RI insurance for two month periods based on probabilities of rainfall shortage during alternative climate phases (El Nino, La Nina, and Neutral) at 4 Alabama Agricultural Experiment Station sites under varying coverage levels. Policy makers and producers are expected to benefit from results that show the varying effects of climate ENSO phases on maximum likely payouts from indemnifying 2 2-month periods. Implications from this study also ask for setting actuarial rates based on specific ENSO phase.

2.9. Conclusion

Rainfall insurance has been introduced in a pilot manner since 2008 as part of pastureland, range and forage insurance program by USDA-RMA. It is important for the risk managers to understand that this insurance may or may not result in indemnity payments for each year. The above analysis was carried out using 60 years of pooled actuarial data. It can be seen that under negative payout scenarios, the most preferred choice is no insurance and under positive pay out scenarios, 70% coverage is the most preferred scenario reported for the hay producers of these two particular grids in Pennsylvania. Another point worth mentioning is that the current indemnities do not take into account the climatic variability associated with ENSO/El Nino phases.

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CHAPTER 3

STRUCTURING/MODELLING A PRECIPITATION OPTION (CALL/PUT) FOR WEST VIRGINIA

If you wish to control the future, study the past...

- Confucius

3.1. Introduction

Weather derivatives are financial instruments that can be used by organizations or individuals as part of a risk- management strategy to reduce risk associated with adverse or unexpected weather conditions. The difference from other derivatives (i.e. options) is that the underlying asset (e.g. rain/temperature/snow) has no direct value to price the weather derivative. Farmers can use weather derivatives as protection against poor harvests caused by drought or frost; theme parks may want to insure against rainy weekends during peak summer seasons; and gas and power companies may use heating degree days (HDD) or cooling degree days (CDD) contracts to smooth their annual earnings. A sports event managing company may wish to hedge its losses by entering into a weather derivative contract in case it rains the day of the sporting event and fewer tickets are sold. HDD is one of the most common types of weather derivative. An HDD contract could be for the November to March period, for each day when the temperature falls below 65⁰F (18⁰C) one can keep a cumulative count of the difference between 65⁰F (18⁰C) and the average daily temperature. Depending upon whether the option is a put option or a call option, a set amount will be paid out per heating degree day that the actual count differs from the strike, where the strike is the trigger rate of the index (heating degree days in this example) as set in the option contract. The first weather derivative contract was created in July 1996, when Aquila Energy (an energy trading firm based in Kansas City, MO) structured a dual-commodity hedge

for Consolidated Edison Co (ConEd), NY (ConEd, 1996). The transaction involved ConEd's purchase of electric power from Aquila for the month of August of that year (speedwell.com). The price of the power was agreed on, but a weather clause was also embedded into the contract. This clause stipulated that Aquila would pay ConEd a rebate if August turned out to be a cooler month than expected. The measurement of this was referenced using CDD measured at New York City's Central Park weather station. If the total expected number of CDDs was found in the range from 0 to 10%, which is below the expected number of 320, the company will not receive a discount in power price. However, if the total expected CDDs was found to be 11 to 20% below the normal expected value, Con Ed would receive a \$16,000 discount. Other discounted levels were calculated for even greater departures from the expected CDD.

After that humble beginning, weather derivatives slowly began to trade over-the-counter (OTC) in 1997. As the market for these products grew, the Chicago Mercantile Exchange (CME) introduced the first exchange-traded weather futures contracts (and the corresponding options) in 1999 (cmegroup.com/trading/weather/). The CME currently trades weather derivative contracts for twenty-four cities in the United States, ten in Europe, six in Canada and three in Japan. Most of these contracts track CDD or HDD, but recent additions track frost days in the Netherlands and monthly/seasonal snowfall in Boston and New York. A major early pioneer in weather derivatives was Enron Corporation, through its Enron Online unit (Climetrix.com). Although agriculture suffers most from weather related risk, most of these weather related derivative deals have been structured for the energy sector to date. This essay discusses the concept of weather derivatives as potentially applied in agriculture, the mechanism of the option based contracts, and the structure of weather contracts based on temperature and rainfall. Also, this essay includes

a literature review, rainfall simulation, and a pricing exercise utilizing both burn and Monte Carlo simulation in consecutive sections.

3.2. How Weather Derivatives Work

Weather derivatives are either bought or sold. The buyer wants to reduce risk from extreme weather conditions by transferring some of the risk to the seller.

Table 3-1: How weather derivatives work

Buyer	Seller
Pays the seller a premium to assume the risk	Takes premium from buyer in exchange for assuming risk.
If Extreme Conditions Occur:	
Receives the insured amount (or the contract amount) to cover business losses	Pays the insured (or the contract) amount
If Extreme Conditions Do Not Occur:	
Does not lose business. Derivative does not pay off	Premium paid by buyer becomes profit.

3.3. Derivatives, Insurance and Reinsurance: A Review of Risk Management Tools

It is important to understand the subtle difference between the three types of risk management tools namely derivatives, insurance and reinsurance. These tools may appear to work as similar instruments in many situations; however, a few subtle differences exist. Native to both the notion of derivatives and insurance contracts is the idea of contingency. Thus, both tools are generally viewed as contingent claims, whose payoffs are dependent on occurrence of a set of outlined

provisions. Moreover, insurance contracts and derivatives are means for individuals to transfer their risk (i.e. risk-sharing). Insurable interest forms the basis of most, if not all, insurance contracts. Insurable interest means that a policyholder has a right to a consideration when a loss or damage to life, property, etc., has resulted and the policyholder suffering a financial loss.

It is true from a mathematical and financial structure point of view that there is not much difference, however, some differences exist although they do not always hold exactly. For example, a set of weather derivatives traded via exchanges (e.g. Chicago Mercantile Exchange) has standardized parameters and contract sizes. This creates a market, and subsequently fair price discovery takes place where traders can act on mispricing of other derivatives. Insurance, on the other hand, is typically tailor made and so is the price. The insurance might reference a specific asset (industrial asset for business insurance, home for property insurance). Another difference is that insurance is event-based, while weather derivatives settle on publicly available weather measurement data recorded at a referenced weather station. Also, weather derivatives cover low-risk, high-probability events. Weather insurance, on the other hand, typically covers high-risk, low-probability events. For example, a company might use a weather derivative to hedge against a winter that forecasters think will be 5° F warmer than the historical average (a low-risk, high-probability event). In this case, the company knows its revenues would be affected by that kind of weather. But the same company would most likely purchase an insurance policy for protection against damage caused by a flood or hurricane (high-risk, low-probability events).

Reinsurance is purchased (Hull, 2007) by an insurance company (insurer such as Travelers) from a “reinsurer” (e.g. Swiss Re) as a means to transfer risk (loss or losses). The reinsurer and the insurer enter into a reinsurance agreement which details the basis in which the

reinsurer will pay the insurer's losses (excess of loss or proportional). The reinsurer is paid a reinsurance premium by the insurer.

A specific example is as follows: Let us consider that Travelers is issuing thousands of policies. If Travelers sells one thousand policies, each with a \$1 million policy limit (the amount Travelers could pay on the policy), theoretically, Travelers could lose \$1 million on each policy – for a total of \$1 billion. It may be better to pass some potential risk to a reinsurance company as this will create financial stability. Usually insurance companies pass off their riskiest portfolio of insurance policies to the reinsurance firms.

3.4. Evolution of Weather Market

The weather market in the U.S. traces its roots to deregulation of the U.S. energy industry which took place in the late 1990s. Variability in weather conditions had always been recognized as one of the most significant factors affecting energy consumption, however, the effects of unpredictable seasonal weather patterns had previously been absorbed and managed within a regulated, monopoly environment (Climetrix.com). With deregulation, the various participants in the process of producing, marketing and delivering energy to U.S. households and businesses were left to confront weather as a new and significant risk to their bottom line (wrma.org). Beyond the obvious initial applications of weather derivatives to hedge energy risk, the market has expanded to address a wide array of weather risks faced by numerous other industry sectors.

The CME Group carved out an important niche in the weather derivatives market, but it has taken a long time for that opportunity to emerge. In 1999, this exchange launched a series of exchange traded futures and options based on temperature indices for various U.S. cities, but volume did not reach meaningful levels until 2003 (cmegroup.com/trading/weather/). Healthy growth came only when the exchange began offering clearing services for these transactions, which currently account for 91% of volume. Today, the exchange offers contracts on

temperature and precipitation indices in 24 cities in the U.S, six in Canada, ten in Europe and two in Asia-Pacific. As can be seen in figure 3-2 volume has grown from 798,000 contracts in 2006 to nearly a million in 2007, with notional or contract value in dollars in 2007 equaling about \$18 billion (cmegroup.com). In 2007-08, this volume has been depressed by the turmoil in the financial markets and the general economic contraction, but not as much as other sectors of the futures industry (cmegroup.com). Total volume for January through November 2008 was 737,506 contracts, down by 16% from the prior year. Open interest was 168,542 contracts, down 35% from 2007. But some industry observers think that the weather risk market will be boosted by the Obama administration's proposed emphasis on wind power and other renewable energy solutions, which are highly dependent on the weather. Also, the use of a clearinghouse (e.g. CME) to reduce counterparty risk as opposed to over the counter derivatives will make this investment more attractive.

The demand for weather derivatives mostly comes from the energy sector which accounts for more than half of the total weather derivatives business. This sector is followed by the construction industry and agriculture, according to the Weather Risk Management Association (wrma.org). Also, while the use of weather derivatives in the energy sector is more common than in any other sector, just 35% of energy companies manage their exposure to weather through the use of either off-exchange (OTC) or exchange-traded weather derivatives, according to the CME/Storm exchange, a provider of weather-related financial risk and information services (artemis.bm/blog). However, this volume is minimal compared to other types of derivatives. Figure 3-3 shows the West Texas Intermediate (WTI) (a type of crude oil) futures contracts traded at The New York Mercantile Exchange (NYMEX) and Intercontinental Exchange (ICE) during 2006-07. This is in the order of millions compared to thousands of weather derivatives

contracts. Figure 3-4 shows the total volume of transactions of different types of derivative contracts including interest rate and CDS .

Figure 3-1.: CME Weather Derivatives Volume (Source: Futures Industry, January/February 2009).

Figure 3-2.: WTI Crude Oil Futures traded at NYMEX and ICE (Source: Futures Industry, May/June2007).

Figure 3-3.: Derivative Transaction Volume.

(Data Source: Bank for International Settlements, bis.org/)

3.5. Weather and Financial Risk

Table 3-2 shows how different adverse weather types may impact various industries and thereby affecting financial revenue generated..

Table 3-2.: Links between Weather and Financial Risk

Risk Holder	Weather Type	Risk
Energy Industry	Temperature	Lower sales during warm winters or cool summers
Energy Consumers	Temperature	Higher heating/cooling costs during cold winters and hot summers
Beverage Producers	Temperature	Lower sales during cool summers
Building Material Companies	Temperature/snowfall	Lower sales during severe winters (Construction sites shut down).
Construction Companies	Temperature/snowfall	Delays in meeting schedules during periods of poor weather
Ski Resorts	Snowfall	Lower revenue during winters with below average snowfall
Agriculture	Temperature/Snowfall	Significant crop losses due to extreme temperature or rainfall
Municipal Governments	Snowfall	Higher snow removal costs during winters with above-average snowfall
Road Salt Companies	Snowfall	Lower revenues during low snowfall winters
Hydro-electric power generation	Precipitation	Lower revenue during periods of drought

(climetrix.com)

3.6. Different elements of a Weather Contract/Derivative

In this section, various elements/terms related to a weather related contract will be explained.

