A COMPARATIVE ANALYSIS OF EXPECTED UTILITY OF FUTURES, OPTIONS, AND LIVESTOCK RISK PROTECTION INSURANCE: WHICH HEDGING TOOL IS DESIRABLE FOR SMALL, MEDIUM, OR LARGE SIZED FEEDER CATTLE PRODUCERS WHOSE FARMS ARE LOW, AVERAGE, OR HIGH MANAGEMENT RISK

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Abstract:

Feeder cattle producers have multiple tools available to mitigate price risk. Few use these tools, with a common reason set of reasons being lack of knowledge and quantity requirements that do not match actual production. The latter is especially true for small producers, who make up a large portion of all producers and USDA's Risk Management Agency created a subsidized insurance tool to overcome that obstacle, but it does not get utilized often by small producers. Therefore, the purpose of this research is to determine which price risk management tool is ideal, especially for small producers. Additionally, when the insurance tool is not optimal, an adjusted subsidy level was determined that left producers equally as well off. The results indicate that futures contracts are the most ideal price risk management tool, especially for larger feeder cattle producers. When producers have small operations, 20 head, no risk management or insurance is preferred. Insurance subsidies in the small producer scenario would need to increase to 32 percent in a declining market and 62 percent or more when prices are increasing.

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CHAPTER I

Introduction

In the cattle industry, small producers have a major impact. Small producers of feeder cattle usually are defined as those who operate a farm with a capacity of less than 100 head within one production period (Lacy et al., 2003; Ward et al., 2008). Small feeder cattle producers are important contributors to U.S. agriculture, accounting for 90 percent of all farms with beef cows and 46 percent of all U.S. beef cows (USDA, 2011). However, increasing wealth is not an easy task for small feeder cattle producers. Small farmers are generally considered to be price takers whose sales and purchases cannot affect the market price, therefore it is difficult for small producers to obtain bargaining power. It is possible to increase efficiency through better farm management and then increase profits, but this does not easily apply to small feeders and producers. Management and marketing practices have less effect on small-scale feeder cattle operations than large operations (Ward et al., 2008; Kim et al., 2005; Wozniak, 1993). Due to the above reasons, small cattle producers have a difficult task to increase their profits from market or management.

As with other forms of agricultural production, feeder cattle prices are seasonal and exhibit cyclical tendencies. However, the cycles have become less predictable in recent years (Petry, 2019). This unpredictability has caused fluctuations in feeder cattle price. Brooks (2015) points out that the feeder cattle price in 2014 did not follow the previous price pattern. Price risk management is an effective response to the uncertain risks (Jones, 1986; Burdine, 2013). However, small producers have limited preferences for the use of price risk instruments and these limited preferences are related to producers having different risk preferences and risk education (Hall et al., 2003). Exploring the kinds of risk management tools that are appropriate for small-scale feeder cattle producers offers the opportunity to determine optimal strategies that reduce these risks.

Price management tools for feeder cattle operations have limitations for small feeder cattle producers. Futures and option contracts have strict contract sizes that may not fit small production quantities. The limitation of Livestock Risk Protection (LRP) policies is that it is difficult to accurately match the production time with the duration of the insurance contract (Thompson et al., 2013). Each of these, however, are mainstream price risk management tools available to feeder cattle producers. Forward contracts are less common for small producers and are generally not suitable because they require a large and stable supply of feeder cattle. (Feuz 2009; Brooks and Parsons 2007; Bradley 2019)

Problem Statement

Which price risk management tools or strategies are better suited for small producers of feeder cattle? Each price risk management tool has its strengths and weaknesses. On the one hand, assuming higher risk typically is associated with the possibility of a higher return. Therefore, there is not a perfect price risk management tool for small feeder cattle producers. The literature on the comparison of price risk instruments is limited. Feuz (2013) lists and compares the risk control effect of futures, options, LRP Insurance, or Adjusted Gross Revenue (AGR-Lite) Insurance as risk management, but the choice of a price risk management tool still puzzles small producers (Hall et al., 2003). The factors influencing risk management decision making includes producers' objectives and attitude toward risk. Usually experienced small feeder cattle producers focus on profit maximization because the farm is their main income resource (McConnell and Dillon, 1997). Even if small feeder cattle producers have a similar objective of maximizing profit, they often have different risk attitudes for feeder cattle price risk, which directly affects the choice of risk management tools. The reason of applying a price risk management tool is not to achieve profit maximization, but largely to reduce risk toward a manageable level. So, we need to combine profit maximization with risk attitude. Price risk management cannot affect the risk of output (i.e., production risk). Therefore, if producers want to maximize output, price risk management tools are not applicable.