These definitions have been compiled from the book on “Weather Derivative Valuation” by Jewson et al. (2005).

Reference Weather Station

All weather contracts are based on the actual observations of weather at one or more specific weather stations. Most transactions are based on a single station, although some contracts are based on a weighted combination of readings from multiple stations and others on the difference in observations at two stations.

Index

The underlying index of weather derivative defines the measure of weather which governs when and how payouts on the contract will occur. This is illustrated in more detail in the next section.

Term

All contracts have a start and an end date that contains the period over which the underlying index is calculated.

Structure

Weather derivatives are based on standard derivative structures such as puts, calls, swaps, collars, straddles and strangles. Key attributes of these structures are the strike (the value of the underlying index at which the contract starts to pay out), the tick size (the payout amount per unit increment in the index beyond the strike) and the limit (the maximum financial pay out of the contract).

Premium

The buyer of a weather option pays a premium to the seller that is typically between 10 and 20% of the notional amount of the contract, however, this can vary significantly depending on the risk profile of the contract.

3.7. Pay-off Diagram for Options

Since options are non-linear instruments, it is a good idea to show their pay off diagrams. Pay-off diagrams can be used as a means of illustrating the risk/return profile of an option position. Pay-off diagrams allow the interested party to visualize any trading strategy in a static form. The x-axis (horizontal line) of a pay-off diagram represents the price of the underlying asset. The y-axis (vertical line) of a pay-off diagram represents the profit/loss on the option position. There are four basic pay-off diagrams for options: (1) a long call, (2) a long put, (3) a short call, and (4) a short put. These are discussed below.

The Option Buyer

Long call

The pay-off diagram below represents the effective pay-off of a long call position of an option at the time of the expiration date. It looks at the option from the point of view of the buyer (i.e. the investor).

Figure 3-4: Pay-off diagram of long call for option buyer/holder.

(investopedia.com/theoptions.net)

If a trader believes the share of a company is on the rise, s/he can purchase a call option without buying the share. Assume s/he bought a call option (strike price is \$5 and premium is 50 cents). The breakeven point for this trade is \$5.50. At the expiration date, if the underlying share is trading at a point between \$5 and \$5.50, s/he will be able to recover a portion of the premium by exercising the option. If the share is above \$5.50 at this time, there will be a linear relationship between the share price and the profit. If the share price has moved up to \$6 by the option expiry date, the profit on the option will be \$0.50 (the different between the exercise price, which is \$5, and the current share price, less the option premium, which is \$0.50)

Long put

The pay-off diagram below represents the effective pay-off of a long put position of an option at the time of the expiry date. It looks at the option from the point of view of buyer (again the investor).

Figure 3-5.: Pay-off diagram of long put for option holder/buyer.

(investopedia.com/theoptions.net)

If a trader believes the share of a company is on the decline, s/he can make money by buying put options. Assume s/he bought a long option (strike price is \$5 and premium is 50 cents). Two weeks later, the share price falls to \$4.50. The put option now has intrinsic value of \$0.50. It will also have a time value, likely to be \$0.30. The option can now be sold in the marketplace for a premium value of \$0.80. The profit would be \$0.30. If at expiry date the underlying share is traded at or above \$5, there will be a loss of the full premium. The breakeven point for this option is \$4.50, which is equal to the strike price minus the premium. If the share is trading below \$4.50 by option expiry date, the option buyer would make a profit. There will be a linear relationship between the share price and the option profit.

The following pay-off is easier to understand by remembering “call up” and “put down”, i.e., exercise call option if the market is up and exercise put option if the market is down.

The Option Seller

Short call

The option seller has limited profit potential and potentially unlimited risk. The pay-off diagram below represents the effective pay-off of a short call position of an option at the time of the expiry date. It looks at the option from the point of view of seller (i.e. the writer of the option).

The diagram below shows a call option with a premium of 50 cents. This position is the reverse of the buyer's. If the share price is below \$5 at the expiry date, the seller will earn the full premium 50 points, which is \$0.50. This is the most s/he can earn. The breakeven point for this option is the same as for the buyer, which is \$5.50. At this price, the premium earned will be exactly offset by the losses on the option position. If the share price moves above \$5.50, the option seller's loss moves in a linear relationship with the share price. At \$6, the option seller's loss will be \$0.50 (made up of \$1 loss on the option position less the premium earned of \$0.50).

Figure 3-6.: Pay-off diagram for short call for option seller.

(investopedia.com/theoptions.net)

Short put

The pay-off diagram below shows the effective pay-off of a short put position of an option at the time of the expiry date. It looks at the option from the point of view of the seller.

Figure 3-7.: Pay-off diagram of short put for option seller.

(investopedia.com/theoptions.net)

In this example, the seller will receive full premium if the share price is at or above the \$5 strike price. However if the share price drops, there is a linear relationship between the index and the loss made on this position. The breakeven point is \$4.50, where the profit is equal to the loss incurred.

Pay-off Diagram of HDD Related Weather Derivative

One common form of weather derivative as discussed in the subsequent section is a put option providing protection against a warm winter. Such a transaction might look like the following (climetrix.com).

Reference weather station: Chicago O'Hare International Airport (Weather Station: WBAN #94846)

Underlying index: Heating Degree Days

Term: Nov. 1 - Mar. 31.

Structure: Put option, Strike = 4850 HDDs, Tick size = \$5,000, Limit = \$1 million,
Premium \$150,000.

Contract payoff diagram (net of premium)

Figure 3-8.: Pay-off diagram of a HDD put
(climetrix.com)

3.8. Structure of Weather Derivatives

In this section, structure of weather derivatives related to temperature and rainfall will be discussed. Currently, temperature related derivatives lead the market of weather derivatives.

3.8.1. Temperature Based Call and Put Options

Heating Degree Days (HDD) and Cooling Degree Days (CDD) contracts were responsible for over 85% of the weather derivative transactions made throughout 2005 (climetrix.com). The primary purpose of these contracts is to allow organizations to hedge against excessively high or low temperature distributions over a pre-specified period of time. Firstly, we define the average

daily temperature as the arithmetic average of the maximum and minimum temperatures recorded in a 24hr period. In other words:

$$T_i = \frac{T_{\max} + T_{\min}}{2} \quad (15)$$

Naturally this average temperature is more reliable to model than either the maximum or minimum temperature are by themselves, however, information is thus lost and this measure would not provide a satisfactory hedge for those seeking protection from extreme daily temperatures. A HDD is simply the number of degrees the days average temperature was below some reference level, $\bar{T}$ generally set at 65° F. Hence the HDDs for the month are given as:

$$\text{HDD} = \sum_{\text{month}} \max \left\{ 0, (\bar{T} - T_i) \right\} \quad (16)$$

The specific terminology derives from the fact that ‘heating’ is generally required for temperatures that are below the reference level (here set at 65°F) thus requiring the expenditure of energy. The converse is also true for CDDs with the consumer’s general requirement for ‘cooling’ energy above the reference temperature. From here an option contract can be set with a payoff and exercise price based on these measures. Hence a call option on the monthly HDD index would have a payoff of the form:

$$V_i = \max \left\{ 0, (\text{HDD} - k) \right\} \cdot \text{tick} \quad (17)$$

Where k is the exercise price of the option and the ‘tick’ provides the conversion from degrees to dollars (i.e. its units are \$ per degree) and generally ranges anywhere from \$1,000 to over \$1,000,000 per degree (speedwell.com).

A CDD contract is the reverse of the HDD in terms of its payoff. A CDD is just the number of degrees a particular day’s average temperature was above some pre-determined reference level. As before the accumulated CDDs for a month are given as:

$$CDD = \sum_{\text{month}} \max \{0, (T_i - \bar{T})\} \quad (18)$$

Other variables over which contracts are common include the monthly or daily average temperature (Asian type option¹) as well as monthly and yearly cumulative temperatures. The maximum daily temperature provides a significant hedge to crop farmers against severe temperatures that can have a devastating impact on a harvest's quality and size. An example could be the production of wine whose yield and quality are highly dependent on temperatures during the two months prior to harvesting (wrma.org). If excessively high temperatures are encountered it can affect the physical vine growth as well as the quality of the grape produced including its flavor and odor. Hence a viticulturist could easily utilize a weather derivative over the maximum daily temperature experienced at a weather station that was in reasonably close proximity to the vineyard. This contract would compensate the farmer for reductions in yield and quality that result from the variations in the temperature.

3.8.2. Rainfall Based Call and Put Options

Rainfall contracts have received significantly less focus, in terms of both the literature and the amount of trading activity, when compared to temperature based derivatives. Primarily this was due to the fact that the weather derivatives market was largely created from the needs of energy and utility companies whose major exposure was to temperature related weather variations. Adding to this, rainfall has proven significantly more difficult to model accurately, particularly where geographically small areas are concerned. This is primarily due to the discrete nature of rainfall; two geographically close recording stations can produce widely different precipitation readings, something that is not encountered with temperature based statistics. These difficulties manifest as geographical 'basis' (discussed in later section) in rainfall derivative contracts in

¹ Please refer to Appendix G for an explanation of Asian/Bermudan Option types.

that the situation of the risk must be relatively close to the measuring station for an effective hedge to be possible. This makes it increasingly hard to find the two (minimum) willing counterparties that all derivative contracts require.

The payoff for weather options usually takes the form of:

$$\text{pay off for put} = \begin{bmatrix} 0 & \text{if } x > \text{strike} \\ \text{strike} - x & \text{if } x \leq \text{strike} \end{bmatrix} * \lambda \quad (19)$$

$$\text{pay off for call} = \begin{bmatrix} 0 & \text{if } x < \text{strike} \\ x - \text{strike} & \text{if } x \geq \text{strike} \end{bmatrix} * \lambda \quad (20)$$

Where strike is a choice variable, x is the cumulative realized value of the underlying index (i.e. rainfall) during the contract period and λ is some predetermined dollar value per unit of the index.

3.9. Other Possible Weather Derivative Structures (Combinations)²

A particular derivative or option strategy can be structure either as a single contract (either a call or put) or as a combination of two option contracts which is known as combination. In this section, various other possible weather derivative structures that can be constructed by a combination of call and put will be discussed. These definitions have been compiled from the book on “Weather Derivative Valuation” by Jewson et al. (2005). It is to be kept in mind that these structures are pertinent to mostly over-the-counter (OTC) derivatives rather than exchange traded.

Call and Put Options With a Maximum Payoff (CAP)

In order to avoid excessive payouts on these contracts due to extreme weather, the options often come with a cap or maximum payoff:

² Please refer to Appendix H for the pay-off diagram w.r.t. stock CAP/Collar/Straddle/Strangle.

$$\text{Payoff Call: } \min(p (\$/D) * \max \{0, X_{t/T} - K\}, h) \quad (21)$$

$$\text{Payoff Put: } \min(p (\$/D) * \max \{K - 0, X_{t/T} \}, h) \quad (22)$$

Where h is the maximum payoff denominated in dollars, D is the tick size and K is the strike rate as set forth in the contract. These are in usually set in dollar nomination in the contract.

Collars

A long collar position consists of a combination of a long call and a short put, usually with different strikes but the same tick and limit (although different ticks and limits are also possible).

Collars have the following payoff function:

$$p(x) = \begin{cases} -L_{\$} & \text{if } x < L_1 \\ D(x - K_1) & \text{if } L_1 \leq x < K_1 \\ 0 & \text{if } K_1 \leq x < K_2 \\ D(x - K_2) & \text{if } K_2 \leq x < L_2 \\ L_{\$} & \text{if } x > L_2 \end{cases} \quad (23)$$

Where $L_{\$}$ and L_2 are related by $L_{\$} = D(L_2 - K_2)$ and $L_{\$}$ & L_1 are related by

$L_{\$} = D(L_1 - K_1)$. This can also be written as:

$$p(x) = \max(-L_{\$}, \min(D(x - K_1), \max(0, \min(D(x - K_2), L_{\$})))) \quad (24)$$

or by combining the expressions for calls and puts given above.

A long collar position provides a hedge against high values of the index for values beyond a certain threshold. Collars, like swaps, are usually costless.

Straddles

A long straddle position consists of a long call and a long put with the same strike, tick and limit.

Straddles have the pay-off function:

$$p(x) = \begin{cases} L_{\S} & \text{if } x < L_1 \\ D(K-x) & \text{if } L_1 \leq x < K_1 \\ D(x-K) & \text{if } K \leq x < L_2 \\ L_{\S} & \text{if } x > L_2 \end{cases} \quad (25)$$

Where $L_{\S}$ and L_1 are related by $L_{\S} = D(K - L_1)$ and $L_{\S}$ & L_2 are related by

$L_{\S} = D(L_2 - K)$. This can also be written as:

$$p(x) = \min(L_{\S}, \max(D(K-x), \min(D(x-K), L_{\S}))) \quad (26)$$

A long straddle position hedges against both high and low values of the index and is hence typically rather inexpensive in terms of premium since the buyer receives a pay-off for all values of the index except $x=K$.

Strangles

A long strangle consists of a long call and a long put but with different strikes (unlike a straddle, where strikes are the same). The strike for the put is usually lower than that for the call.

Strangles has the pay-off function:

$$p(x) = \begin{cases} L_{\S} & \text{if } x < L_1 \\ D(K_1 - x) & \text{if } L_1 \leq x < K_1 \\ 0 & \text{if } K_1 \leq x < K_2 \\ D(x - K_2) & \text{if } K_2 \leq x < L_2 \\ L_{\S} & \text{if } x > L_2 \end{cases} \quad (27)$$

Where $L_{\S}$ and L_2 are related by $L_{\S} = D(L_2 - K_2)$ and $L_{\S}$, L_1 are related by

$L_{\S} = D(L_1 - K_1)$. This can also be written as

$$p(x) = \min(L_{\S}, \max(D(K_1 - x), \max(0, \min(D(x - L_2), L_{\S})))) \quad (28)$$

A long strangle position hedges against both high and low values of the index in a similar way to a straddle, but pays out only when the index moves a certain distance. They are thus typically a little cheaper than straddles.

Weather Swaps

The pay-off, p , from a long swap contract is given by:

$$p(x) = \begin{cases} -L_{\$} & \text{if } x < L_1 \\ D(x-K) & \text{if } L_1 \leq x \leq L_2 \\ L_{\$} & \text{if } x > L_2 \end{cases} \quad (29)$$

Where x is the index, D is the tick, K is the strike, $L_{\$}$ is the limit expressed in currency terms and L_1 and L_2 are the upper and lower limits expressed in units of the index. $L_{\$}$ and L_1 are related by $L_{\$} = D(K - L_1)$ and $L_{\$}$ & L_2 are related by $L_{\$} = D(L_2 - K)$. This payoff can also be written as:

$$p(x) = \max(-L_{\$}, \min(D(x - K), L_{\$})) \text{ Or } p(x) = \min(L_{\$}, \max(D(x - K), -L_{\$})) \quad (30)$$

The upper and lower limits (in monetary terms) are set to be equal and opposite. More generally, it would be possible to structure a swap contract (and also all the other contract types) with limits of different sizes on the two sides, although this is very unusual. It is also possible to structure swaps without financial limits; the pay-off is then a linear function of the index, given by $p(x) = D(x - K)$. This is called a linear swap. Even for swaps with limits, the limits are usually set at rather extreme values. OTC contracts are usually traded with limits while the CME contracts do not have limits. Most swaps are costless, i.e. there is no premium, and the profit or loss from a swap is equal to the pay-off. When the contract is set up the two counterparties simply exchange a contract agreeing to pay each other according to the weather at some point in the future. In this sense, a swap is like a spread bet on the future weather. A long swap contract has the economic function of insuring against high values of the index.

Binaries

A long binary option has a pay-off function of the form

$$p(x) = \begin{cases} 0 & \text{if } x < K \\ L_{\$} & \text{if } x \geq K \end{cases} \quad (31)$$

A long binary option can be considered to be a special case of a call option. In this case, in which the index x is considered to be continuous; it is a call option with infinite tick. In the case in which the index x is a discrete number to certain values with spacing Δx the tick is equal to $\frac{L_{\$}}{V_x}$.

3.10. Other Exotic Weather Derivatives

Examples of exotic weather derivatives other than based on temperature or rainfall include those that depend on snowfall, wind speed, etc. Among these categories, snowfall derivatives have shown better promise as they have been introduced at CME December 2009 for five US cities. Although the number of snowfall contracts is still in the hundreds, leading industry experts are very optimistic about them. The idea behind a snowfall derivative is similar to what has already been discussed, i.e., a business which is directly affected by snowfall can use the market to transfer the risk of uncertainty in weather. Here is a brief hypothetical case study of a snowfall derivative that might work well for a snow removal company:

The winter of 2009-2010 has been one of the harshest in West Virginia. The University had to be shut down twice during January-February 2010. The city of Morgantown spent a few million dollars in snow removal activities in winter 2010. From this experience comes this hypothetical case study utilizing snowfall derivative which has already been used in a few places, including Chicago. This case study is concerned with a snow removal company. For these types of parties, uncertainty in winter weather, particularly snowfall levels, presents an inherent risk. In order to do their job, these companies must have all their supplies and labor on

hand to effectively respond when snow hits. Most of these firms set up contracts in the spring and summer in which they commit to removing snow the following winter. These companies need to bear fixed costs with getting the contract, which includes staff, trucks, salt, gas, etc. If snowfall is low, they will not meet those costs or the business volume will not be high enough to cover for all these costs. Some supplies can be stored but others cannot and the company is forced to absorb the cost, hurting the snow-removal company's bottom-line. For example, salt gets wet and evaporates. On the opposite end of the spectrum, if snow levels are much higher than expected, extra staff is hired, overtime is paid and additional supplies are purchased. All of these factors increase overhead, which is generally higher once winter begins, leading to declining revenue margins.

The first snowfall contracts were listed in 2006, futures contracts based on snowfall at Boston Logan International Airport and New York Central Park. CME now offers six snowfall contracts based on weather data from six locations, in five U.S. cities: Boston, Chicago, Detroit, Minneapolis and two in New York. This range includes futures and options, but so far only two of the contracts have traded: the seasonal and monthly binary options (discussed in section 3.9). A snowfall binary option allows end-users to protect themselves from extra expenses if snowfall is outside of expectations. If a snow removal company has supplies to plow up to a certain amount of snow it can buy a binary options contract with a strike point at that level of snowfall. If snowfall is above the strike point, the company can "call" the option and is paid a fixed-dollar amount for whatever the contract specifies. That money can be used to cover extra expenses in the case of too much snow. If snowfall is below the strike price, the option simply expires worthless. On the opposite side, if a company chose to use "pay per event" contracts in which they are paid for each time their services are used, they could hedge against the possibility of too

little snow by selling binary options. If snowfall is low, the premium they received from selling the options supplements the bottom line. If snow is piling up, they pay out on the option but have increased revenue with which to do so. In essence, these contracts function as an insurance policy against potential losses if snow levels inhibit business or profit margins. So this is an extra risk management strategy for the companies affected by snowfall (too much or too little) in addition to usual snowfall related insurance policy. There are players in the market who can underwrite the snowfall related risk and provide an insurance coverage. However, many market practitioners rely on weather derivatives traded on CME rather than an insurance company simply because CME insures guaranteed pay out by working as a clearing house. During recent turmoil, many insurance companies have defaulted on indemnity payments. Also, the capital market may provide better transparency and more choices compared to traditional insurance players.

3.11. Geographic Basis Risk

Basis risk is defined as the risk that offsetting investments in a hedging strategy will not experience price changes in entirely opposite directions from each other. This imperfect correlation between the two investments creates the potential for excess gains or losses in a hedging strategy, thus adding risk to the position. Geographic basis risk is very unique to weather derivatives as weather is a very spatial phenomenon; hence the underlying index needs to be correctly tied to the local weather station data.

3.12. Precipitation/Rainfall Modeling

A review of the literature reveals three types of rainfall models that have been used in pricing rainfall derivatives. They are: generalized linear models or GLMs, hidden Markov models and Non parametric models. GLM models were introduced by Coe and Stern (1982, 1984) to model a daily time series of rainfall measurement at a single site. GLMs are the simplest stochastic

weather models and have been used widely due to their simplicity. These are basically parametric models with the outcome variable as the daily rainfall which is modeled with explanatory variables of sine/cosine functions of time for seasonality. They also sometimes incorporate other covariates like climatological variables and regional forecasts. Single site models can be enhanced to model multiple sites using multivariate time series methods. In these models, correlations across space are modeled together with rainfall outcomes at unobserved locations. The marginal distribution of daily rainfall data has a point mass at zero (dry days), so these models often comprise two parts: 1. A model for dependent binary data-such as a two-state Markov chain (as has been used in this study) model to model the occurrence of rainfall on a given day conditional on whether the previous day was dry or wet. 2. For wet days, a right-skewed distribution such as exponential, gamma or mixed exponential distributions are used to model the magnitude of rainfall. Most GLMs are fit using maximum-likelihood methods (Jewson, 2002).

Hidden Markov Chain or HMM models differ from GLMs in that they model autocorrelation and spatial correlation through some number, K , of discrete, unobserved hidden states (Jewson, 2002). These hidden states often correspond to different “weather states” that result in different patterns of rainfall. These hidden states change through time according to a first-order Markov chain and the outcomes are modeled as independent draws from distributions conditional on their corresponding hidden states.

Nonparametric models are attractive due to their freedom from parametric distribution assumptions. Hence these models may be best suited to model certain features of the rainfall process better than GLMs or HMM. The key feature of these models is a resampling algorithm, in which daily time series of rainfall are simulated by resampling the observed data in a way that

accounts for the autocorrelation of observed rainfall (Wilks, 1989). This also takes care of the relationships between rainfall and other weather variables.

Local Correlation of Weather Stations of WV

Temperatures diffuse quickly to produce homogenous areas with nearly uniform levels of the desired statistics. Rainfall, on the other hand, is discrete by its very nature and this provides difficulties when attempting to produce reliable models of its variability. This local variability manifests already discussed geographic basis risk. This is a huge limitation when considering the use of derivatives to hedge rainfall/precipitation exposure and is one of the primary reasons that these types of weather derivatives are slow to be taken up compared with temperature derivatives. As a remedy, the derivative contract can be based on the average of several nearby weather stations in order to reduce much of the spatial basis risk that is inherent in precipitation derivatives. Hence two weather stations in close proximity to each other often record vastly different rainfall measures on the same day. The local rainfall correlations between Monongalia/Hartfield and Martinsburg/Berkeley weather stations of WV are reported in section 3.5 along with other results.