From the perspective of economic value and industry development, it is useful to reduce the risk of feeder cattle prices by hedging (Jones, 1968). However, small feeder cattle producers do not have great interest in hedging (Thompson et al., 2013). So, examining the risk mitigating outcomes of price risk management tools and strategies associated with wealth may shed light on new information that encourages small feeder cattle producers to engage in price risk management. Encouraging small feeder cattle producers to use the appropriate price risk management tools is important for long term financial viability. This is evidenced by willingness of the United States government to subsidize producers of feeder cattle to use price risk management tools. For example, LRP is a program that subsidizes insurance for feeder cattle.

The current literature does not explore how the small producer of feeder cattle chooses price risk tools within the full portfolio of available options. Simply pointing out the effect of price risk control is not enough to allow small producers of feeder cattle to make desirable choices.

Objectives

This research determines the preferred risk management tool -- among futures, options, and LRP along with a strategy of no risk management. The research also determines under what specific conditions risk management tools are more advantageous for small feeder cattle producers – relative to large operations. Therefore, the research used simulation techniques to incorporate risk under the theory of expected utility to account for risk aversion to study these three tools and no risk management for small feeder cattle producers in the Southern Plains.

After learning which tool is the most advantageous for risk management, the research determined the necessary subsidy level of LRP insurance that feeder cattle producers were equally as well off compared with the optimal risk management outcome.

CHAPTER II

Literature Review

Feeder Cattle Price Risk

There are two type risks facing feeder cattle producers; production risk and price risk. The goal of production risk management is to increase the weight of the cattle to desired levels (Bradley, 2017). Price risks, or market risk, are different since the individual producer has less control on the factors that influence more broad market fundamentals whereby small feeder cattle producers are price takers. Typically, increasing or decreasing the number of feeder cattle, or pounds of cattle, by an individual producer has no significant effect on prices. The more important factor of effect on price is the cattle production cycle and the concentration of the beef packaging industry. When buyer concentration increases, they have stronger bargaining power (Crespi, Xia, and Jones, 2010). Therefore, price risk originates from sources outside of the control of feeder cattle producers.

Compared to production risk, feeder cattle price risk management may offer more stability. The development of farming technology and advanced animal medicine has gradually weakened the impact of production risks for feeder cattle producers (Thompson et al., 2013). According to a survey of Texas small feeder cattle producers, Hall et al. (2003) argues that extreme cold weather and disease have limited impact on profits in the central and southern regions. Their research also suggests that changes in cattle prices are perceived as a major risk factor affecting agricultural income. Cattle producers will face the more serious feeder cattle price risk problems than the past ten years (Brooks, 2015). In the past 15 years, an abnormal number of external events have caused the cycle to become less predictable, which has been plaguing the beef industry (Petry, 2018).

Hedging price risk is the overall idea of controlling market risk and hedging is usually lower than the cash settlement under the physical delivery contract specifications (Schroeder and Minitert, 1988). Hedging eliminates some uncertainty. Even though various futures and options strategies reduce average returns, hedging can reduce the standard deviation (Klassen, 2017). The price risk of feeder cattle can be controlled by price risk management tools at the producers' expected level. There are three price risk management tools available to feeder cattle producers that employ hedging activities: future contracts, option contracts, and Livestock Risk Protection insurance plan for Feeder Cattle (LRP-Feeder Cattle).

Prices Risk Management Tools for Feeder Cattle

Feeder cattle futures contracts are the most common hedging instruments (Jones, 1968). Usually feeder cattle producers are long cash positions but will take a short position in the futures market to lock the price. For example, if a feeder cattle producer wants to hedge, he will sell the futures contracts in the current period at a locking price and buy them back when it is time to sell the cattle herd in the cash market. Jones (1968) applies two economic theories, the Keynes-Hicks Theory (1939) and the Working Theory

(1953), to analyze hedging. Jones (1968) found using hedging tools for risk transfer is an effective means. Margin accounts and margin calls are another potential reason why feeder cattle producers do not to choose to use futures (Burdine, 2013). Futures participants are obligated to provide good faith money to guarantee their contract performance with the futures exchange. In the case of CME© Feeder Cattle Futures contract at $140 per cwt, the contract value is roughly $70,000 (500 cwt. x $140). However, the margin required to control such a large position is relatively small ($2,800 in September 2019, or approximately four percent of contract value) (CME Group, 2019). Even though margin allows producers to take advantage of leverage, it still can be a great financial pressure for small producers (Burdine, 2013).