Linear Trend

It is important to check for long term trends which are usually found in temperature data. A regression was performed on the yearly cumulative rainfall of Monongalia/Hartfield Airport to check if any significant trend can be established. The result is included again in the results section.

Transition Probability and Seasonality

Following Cao (2004), let X_t be a binary variable that takes a value of 1 if it rains on day t and 0 otherwise. X_t is an n th order Markov chain if X_t is independent of X_{t-k} for all $k > n$. Let us keep

only the first order Markov Chain i.e. $n=1$. Let p be the probability that day t is wet, then for the first order Markov chain we have,

$$p_t = p_{t-1}q_{11} + (1-p_{t-1})q_{01} \quad (32)$$

Where q_{11} and q_{01} are the one-step transition probabilities.

In layman's terms this is equivalent to asking:

What is the probability of wet today, conditional on a dry yesterday or a wet yesterday?

If today is wet, then what is the expected rainfall/precipitation?

Given two states, Dry (D) or Wet (W), there could be four possible one stage transition probabilities:

Dry (D) | $t-1 \longrightarrow$ Wet (W) | t (a)

Wet (W) | $t-1 \longrightarrow$ Dry (D) | t

Dry (D) | $t-1 \longrightarrow$ Dry (D) | t (c)

Wet (W) | $t-1 \longrightarrow$ Wet (W) | t (d)

We are interested only in (a) which is denoted by q_{01} and (d) which is denoted by q_{11} .

Conditional on $X_t=1$ (i.e. a wet day), the amount of rainfall Y_t follows a gamma distribution, and the probability density function is:

$$f(x, \alpha, \beta) = \left(\frac{x}{\beta}\right)^{\alpha-1} \left[\frac{\exp\left(-\frac{x}{\beta}\right)}{\beta\tau(\alpha)} \right], x > 0; \alpha, \beta > 0, \quad (33)$$

Where α is the shape parameter and β is the scale parameter, x is the random variable which is cumulative precipitation in this case. Scale and shape parameters can be estimated using MLE (Greene, 2007).

Seasonality can also be built into the framework. We can allow the one-step transition probability q_{11} to vary with the time of the year as follows:

$$q_{11} = c_0 + \sum_{i=1}^m [c_{1i} \sin(\frac{2\pi i}{365} t) + c_{2i} \cos(\frac{2\pi i}{365} t)] \quad (34)$$

Where t is time and m is an integer to be set by the user, c 's are the parameters to be estimated.

The mean conditional precipitation for day t can be modeled as:

$$\bar{Y}_t = d_0 + \sum_{i=1}^m [d_{1i} \sin(\frac{2\pi i}{365} t) + d_{2i} \cos(\frac{2\pi i}{365} t)] \quad (35)$$

Where m is same as above and d 's are the parameters to be estimated.

If the transition probabilities (i.e. the transition from either a dry or wet day at $(t-1)$ or previous day to a wet day at t or present day) are constant, then the maximum likelihood estimate for q_{01} (q_{11}) is the ratio of The total number of raining days where the previous day is dry (wet) and The number of dry (wet) days.

To estimate the seasonal transition probabilities as defined in equation (34), the following regression model can be estimated for those days where it rained the previous day:

$$I_t(1) = \bar{c}_0 + \sum_{i=1}^m [\hat{c}_{1i} \sin(\frac{2\pi i}{365} t) + \hat{c}_{2i} \cos(\frac{2\pi i}{365} t)] + \varepsilon_t \quad (36)$$

Where $I_t(1) = 1$ if day t rains and 0 otherwise. ε_t is the regression error term.

Use of a gamma distribution in modeling cumulative rainfall is popular in previous Rainfall derivative modeling work (Martin et al, 2001). Cao, 2004 has shown use of both parametric and non parametric (kernel density) methods to model the cumulative rainfall. I have used both the gamma and exponential distribution to model the rainfall. SAS/ETS has been used for the estimation purposes. It generates Kolmogorov-Smirnoff and Anderson-Derling test statistics

which can be used to compare the goodness-of-fit of both parametric and non parametric assumptions.

3.13. Simulation

Once the parameters have been estimated for both frequency and magnitude processes, it is possible to simulate precipitation values and compare them with historical values. A simulation exercise has been carried out for Monongalia/Hartfield weather station historical data which is reported in section 3.5.

3.14. The Effects of El Nino

The main source of seasonal predictability is a phenomenon known as El Nino Southern Oscillation. The ‘El Nino’ part of ENSO is a fluctuation in the surface temperatures of the eastern half of the equatorial Pacific Ocean, while the ‘Southern Oscillation’ part is a shift in the wind and pressure patterns over the whole of the Pacific (Jewsen, 2007). In fact, the two phenomena are intimately linked through a cycle of cause and effect, and they are usually discussed as part of the same phenomenon: hence the name ENSO. The changes in the atmosphere associated with El Nino cause changes in the weather around large parts of the globe. In particular, El Nino has very strong effects in other parts of the tropics: this is because atmospheric signals travel most easily along the equator. Certain parts of South America and Australia experience very strong El Nino effects, while parts of Africa and the Indian Ocean also feel some effect. The impact of El Nino on the extratropics is weaker. Among these weaker signals, the strongest are those in North America. Many studies (Jewson, 2002) have been carried out to quantify such effects, although precise quantification is very difficult for a number of reasons, such as (a) every El Nino is slightly different, (b) there have only been a small number of El Nino events during the last forty years, and (c) the effects are not necessarily simple in structure. However, two basic features of the response to El Nino over the United

States during the winter have been observed quite frequently. They are: s warming over most of the northern United States, and increased rainfall in the southern United States and coastal California. El Nino effects have not been considered in this study, since West Virginia is quite free from its effects.

3.15. Rainfall/Precipitation Data, Estimation and Results

NOAA data from four weather stations in West Virginia were obtained. The weather stations are: Hartfield airport of Monongalia County, Martinsburg of Berkeley County, Monroe County and Randolph County. Each weather station contains about ten thousand observations of the past 30 years of daily data (1971-2000).

Precipitation Trend/Seasonality

Figure 3-9.: Precipitation Trend of Annual Precipitation of Four West Virginia Weather Stations over 1971-2000.

Local Trend

Monthly Precipitation Trend-Monongalia/Hartfield vs. Martinsburg

Figure 3-10.: Monthly Precipitation Trend-Monongalia/Hartfield vs. Martinsburg (1971-2000).

Figure 3-11.: Cumulative August Rain Inches (1971-2000) of Four West Virginia Weather Stations.

Linear Trends

Annual Cumulative Rainfall-Monongalia/Hartfield

Figure 3-12.: Annual Cumulative Precipitation-Monongalia/Hartfield

From the R-squared value, it is evident that there is no linear trend present.

Transition Probability and Seasonality

Monongalia

Figure 3-13: Transition Probability (q01/q11) for Monongalia

Figure 3-14: Conditional Precipitation of Monongalia across days of year

Monroe

Figure 3-15: transition probability (q01/q11) of Monroe

Figure 3-16: conditional precipitation amount of Monroe across days of year

Figures from 3-13 to 3-16 represent the transition probability (i.e. the transition probability from a dry day ($t-1$) to a wet day (t) which is q_{01} or the transition from a wet day ($t-1$) to a wet day (t) which is q_{11}) and the conditional precipitation depending on the state of previous day (i.e. whether it was a dry or a wet day) for the weather stations of Monongalia-Hartfield and Monroe.. These transition probabilities and conditional precipitation amount have been plotted against the day of the year (e.g. $p50 = 50^{\text{th}}$ day, $p100=100^{\text{th}}$ day and so on).

Tables 3-3. And 3-4. Represent the Gamma and Exponential Distribution Parameter estimates. According to the Kolmogorov-Smirnoff/Anderson-Derling statistics generated by SAS/ETS, Gamma distribution was found to be a better match between gamma and exponential distributions. Further, @Risk had been called to check which distribution best fits the data. It was found that this software validates selection of this distribution choice.

Table 3-3.: Gamma Distribution Parameter Estimates

Weather Stations	Time Period	Scale parameter, beta or sigma	Shape Parameter, alpha	Mean	Std.Dev
Hart Field, Monongalia	August	1.03	3.94	4.05	2.04
Martinsburg, Berkeley	August	1.012	3.36	3.39	1.85
Monroe	August	0.874	3.57	3.12	1.65
Randolph	August	2.68	2.01	5.4	3.8

Table 3-4. : Exponential Distribution Parameter Estimates

Weather Station	Estimated Theta or Threshold	Sigma or Scale Parameter	Mean	Standard Deviation
Hart Field, Monongalia	0.908	3.14	4.04	3.14
Martinsburg, Berkeley	0.63	2.761	3.39	2.761
Monroe	0.66	2.498	3.157	2.498
Randolph	0.948	4.398	5.346	4.398

3.16. Derivative (Option) Pricing: Classical Methods

There are four classical methods to price a derivative according to the book “Options, Futures and Other Derivatives” (Hull, 2007). They are briefly described here.

Black-Scholes model

Fischer Black and Myron Scholes first articulated the Black-Scholes formula in their 1973 paper, "The Pricing of Options and Corporate Liabilities". The fundamental insight of Black-Scholes is that the option is implicitly priced if the stock is traded.

The Black-Scholes Partial Differential Equation (hereinafter B/S PDE):

Notation:

S , the price of the stock

$V(S,t)$, the price of a derivative as a function of time and stock price.

$C(S,t)$ the price of a European call and $P(S, t)$ the price of a European put option.

K , the strike of the option.

r , the annualized risk-free interest rate, continuously compounded.

μ , the drift rate of S , annualized.

σ , the volatility of the stock; this is the square root of the quadratic variation of the stock's log price process.

t a time in years; we generally use now = 0, expiry = T .

Π , the value of a portfolio.

R , the accumulated profit or loss following a delta-hedging trading strategy.

As per the model assumptions above, we assume that the underlying asset (typically the stock) follows a Geometric Brownian motion/Wiener Process. That is,

$$dS = \mu S dt + \sigma S dW \quad (37)$$

where W is Brownian—the dW term here stands in for any and all sources of uncertainty in the price history of a stock. The payoff of an option $V(S, T)$ at maturity is known. To find its value at an earlier time we need to know how V evolves as a function of S and T . By Itô's lemma for two variables we have:

$$dV = \left(\mu S \frac{\partial V}{\partial S} + \frac{\partial V}{\partial t} + \frac{1}{2} \sigma^2 S^2 \frac{\partial^2 V}{\partial S^2} \right) dt + \sigma S \frac{\partial V}{\partial S} dW \quad (38)$$

After careful manipulation, one finally obtains the B-S PDE which is given by:

$$\frac{\partial V}{\partial t} + \frac{1}{2} \sigma^2 S^2 \frac{\partial^2 V}{\partial S^2} + rS \frac{\partial V}{\partial S} - rV = 0 \quad (39)$$

This partial differential equation holds whenever V is twice differentiable with respect to S and once with respect to t .

Model Assumptions:

The Black–Scholes model of the market for a particular equity makes the following explicit assumptions:

- It is possible to borrow and lend cash at a known constant risk-free interest rate. This restriction has been removed in later extensions of the model.
- The price follows a Geometric Brownian motion with constant drift and volatility. This often implies the validity of the efficient-market hypothesis.
- There are no transaction costs or taxes.
- Returns from the security follow a log-normal distribution.
- The stock does not pay a dividend. All securities are perfectly divisible (i.e. it is possible to buy any fraction of a share).
- There are no restrictions on short selling³.
- There is no arbitrage opportunity
- Options use the European exercise terms, which dictate that options may only be exercised on the day of expiration.

Several of these assumptions of the original model have been removed in subsequent extensions of the model. Modern versions account for changing interest rates (Merton, 1976), transaction costs and taxes (Ingerson, 1976), and dividend payout (Merton, 1973).

$N(x)$ denotes the standard normal cumulative distribution function,

$$N(x) = \frac{1}{\sqrt{2\pi}} \int_{-\infty}^x e^{-\frac{z^2}{2}} dz \quad (40)$$

³ Short selling is when the seller borrows stocks from a broker and sells them immediately, speculating that price of stock will decline. When the stock price declines, he buys them back at a lower price and returns them to the broker. Hence, makes a profit by drop in stock price.

$$N'(x) = \frac{e^{-\frac{x^2}{2}}}{\sqrt{2\pi}} \quad (41)$$

$N(x)$ denotes the standard normal probability density function.

The Black Scholes Formula

The Black Scholes formula calculates the price of European put and call options. It can be obtained by solving the Black–Scholes partial differential equation.

The value of a call option in terms of the Black–Scholes parameters is:

$$C(S, t) = SN(d_1) - Ke^{-r(T-t)}N(d_2) \quad (42)$$

$$d_1 = \frac{\ln\left(\frac{S}{K}\right) + \left(r + \frac{\sigma^2}{2}\right)(T-t)}{\sigma\sqrt{T-t}} \quad (43)$$

$$d_2 = d_1 - \sigma\sqrt{T-t} \quad (44)$$

The price of a put option is:

$$P(S, t) = Ke^{-r(T-t)} - S + (SN(d_1) - Ke^{-r(T-t)}N(d_2)) = Ke^{-r(T-t)} - S + C(S, t) \quad (45)$$

For both, as above:

- $N(\bullet)$ is the cumulative distribution function of the standard normal distribution
- $T - t$ is the time to maturity
- S is the spot price of the underlying asset
- K is the strike price
- r is the risk free rate (annual rate, expressed in terms of continuous compounding)
- σ is the volatility in the log-returns of the underlying

Interpretation

$N(d_1)$ and $N(d_2)$ are the probabilities of the option expiring in-the-money under the equivalent exponential martingale probability measure (numéraire = stock) and the equivalent martingale probability measure (numéraire = risk free asset), respectively. The equivalent martingale probability measure is also called the risk-neutral probability measure. Note that both of these are *probabilities* in a measured theoretic sense, and neither of these is the true probability of expiring in-the-money under the real probability measure.

Monte Carlo Methods

The Monte Carlo option model uses Monte Carlo methods to calculate the value of an option with multiple sources of uncertainty or with complicated features. In general the technique is to generate several thousand possible (but random) price paths for the underlying index via simulation, and then calculate the associated exercise value (i.e. "payoff") of the option for each path. These payoffs are then averaged and discounted to today, and this result is the value of the option today.

Binomial Method

The binomial options pricing model (BPM) provides a generalized numerical method for the valuation of options. The binomial model was first proposed by Cox, Ross and Rubinstein (1979). Essentially, the model uses a "discrete-time" model of the varying price over time of the underlying financial instrument. The Binomial options pricing model approach is widely used as it is able to handle a variety of conditions for which other models cannot easily be applied. This is largely because the BPM models the underlying instrument over time - as opposed to at a particular point. So this model can be used to value American options which can be exercised at any point and Bermudan options which can be exercised at various points. The model is also relatively simple, mathematically, and can therefore be readily implemented in software like

MATLAB (or even in spreadsheet). Although slower than the Black-Scholes formula, it is considered more accurate, particularly for longer-dated options, and options on securities with dividend payments. For these reasons, various versions of the binomial model are widely used by practitioners in the options markets.

Finite Difference Techniques

Finite difference methods for option pricing are a numerical method used in mathematical finance for the valuation of options using finite difference methods. The method was first applied to option pricing by Eduardo Schwartz in 1977. Finite difference methods can solve derivative pricing problems that have, in general, the same level of complexity as those problems solved by tree approaches (BPM), and are therefore usually employed only when other approaches are inappropriate. At the same time, like tree-based methods, this approach is limited in terms of the number of underlying variables, and for problems with multiple dimensions, Monte Carlo methods for option pricing are usually preferred. This approach is based on the fact that the evolution of the option value can be modeled using a partial differential equation (for example Black–Scholes PDE discussed above). Once in this form, a finite difference model can be derived, and the valuation obtained.

3.17. Weather Derivative Valuation: A Review of Literature and Methods

Since the inception of the weather derivatives market, the number and type of market participants have continuously expanded. A range of market participants including investment banks, insurance firms, energy companies to hedge funds offer weather risk management products. Each participant has its own distinct product line and pricing models (Sloan, Palmer, and Burrow, 2002). These pricing models very often follow either one of the basic models described in the earlier section but they come with more standardized form. In other words, these

contracts are commonly valued by the expected payoff under the physical measure, discounted at the risk-free rate, i.e., an actuarial approach (Davis, 2001). This is the fundamental concept behind any asset valuation. Subsequently, various alternative pricing mechanisms, as off-shoots of the fundamentals, have been developed and applied for the incomplete markets, including super-replication (El Karoui and Quenez, 1995), quadratic approaches (Follmer and Sondermann, 1986; Schweizer, 1988, 1991; Bouleau and Lamberton, 1989; Duffie and Richardson, 1991), quantile hedging and shortfall minimization (Cvitanic, 1998; Follmer and Leukert, 1999, 2000), the marginal utility approach (Davis, 1998), and indifference pricing (Hodges and Neuberger, 1989; Davis, Panas, and Zariphopoulou, 1993). The incomplete financial market models that acknowledge both the hedgeable and unhedgeable risks are more appropriate for the valuation of weather derivatives.

Some researchers have also attempted to explore the problem of weather derivative valuation in the incomplete market. In one of the earliest papers in weather derivative valuation, by Cao and Wei (2000), the authors propose and implement an equilibrium valuation framework for weather derivatives. This paper generalizes the Lucas model of 1978 to include weather as a fundamental variable in the economy. The numerical analyses provided in this paper show that the market price of risk associated with the temperature variable is insignificant in most cases, especially when risk aversion is high or when the aggregate dividend process is close to a random walk. Davis (2001) explores weather derivative pricing using the marginal utility approach, based on the assumption that agents in the weather derivatives market are not representative but face very specific weather risks. Brockett, Wang, and Yang (2003) adopt an incomplete market pricing model, namely the indifference valuation approach, to analyze the valuation of weather derivatives. The indifference valuation approach starts from the economic

principle of certainty equivalent (discussed in essay I), but is modified and extended to accommodate partial hedging in the financial market. In a mean–variance framework (again discussed in essay I), the relationship between weather derivatives indifference prices and the transaction volume has been examined, and a number of conditions are obtained when the actuarial price is not an appropriate valuation for weather derivatives. By comparing the buyers and sellers indifference prices, the authors also examine the conditions for the viability of the weather derivatives market. In addition, by examining explicitly the distributional impacts of all the stochastic variables involved, Brockett, Wang, and Yang investigate the impacts of partial hedging, natural hedges, basis risk, quantity risk, and price risk on the investors indifference prices.

In practice, most issuers of weather contracts write a large portfolio to take advantage of geographic diversification and hedging effects. For hedgers, they would desire to use a combination of standardized weather contracts and basis weather derivatives designed to hedge the basis risk (mostly geographic basis risk) of the standardized contracts. Single contracts can be priced in the context of the marginal changes they cause to the portfolio rather than on their stand-alone performance (Jewson et al., 2002). Also in a mean–variance framework, Brockett et al. (2003) adopt the indifference pricing approach to examine the portfolio effects on weather derivatives indifference prices. In this article, portfolio effects are defined as the effects on the indifference prices of weather derivatives when investors usually hold a portfolio of weather derivatives and other financial assets. Their simulation results illustrate how the magnitude of the portfolio effects is related to the correlation between weather indexes, between weather indexes and the payoff of the risky assets in the financial market, and to some other distributional characteristics of the relevant stochastic variables, as well as to the payoff structures of the

weather contracts already in the investor's portfolio. This is a growing area in research and a pricing model can be made as complex as one wishes with adequate understanding of basic nature of pay-outs, stochastic calculus and derivatives. In the present essay, a simple pricing exercise has been carried out as discussed in the following section.

Since weather derivatives do not have any underlying index like stock in stock options which trades in a primary market, valuation of a weather derivative is very different from the four approaches discussed above. Monte Carlo approach can always be used to price any type of derivative contract. According to Jewson et al., 2005, there are two different pricing approaches available. They are discussed as follows:

'Burn' Analysis

Burn analysis or just 'burn' is based, very simply, on the idea of evaluating how a contract would have performed in previous years (Jewson, 2002). It explicitly does not include fitting distributions and using Monte Carlo simulations. Although there are cases when other methods may be more accurate or give more information, burn analysis is a good first step in pricing almost any contract. Burn analysis had been performed in this essay to price Rainfall contracts over month of August using cumulative August precipitation as the underlying index using four weather station data of West Virginia over 1971-2000. So in essence, I had 30 cumulative August rainfall observations. I averaged out the respective call and put prices utilizing the 5 different tick sizes (in \$ terms) which essentially give me the Rainfall call & put premiums as per Burn analysis in \$ denomination.

Monte Carlo Simulation

Since traditional models like Black-Scholes are not applicable to value weather based contracts, the best approach would be to use Monte Carlo simulation. It starts out by simulating the various paths the underlying variable (here the weather variable) would take using a parametric

assumption and generates a substantial number of observations (1,000s) and then averages them using a discount rate to find the contract value at the expiration date. Both the Burn and Monte Carlo simulation have been utilized in this essay to find the optimal value of a rainfall based call option for West Virginia (as described in section 3.20) using weather data of 4 weather stations in West Virginia.

3.18. Previous Applications of Precipitation Contracts/Derivatives

Precipitation, both in the form of rain and snow, exerts a significant impact on the revenue of many businesses. Farming is an obvious example. Drought or flood can both adversely affect the crop yield. Too little rainfall affects the quantity of forage produced and hence affects the grass-fed producers. They are forced to sell their cattle earlier in the market or send them to the feedlot. By the same token, outdoor recreational parties (e.g. golf, skiing etc.) have much to worry about excess precipitation or the lack of it. Hydroelectric generators are very keen on the accumulative precipitation over any given time period. Lack of precipitation means a low water level in reservoirs, which in turn means a shortage of power supply. The reduced power output not only leads to a loss of revenue, sometimes it also means purchasing power at unfavorable prices from other generators in order to make up the supply shortage. Some of the deals that have been constructed in precipitation derivatives include the Southern hydro partnership versus Credit Lyonnais Rouse Derivatives (Artemis.bm/index.htm). Southern Hydro Partners (SHP) is a hydroelectric power generator in South East Australia, with most of its facilities located in Victoria and New South Wales. With rainfall levels being significantly below the historical average for several years, the company decided to enter into a precipitation contract with Credit Lyonnais Rouse Derivatives or Calyon in 2003. SHP's primary goal was to stabilize cash flows and revenue. The precipitation contract was structured as a collar (described earlier) whereby

SHP would receive payments from Calyon should the rainfall be lower than a specified threshold level and pay Calyon should the rainfall be above a certain level.

Another precipitation deal was struck between Sacramento Municipal Utility District (SMUD) versus Aquila (Cao, 2004). SMUD is America's sixth largest community-owned electric utility in terms of customers served. The utility generates half of its electricity and buys the rest. The generated portion is primarily from hydroelectric and cogeneration power plants. In September 2000, SMUD entered into a five-year precipitation contract with Aquila to protect against low rainfall levels. The contract was structured as a collar (described earlier) whereby Aquila would pay SMUD annually up to \$20 million when the water flow through the hydro plants is below a certain amount while SMUD would pay Aquila \$20 million in years when precipitation is abundant. To further reduce the cost of hedging, the payments to Aquila were capped at \$50 million.

Another example is a precipitation contract between golf course operators versus Societie Generale (sgcib.com/). A golf course owner entered into a derivative contract with Societie Generale, SG, after assessing that his business suffers when the weather was wet. The structured deal covered the period from May to September, within which the golf course owner would receive compensation should the total number of rainy days go beyond 50. Specifically, once the number of days with rainfall of more than a millimeter passed 50, SG would pay for every wet day.

Similarly, World Bank is also proposing to introduce index based weather derivative contracts in developing countries to reduce the impact of drought (artemis.bm/blog/2008/06/25/world-bank-to-offer-index-based-weather-derivative-contracts/).

World Bank proposes to offer financial intermediation services to low-income client countries of

the International Development Association (IDA) and will add to the range of risk-management tools available to middle income client countries of the International Bank for Reconstruction and Development (IBRD). Malawi is expected to be the first country to take advantage of this new offer. The World Bank is expected to work as the intermediary by entering into mirroring transactions with the client country and a financial market counterpart. In the event of a severe weather event, client countries, such as Malawi, would receive a payout from the Bank, the total value of which would be based on an index used as an estimate of the financial impact. This would be funded with the payout that the World Bank would receive from the mirroring transaction.

3.19. A Pricing Exercise by ‘Burn’ and Monte Carlo Simulation for the Current Essay

Assuming a parametric distribution (both gamma and exponential), 10,000 observations have been iterated and pricing of the contract has been calculated for different strike/exercise rates of 1.5, 2.0, 2.5, 3.0, 3.5 and 4.0 inches of rainfall with a tick size or liability of \$1000 per contract. Table 3-4 shows the sample pricing/valuation at expiration for a call option and Table 3-5 shows the sample pricing/valuation at expiration for a put option utilizing four weather stations data from West Virginia for both burn and Monte Carlo exercises.

CALL PRICING **Terms of this contract**

- Period: August, Measure: Cumulative Monthly Rainfall
- Exercise/Strike Levels: 1.50 inches, 2.00 inches, 2.50 inches, 3.00 inches, 3.50 inches and 4.00 inches.
- Tick/Contract Size: \$1000/inch, Limit: \$3000.
- Interest Rate: 5% Annual Compounding.

- Locations: Martinsburg, Monongalia, Monroe, Randolph of West Virginia.

Table 3-5.: Call Price in \$ (Strike/Exercise rate is in rain inches)

Valuation Type	Exercise/Strike Rate	1.50	2.00	2.50	3.00	3.50	4.00
Burn	Martinsburg	1953.67	1542.00	1197.67	935.55	727.67	567.67
	Monongalia	2564.84	2101.16	1712.26	1359.68	1069.35	832.9
	Monroe	1689.31	1307.24	987.24	711.03	490.69	338.62
	Randolph	2778.96	2310.00	1887.24	1498.28	1128.62	853.10
Monte Carlo (Gamma Distribution)	Martinsburg	1926.93	1521.41	1176.19	892.69	665.93	488.83
	Monongalia	2490.16	2044.48	1644.46	1298.74	1008.79	771.25
	Monroe	2127.71	1705.50	1338.81	1031.72	781.73	583.15
	Randolph	2368.45	2109.67	1544.32	1324.78	897.65	533.25
Monte Carlo (Exponential Distribution)	Martinsburg						
		1621.32	1355.95	1135.97	951.76	798.20	669.01
	Monongalia	1971.46	1686.23	1443.12	1235.22	1058.41	907.68
	Monroe	1347.34	1100.42	897.88	731.57	595.35	484.99
	Randolph	3066.82	2732.02	2432.71	2166.91	1929.82	1718.32

Figure 3-17.: Geographic Basis Risk in Call Value (Burn Pricing)

Figure 3-18: Geographic Basis Risk in Call Value (Monte Carlo Pricing)

PUT PRICING

Terms of this Contract

- Period: August, Measure: Cumulative Monthly Rainfall
- Exercise/Strike Levels: 6.00 inches, 6.50 inches, 7.00 inches, 7.50 inches and 8.00 inches.
- Tick/Contract Size: \$1000/inch. Limit: No Limit.
- Interest Rate: 5% Annual Compounding
- Locations: Martinsburg, Monongalia, Monroe, Randolph of West Virginia.

Table 3-6.: Put Value at Expiry in \$ (Strike/Exercise rate is in precipitation inches)

Valuation Type	Exercise/Strike Rate (in Inches of Precipitation)	6.00	6.50	7.00	7.50	8.00	8.50
Burn	Martinsburg	2677.333	3136.00	3606.333	4101.333	4601.333	5101.333
	Monongalia	2292.90	2728.38	3163.87	3599.67	4051.29	4518.71
	Monroe	2892.414	3378.621	3878.621	4378.621	4878.621	5378.621
	Randolph	1958.33	2375.00	2797.00	3240.00	3690.66	4157.33
Monte Carlo (Gamma)	Martinsburg	2728.78	3189.19	3657.65	4141.18	4626.44	5116.437
	Monongalia	2189.37	2623.21	3071.43	3533.50	4006.07	4484.665
	Monroe	2921.96	3425.25	3907.13	4395.70	4886.90	5381.848
	Randolph	1838.66	2176.10	2533.52	2907.56	3297.37	3701.027
Monte Carlo (Exponential)	Martinsburg	3536.74	3983.45	4437.36	4897.69	5364.34	5838.00
	Monongalia	3314.12	3744.13	4182.96	4630.40	5084.65	5546.85
	Monroe	4170.08	3712.40	4633.97	5103.83	5579.71	6058.80
	Randolph	2719.76	3096.43	3486.60	3888.54	4301.38	4722.87

Figure 3-19.: Geographic Basis Risk in Put Pricing (Burn Pricing).

Figure 3-20.: Geographic Basis Risk in Put Pricing (Burn Pricing).

3.20. Option Calculator

Subsequently, an option calculator has been developed in Visual Basic (VB.Net). The logical flow chart is as follows:

Figure 3-21.: Flowchart of Option Calculator

3.21. Possible Applications of the Structured Contract

In the previous section I have discussed historical precipitation/rainfall based deals. Following that, the structured precipitation contract for West Virginia has potential application for crop insurance, event insurance, golf course operators etc. Outdoor recreational operators may find it useful to hedge the bottom line of their business. Another possible application is event insurance, which is becoming popular of late. In this case, basis risk between the contract and the economic exposure needs to be matched as accurately as possible.

3.22. Limitation of the Study and Suggested Derivative Strategies for Grass Fed Producers

The main limitation of the current study is lack of a hedging effectiveness of the structured rainfall based contract. It was not possible to determine how much of the revenue of a grass fed producer is actually affected by too much or too little rainfall. In our email based survey 7 out of 16 respondents mentioned that drought or lack of rainfall affects their production related

activities. The next step in this study should be a hedging analysis using the structured contract and revenue generated by the grass fed producer. Though it was not possible to complete such study during the time frame of this study, the following steps should constitute the basic framework.

Figure 3-22.: Framework for Hedging effectiveness with Rainfall Option for Grass fed producers

Derivative Strategy:

Either a put/collar or strangle could work for these producers. A put option is identical to insurance. A collar works well as it means buying a put and selling a call, so it could be possible that no initial investment is necessary. Appendix E contains the pay-off diagrams of these strategies.

3.23. Conclusion

As the overall market for weather derivatives grows, contracts on precipitation are gradually making their way into the scene. However, compared with temperature derivatives, the market share of precipitation derivatives is still very minimal. This slow growth does not indicate a lack of interest or demand. There is enough demand from the farmers, hydro-power generators, sports event managers or recreation parks, the end users of this derivative product. However, there is lack of interest from the financial services firms or investment banks to provide a quote or

underwrite the risk. This disinterest comes from difficulty of rainfall modeling. Though various models of rainfall have been described in earlier sections, it is still a challenge to model extreme rainfall like a flood or severe drought and incorporate the spatial variability that generally comes with rainfall or any other weather phenomena. Application of a Kalman filter could be a possible solution towards better rainfall modeling. Non parametric methods can be investigated and modern techniques like artificial intelligence or support vector machines can be used for simulation/forecasting purposes. Extreme value theory (EVT) can be investigated to model extreme rainfall.

Albeit being new in the derivative world, interest in weather derivatives is certainly growing. Increase in the volume of trade at CME is a proof of this interest. However, the spatial nature of weather phenomena and the associated geographic basis risk are big roadblocks towards a major acceptance of this unique weather related risk management tool by companies hit by adverse weather. This rainfall/precipitation based contract, when made available either as OTC or exchange (CME) traded, could provide yet another risk management strategy to manage businesses suffering from too-little (use of put-option) or too-much rainfall (use of call option). This could successfully be applied to the grass-fed producers as well.

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APPENDIX A

USDA/RMA Coverage Reports used in Essay I

Date: 06/16

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LRP Coverage Prices, Rates, and Actual Ending Values - Report for 6/16/2008

USDA subsidizes 13 percent of total LRP premium

State	County	Endorsement Length	Commodity	Type	Practice	Crop Year	Exp. End Value	Coverage Price	Coverage Level	Rate	Cost Per CWT	End Date	Actual End Value
54 WEST VIRGINIA	998 ALL COUNTIES	13	0802 FED CATTLE	820 STEERS & HEIFERS	997 NO PRACTICE SPECIFIED	2008	105.807	\$91.230	0.862200	0.005897	0.538	09/15/2008	98.590
54 WEST VIRGINIA	998 ALL COUNTIES	13	0802 FED CATTLE	820 STEERS & HEIFERS	997 NO PRACTICE SPECIFIED	2008	105.807	\$87.230	0.824400	0.003198	0.279	09/15/2008	98.590
54 WEST VIRGINIA	998 ALL COUNTIES	13	0802 FED CATTLE	820 STEERS & HEIFERS	997 NO PRACTICE SPECIFIED	2008	105.807	\$81.230	0.767700	0.001157	0.094	09/15/2008	98.590
54 WEST VIRGINIA	998 ALL COUNTIES	13	0802 FED CATTLE	820 STEERS & HEIFERS	997 NO PRACTICE SPECIFIED	2008	105.807	\$79.230	0.748800	0.000757	0.060	09/15/2008	98.590

Notes:

- Some endorsement lengths may not be available due to insufficient pricing or rating information.
- For LRP Fed Cattle, Feeder Cattle and Swine, sales open from the time sales data is available (approximately 3:30 P.M. central time) until 9 A.M. central time the next day.
- For Lamb, sales available MONDAY ONLY. Sales open from the time of official release of coverage prices and rates on Monday morning (approximately 10 A.M. central time) until 7 P.M. central time Monday.
- For Lamb, preliminary coverage prices and rates may be available for viewing Friday evening and over the weekend but are subject to change at the official release time on Monday. Coverage prices and rates may also be available for viewing following sales during the week.
- Purchase of LRP must be made through an authorized livestock insurance agent.
- For LRP Fed Cattle, Feeder Cattle, and Swine, coverage levels and rates shown are available only on the selected effective date until 9 a.m. the following day.
- For LRP Lamb, coverage levels and rates shown are available only on the selected effective date until 7 p.m.
- For the Formatted Print option, Adobe Acrobat is required. For unformatted printing, use the File->Print option from your browser menu.
- Use landscape mode when doing unformatted printing for best results.

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USDA/RMA Coverage Reports used in Essay I

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LRP Coverage Prices, Rates, and Actual Ending Values - Report for 5/19/2008

USDA subsidizes 13 percent of total LRP premium

State	County	Endorsement Length	Commodity	Type	Practice	Crop Year	Exp. End Value	Coverage Price	Coverage Level	Rate	Cost Per CWT	End Date	Actual End Value
54 WEST VIRGINIA	998 ALL COUNTIES	13	0802 FED CATTLE	820 STEERS & HEIFERS	997 NO PRACTICE SPECIFIED	2008	97.300	\$91.000	0.935300	0.021341	1.942	08/18/2008	98.840
54 WEST VIRGINIA	998 ALL COUNTIES	13	0802 FED CATTLE	820 STEERS & HEIFERS	997 NO PRACTICE SPECIFIED	2008	97.300	\$89.000	0.914700	0.014820	1.319	08/18/2008	98.840
54 WEST VIRGINIA	998 ALL COUNTIES	13	0802 FED CATTLE	820 STEERS & HEIFERS	997 NO PRACTICE SPECIFIED	2008	97.300	\$87.000	0.894100	0.009747	0.848	08/18/2008	98.840
54 WEST VIRGINIA	998 ALL COUNTIES	13	0802 FED CATTLE	820 STEERS & HEIFERS	997 NO PRACTICE SPECIFIED	2008	97.300	\$85.000	0.873600	0.006235	0.530	08/18/2008	98.840
54 WEST VIRGINIA	998 ALL COUNTIES	13	0802 FED CATTLE	820 STEERS & HEIFERS	997 NO PRACTICE SPECIFIED	2008	97.300	\$79.000	0.811900	0.001367	0.108	08/18/2008	98.840
54 WEST VIRGINIA	998 ALL COUNTIES	17	0802 FED CATTLE	820 STEERS & HEIFERS	997 NO PRACTICE SPECIFIED	2008	99.956	\$93.660	0.937000	0.026799	2.510	09/15/2008	98.590
54 WEST VIRGINIA	998 ALL COUNTIES	17	0802 FED CATTLE	820 STEERS & HEIFERS	997 NO PRACTICE SPECIFIED	2008	99.956	\$91.660	0.917000	0.019889	1.823	09/15/2008	98.590
54 WEST VIRGINIA	998 ALL COUNTIES	17	0802 FED CATTLE	820 STEERS & HEIFERS	997 NO PRACTICE SPECIFIED	2008	99.956	\$89.660	0.897000	0.014142	1.268	09/15/2008	98.590
54 WEST VIRGINIA	998 ALL COUNTIES	17	0802 FED CATTLE	820 STEERS & HEIFERS	997 NO PRACTICE SPECIFIED	2008	99.956	\$87.660	0.877000	0.009868	0.865	09/15/2008	98.590
54 WEST VIRGINIA	998 ALL COUNTIES	17	0802 FED CATTLE	820 STEERS & HEIFERS	997 NO PRACTICE SPECIFIED	2008	99.956	\$81.660	0.817000	0.002964	0.242	09/15/2008	98.590
54 WEST VIRGINIA	998 ALL COUNTIES	21	0802 FED CATTLE	820 STEERS & HEIFERS	997 NO PRACTICE SPECIFIED	2008	103.700	\$92.600	0.893000	0.017732	1.642	10/13/2008	89.790
54 WEST VIRGINIA	998 ALL COUNTIES	21	0802 FED CATTLE	820 STEERS & HEIFERS	997 NO PRACTICE SPECIFIED	2008	103.700	\$90.600	0.873700	0.013212	1.197	10/13/2008	89.790
54 WEST VIRGINIA	998 ALL COUNTIES	26	0802 FED CATTLE	820 STEERS & HEIFERS	997 NO PRACTICE SPECIFIED	2008	104.032	\$92.930	0.893300	0.021898	2.035	11/17/2008	87.280
54 WEST VIRGINIA	998 ALL COUNTIES	26	0802 FED CATTLE	820 STEERS & HEIFERS	997 NO PRACTICE SPECIFIED	2008	104.032	\$90.930	0.874100	0.016969	1.543	11/17/2008	87.280
54 WEST VIRGINIA	998 ALL COUNTIES	30	0802 FED CATTLE	820 STEERS & HEIFERS	997 NO PRACTICE SPECIFIED	2008	104.500	\$95.700	0.915800	0.034347	3.287	12/15/2008	84.110

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USDA/RMA Coverage Reports used in Essay I

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LRP Coverage Prices, Rates, and Actual Ending Values - Report for 4/21/2008

USDA subsidizes 13 percent of total LRP premium

State	County	Endorsement Length	Commodity	Type	Practice	Crop Year	Exp. End Value	Coverage Price	Coverage Level	Rate	Cost Per CWT	End Date	Actual End Value
54 WEST VIRGINIA	998 ALL COUNTIES	13	0802 FED CATTLE	820 STEERS & HEIFERS	997 NO PRACTICE SPECIFIED	2008	94.205	\$90.410	0.959700	0.025252	2.283	07/21/2008	94.750
54 WEST VIRGINIA	998 ALL COUNTIES	13	0802 FED CATTLE	820 STEERS & HEIFERS	997 NO PRACTICE SPECIFIED	2008	94.205	\$88.410	0.938500	0.018312	1.619	07/21/2008	94.750
54 WEST VIRGINIA	998 ALL COUNTIES	13	0802 FED CATTLE	820 STEERS & HEIFERS	997 NO PRACTICE SPECIFIED	2008	94.205	\$86.410	0.917300	0.012661	1.094	07/21/2008	94.750
54 WEST VIRGINIA	998 ALL COUNTIES	13	0802 FED CATTLE	820 STEERS & HEIFERS	997 NO PRACTICE SPECIFIED	2008	94.205	\$84.410	0.896000	0.008885	0.750	07/21/2008	94.750
54 WEST VIRGINIA	998 ALL COUNTIES	13	0802 FED CATTLE	820 STEERS & HEIFERS	997 NO PRACTICE SPECIFIED	2008	94.205	\$80.410	0.853600	0.003408	0.274	07/21/2008	94.750
54 WEST VIRGINIA	998 ALL COUNTIES	17	0802 FED CATTLE	820 STEERS & HEIFERS	997 NO PRACTICE SPECIFIED	2008	97.200	\$92.550	0.952200	0.030675	2.839	08/18/2008	98.840
54 WEST VIRGINIA	998 ALL COUNTIES	17	0802 FED CATTLE	820 STEERS & HEIFERS	997 NO PRACTICE SPECIFIED	2008	97.200	\$90.550	0.931600	0.022562	2.043	08/18/2008	98.840
54 WEST VIRGINIA	998 ALL COUNTIES	17	0802 FED CATTLE	820 STEERS & HEIFERS	997 NO PRACTICE SPECIFIED	2008	97.200	\$88.550	0.911000	0.015822	1.401	08/18/2008	98.840
54 WEST VIRGINIA	998 ALL COUNTIES	17	0802 FED CATTLE	820 STEERS & HEIFERS	997 NO PRACTICE SPECIFIED	2008	97.200	\$84.550	0.869900	0.007558	0.639	08/18/2008	98.840
54 WEST VIRGINIA	998 ALL COUNTIES	21	0802 FED CATTLE	820 STEERS & HEIFERS	997 NO PRACTICE SPECIFIED	2008	98.994	\$94.340	0.953000	0.034948	3.297	09/15/2008	98.590
54 WEST VIRGINIA	998 ALL COUNTIES	21	0802 FED CATTLE	820 STEERS & HEIFERS	997 NO PRACTICE SPECIFIED	2008	98.994	\$92.340	0.932800	0.026781	2.473	09/15/2008	98.590
54 WEST VIRGINIA	998 ALL COUNTIES	21	0802 FED CATTLE	820 STEERS & HEIFERS	997 NO PRACTICE SPECIFIED	2008	98.994	\$90.340	0.912600	0.019714	1.781	09/15/2008	98.590
54 WEST VIRGINIA	998 ALL COUNTIES	21	0802 FED CATTLE	820 STEERS & HEIFERS	997 NO PRACTICE SPECIFIED	2008	98.994	\$86.340	0.872200	0.010551	0.911	09/15/2008	98.590
54 WEST VIRGINIA	998 ALL COUNTIES	26	0802 FED CATTLE	820 STEERS & HEIFERS	997 NO PRACTICE SPECIFIED	2008	102.050	\$92.350	0.904900	0.022794	2.105	10/20/2008	90.500
54 WEST VIRGINIA	998 ALL COUNTIES	26	0802 FED CATTLE	820 STEERS & HEIFERS	997 NO PRACTICE SPECIFIED	2008	102.050	\$90.350	0.885400	0.017156	1.550	10/20/2008	90.500

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USDA/RMA Coverage Reports used in Essay I

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LRP Coverage Prices, Rates, and Actual Ending Values - Report for 3/17/2008

USDA subsidizes 13 percent of total LRP premium

State	County	Endorsement Length	Commodity	Type	Practice	Crop Year	Exp. End Value	Coverage Price	Coverage Level	Rate	Cost Per CWT	End Date	Actual End Value
54 WEST VIRGINIA	998 ALL COUNTIES	13	0802 FED CATTLE	820 STEERS & HEIFERS	997 NO PRACTICE SPECIFIED	2008	89.359	\$85.430	0.956000	0.021327	1.822	06/16/2008	95.150
54 WEST VIRGINIA	998 ALL COUNTIES	13	0802 FED CATTLE	820 STEERS & HEIFERS	997 NO PRACTICE SPECIFIED	2008	89.359	\$81.430	0.911300	0.010131	0.825	06/16/2008	95.150
54 WEST VIRGINIA	998 ALL COUNTIES	17	0802 FED CATTLE	820 STEERS & HEIFERS	997 NO PRACTICE SPECIFIED	2008	90.663	\$86.740	0.956700	0.025536	2.215	07/14/2008	97.240
54 WEST VIRGINIA	998 ALL COUNTIES	17	0802 FED CATTLE	820 STEERS & HEIFERS	997 NO PRACTICE SPECIFIED	2008	90.663	\$82.740	0.912600	0.013947	1.154	07/14/2008	97.240
54 WEST VIRGINIA	998 ALL COUNTIES	21	0802 FED CATTLE	820 STEERS & HEIFERS	997 NO PRACTICE SPECIFIED	2008	93.234	\$91.860	0.985300	0.046277	4.251	08/11/2008	99.800
54 WEST VIRGINIA	998 ALL COUNTIES	21	0802 FED CATTLE	820 STEERS & HEIFERS	997 NO PRACTICE SPECIFIED	2008	93.234	\$85.860	0.920900	0.019241	1.652	08/11/2008	99.800
54 WEST VIRGINIA	998 ALL COUNTIES	21	0802 FED CATTLE	820 STEERS & HEIFERS	997 NO PRACTICE SPECIFIED	2008	93.234	\$79.860	0.856600	0.006136	0.490	08/11/2008	99.800
54 WEST VIRGINIA	998 ALL COUNTIES	26	0802 FED CATTLE	820 STEERS & HEIFERS	997 NO PRACTICE SPECIFIED	2008	95.341	\$93.970	0.985600	0.050005	4.699	09/15/2008	98.590
54 WEST VIRGINIA	998 ALL COUNTIES	26	0802 FED CATTLE	820 STEERS & HEIFERS	997 NO PRACTICE SPECIFIED	2008	95.341	\$87.970	0.922700	0.023485	2.066	09/15/2008	98.590
54 WEST VIRGINIA	998 ALL COUNTIES	26	0802 FED CATTLE	820 STEERS & HEIFERS	997 NO PRACTICE SPECIFIED	2008	95.341	\$81.970	0.859800	0.008979	0.736	09/15/2008	98.590
54 WEST VIRGINIA	998 ALL COUNTIES	30	0802 FED CATTLE	820 STEERS & HEIFERS	997 NO PRACTICE SPECIFIED	2008	98.655	\$93.260	0.945300	0.041433	3.864	10/13/2008	89.790
54 WEST VIRGINIA	998 ALL COUNTIES	30	0802 FED CATTLE	820 STEERS & HEIFERS	997 NO PRACTICE SPECIFIED	2008	98.655	\$89.260	0.904800	0.025835	2.306	10/13/2008	89.790
54 WEST VIRGINIA	998 ALL COUNTIES	34	0802 FED CATTLE	820 STEERS & HEIFERS	997 NO PRACTICE SPECIFIED	2008	99.214	\$93.810	0.945500	0.044441	4.169	11/10/2008	92.690

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APPENDIX B

Decision Support Tool for Pasture, Rangeland and Forage

Website: <http://www.rma.usda.gov/policies/pasturerangeforage>

APPENDIX C

Basis Risk in Local Cattle Market vs. AMS 5 Area Market

Year	AMS 5 Market (\$)	VA(\$)	PA(\$)	Year	AMS 5 Market(\$)	VA(\$)	PA(\$)
Apr-05	91.91	93	80.7	Sep-07	92.9	88.6	78.3
May-05	88.76	90.2	81.6	Oct-07	93.63	84.7	76.2
Jun-05	83.76	88.7	76.3	Nov-07	92.85	76.9	72.6
Jul-05	80.23	84.6	72	Dec-07	92.92	67.5	74.6
Aug-05	79.13	88.1	71.2	Jan-08	90.35	65.8	74.7
Sep-05	86.39	88.1	72.2	Feb-08	91.15	73.9	77.1
Oct-05	88.87	88	73.4	Mar-08	89.93	79.1	77.4
Nov-05	90.07	84.2	73.9	Apr-08	89.96	78.5	75.9
Dec-05	94.45	74.9	77.6	May-08	94.09	79	79.1
Jan-06	93.42	74.8	79.1	Jun-08	93.22	80.1	80.6
Feb-06	88.87	77	77.7	Jul-08	97.24	80	83.7
Mar-06	85.96	75.8	75.6	Aug-08	99.8	82.4	83.5
Apr-06	82.19	77.5	73.1	Sep-08	98.59	81.7	82.6
May-06	79.21	74.4	72.3	Oct-08	89.79	74.6	76.9
Jun-06	80.11	77.7	73.2	Nov-08	92.69	69.8	73.9
Jul-06	81.39	81.3	73.1	Dec-08	84.11	59.9	72.1
Aug-06	85.6	82.1	72.7	Jan-09	83.75	65.1	73.1
Sep-06	87.92	86.8	74.2	Feb-09	82.76	67.2	71.4
Oct-06	86.89	82.4	72.5	Mar-09	82.96	72.1	70.2
Nov-06	86.59	71.8	72.2	Apr-09	88.01	76.7	72.4
Dec-06	85.12	62.2	72	May-09	85	76.1	74.9
Jan-07	86.77	62.7	73.9	Jun-09	81.84	73	71.9
Feb-07	90.48	68.4	76.6	Jul-09	83.88	75.7	72
Mar-07	98.14	77.8	79.4	Aug-09	81.95	74.3	71.2
Apr-07	96.03	84.7	81.2	Sep-09	84.23	75.4	69.7
May-07	97.59	77.8	83.6	Oct-09	82.99	71.2	68.9
Jun-07	89.79	75	79	Nov-09	84.03	67.1	69.3
Jul-07	89.71	79.7	77.3	Dec-09	81.2	62.7	69.4
Aug-07	90.3	83.4	78.5				

Data Source: NASS/Market News, VA/PA.

APPENDIX D

Actual LRP end value (\$) from 15th Sep.-15th Oct., 2005 to 15th Sep.-15th Oct., 2009

Date	2005	2006	2007	2008	2009
15-Sep	86.39	88.7	92.9	98.59	84.23
16-Sep	86.39	88.7	92.9	98.59	84.23
17-Sep	86.39	88.7	92.9	98.59	84.23
18-Sep	86.39	88.75	93.99	98.59	84.23
19-Sep	86.21	88.75	93.99	98.59	84.23
20-Sep	86.21	88.75	93.99	98.59	84.23
21-Sep	86.21	88.75	93.99	98.59	84.31
22-Sep	86.21	88.75	93.99	98.47	84.31
23-Sep	86.21	88.75	93.99	98.47	84.31
24-Sep	86.21	88.75	95.77	98.47	84.31
25-Sep	86.21	91.19	95.77	98.47	84.31
26-Sep	86.98	91.19	95.77	98.47	N/A
27-Sep	86.98	91.19	95.77	N/A	N/A
28-Sep	86.98	91.19	95.77	N/A	N/A
29-Sep	86.98	91.19	91.75	96.32	N/A
30-Sep	86.98	91.19	91.75	96.32	N/A
1-Oct	86.98	91.19	91.75	96.32	N/A
2-Oct	86.98	90.22	91.75	96.32	N/A
3-Oct	86.98	90.22	91.75	91.79	N/A
4-Oct	88.86	90.22	91.75	91.79	N/A
5-Oct	88.86	90.22	91.75	91.79	N/A
6-Oct	88.86	90.22	92.21	91.79	N/A
7-Oct	88.86	90.22	92.21	91.79	81.35
8-Oct	88.86	90.22	92.21	91.79	81.35
9-Oct	88.86	87.92	92.21	91.79	81.35
10-Oct	88.86	87.92	92.21	91.79	N/A
11-Oct	88.86	87.92	92.21	N/A	N/A
12-Oct	88.87	87.92	92.21	N/A	82.99
13-Oct	88.87	87.83	92.21	N/A	82.99
14-Oct	88.87	87.83	92.21	89.79	82.99
15-Oct	87.68	87.83	92.21	89.79	82.99

Website: http://www3.rma.usda.gov/apps/livestock_reports/main.aspx

APPENDIX E

List of Weather Stations and Weather Futures Contracts

(Data Source: CME website, www.cmegroup.com)

Weather Location	Station	WBAN
Atlanta Hartsfield Airport	KATL	13874
Baltimore-Washington International Airport	KBWL	93721
Boston Logan Airport	KBOS	14739
Chicago O'Hare Intl Airport	KORD	94846
Cincinnati Northern Kentucky Airport	KCVG	93814
Dallas Fort Worth Airport	KDFW	3927
Des Moines Intl Airport	KDSM	94847
Detroit Metro Airport	KDTW	14933
Houston Bush Intercontinental Airport	KIAH	12960
Kansas City International Airport	KMCI	3947
Las Vegas McCarran Airport	KLAS	23169
Minneapolis-St.Paul International Airport	KMSP	14922
New York La Guardia Airport	KLGA	14732
Philadelphia International Airport	KPHL	13739
Portland International Airport	KPDX	24229
Sacramento Executive Airport	KSAC	23232
Salt Lake City International Airport	KSLC	24127
Tucson International Airport	KTUS	23160

APPENDIX F

CME Weather Contract Specifications

Trading Hours	Futures products trade electronically only on CME Globex from Monday through Friday from 3:45 PM to 3:15 PM (central time) of the following day and on Sundays from 5:30 PM to 3:15 PM. On the last trading day they trade until 9 AM. Option products trade only Monday through Friday from 8:15 AM to 3:15 PM on the CME trading floor.
Contract Size	\$100 times the monthly index. The monthly index is provided by the Earth Satellite Corporation.
Minimum Tick Fluctuation	One degree day index point
Settlement	Cash settled. All contracts that remain open at the termination of trading of a particular contract shall be settled using the respective CME Degree Days Index for that city and that contract season, using the methodology in effect on that date, on the first Exchange business day that is at least two calendar days after the derivatives contract month
Maximum Order Size	10,000 contracts net long or short in all contract months combined.
Trading Venue	Only options can be traded via open outcry; the futures products are traded exclusively on the CME Globex electronic trading platform.

(Data Source: CME website, www.cmegroup.com)

APPENDIX G

Glossary of few option types

Type	Description
Vanilla	A standard option like European or American option.
European	An option which can only be exercised at the end of its term i.e. at the expiry date.
American	An option which can only be exercised at any date in its term.
Asian	This is like vanilla option only the strike price is the arithmetic average of the underlying during its lifetime.
Bermudan	An option that can be exercised only during a part of its lifetime, a similar example is the employee stock option, since employees will exercise this option only during their tenure with the firm.
Binary or Digital	Options with binary or discontinuous pay-off. Cash or nothing call or put option pays-off a certain amount of money or nothing if the underlying is above or below a fixed level. Asset or nothing options delivers the underlying if the asset is above or below a fixed level or otherwise have zero pay-off.

APPENDIX H

Pay-off Diagram for Combinations

A. CAP (or Call/Put with a maximum pay-off)

Figure: Long Call with a maximum pay-off. (Source: www.theoptions.net)

B. Straddle

Figure: Straddle. (Source: www.theoptions.net)

Here, strike rate for long call and long put was 500 points.

C. Strangle

Figure: Strangle.

(Source: www.theoptions.net)

Here, strike rate for long call was 500 points and strike rate for long put was 400 points.

D. Collar

Figure: Collar. (Source: www.theoptions.net).

APPENDIX I

RAINFALL OPTION CALCULATOR

APPENDIX K

Grass-Fed Survey Questionnaire

1. How large is your average annual calf crop and in any given year, what portion of your calf crop do you retain for grass-finishing?
2. What types of grass-fed beef products do you sell (whole carcasses, half carcasses, quarter carcasses, individual cuts, and ground beef)? What portion of your sales volume is made up of each of these product types?
3. If you sell individual cuts or ground beef, are they sold frozen?
4. What is your estimated monthly sales volume (in pounds) for at least the past five years?
5. Do your prices reflect retail-level beef prices or are they fixed from year to year?
6. Do you think climatic/weather variability has been a factor that affects your farm's production performance?