The put option contract gives producers the right to take a short position on the underlying commodity at a specific price but does not have the obligation to sell the underlying contract. Thus, option contracts are more flexible than futures. First, put options do not require margin calls. A put option creates a price floor but not an upper limit. A put option has the advantage as an appropriate intermediate route between selling a futures contract and doing nothing, because when it protects the possibility of a decreasing price but still allows for rising markets (Burdine, 2013). However, options come with downsides as they carry what many perceive to be costly premiums (Hall et al., 2003). The standard deviation of payout from the options is higher than the futures, which means the control of the price risk of an option is weaker than the futures. Buying feeder cattle options have the potential to provide producer’s a higher average return, but futures are more effective tools for eliminating variability in earnings (Feuz, 2009). Another limitation of both exchange traded options and futures contracts is liquidity (Diersen and Klein, 2000). The trading unit of feeder cattle futures is 50,000 lbs. of 700 to 849 lb. (Smith, 2014), which means that a contract is covering about 56 to 71 head of feeder cattle. A standard contract is difficult to precisely cover the feeder cattle owned by a small producer whose individual lot size (number of head) falls below these contract thresholds.

The Livestock Risk Protection insurance plan for Feeder Cattle (LRP-Feeder Cattle) attempts to deal with this problem. This plan covers any quantity of feeder cattle a producer chooses. Although only up to 2,000 head may be insured per producer per year, the number of feeder cattle insured is arbitrary per policy. LRP-Feeder Cattle cannot be used to speculate, but the program is designed to ensure that the price received by producers is not affected by falling market prices (USDA, 2018). From the perspective of risk protection, put options and LRP insurance have the similar effects (Feuz, 2009). LRP-Feeder Cattle insurance has four different specifications and they are according to cattle weight and type criteria. If the put option is a very appropriate intermediate route between selling a futures contract and doing nothing, LRP-Feeder Cattle insurance offer more flexibility. As a price risk management tool, LRP insurance has a higher degree of customization than futures and options for producers. Another advantage of LRP insurance is its costs. First, LRP insurance does not require pay the commission for brokers or an agency, but the trading of options and futures does require it. Second, LRP insurance is authorized by Agriculture Improvement Act, 2018 (Congress, 2018). The support LRP from the government makes its premium level slightly lower than the premium of the put option. However, LRP insurance is not flawless. Like put options, the LRP is not the best price risk reducing tools. Another major drawback of the LRP program is that it has limited flexibility in changing the contracts. Insurance policies cannot be sold by producers or canceled with refund. At the same time, the LRP-Feeder Cattle Insurance limits the time that producers sell feeder cattle. If the feeder cattle are sold thirty days before the insurance expires, the policy is voided (Burdine and Halich, 2008).

Different price risk management tools have their own advantages and disadvantages, and they also represent different risk control effects. Futures can control risk the most, but average returns are typically lowest. Put options and LRP-Feeder Cattle Insurance retain a certain amount of upside of return, but only control moderate risks. Failure to take any price risk management will be subject to the greatest price volatility but may also yield the highest price. Every step of the producers' decision will bring risks, including the choice of risk management tools.

Option Pricing

Black and Scholes (1973) first introduced the options pricing model. Later, Fischer Black (1976) further refined the model based on an extended study by Merton (1973). Like any model in any discipline, the BSM model is based on many assumptions, and although many assumptions are often controversial or known to be enough at best, it is still widely used to calculate "fair" option prices (Weatherall, 2017). As a derivative, the price of an option is closely related to the underlying asset price, holding time, risk-free rate, and market risk. The BSM model establishes a reliable mathematical connection between the value of the option and the underlying asset price, expected asset price, duration, risk-free rate, and market volatility risk. Through the model, the strike price of the option can be viewed as the expected target asset price. The execution deadline of an option contract can be considered as duration. According to historical price fluctuations of the underlying asset, we can know the "fair" price of the current option.

Risk Decision Analysis and Expected Utility Theory

To determine what kind of price risk management tools is best for small feeder cattle producers, risk decision analysis is necessary. Decision analysis can be defined as the philosophy, theory, methods, and practices necessary to systematically address important risk decisions (Hardaker, Lien, Anderson and Huirne, 2015). Decision trees are an important tool that helps decision analysis to define and represent risks.

Expected utility theory can deal with situations of quantifiable risk directly (Von Neumann and Morgenstern, 1944). Every decision of the small feeder cattle producer has an associated expected utility of that decision since final outcomes are unknown. Expected utility is the relevant standard for rational choice and maximum expected utility is the best option (Hardaker, Lien, Anderson and Huirne, 2015).

Utility maximization from a production standpoint can more accurately predict and direct the optimal production plan than profit maximization goal (Lin, Dean, and

Moore, 1974). Like the utility of goods affects consumer choice, small feeder cattle producers make a “consumption choice” in practice when they consider price risk management products. Taking profit as the target of expected utility, the expected utility expresses a combination of profit level and risk level. The combination of maximum expected utility or maximum expected profit helps producers make risk management decisions. Small feeder cattle producers can be assumed to maximize expected profits, then select the appropriate risk management tools based on their level of risk.

Expected Utility and Certainty Equivalent

Compared to expected utility, certainty equivalent (CEs) has two main advantages in analyzing different risk decisions and alternatives. CEs are easier to analyze and compare than expected utility because it can be quantitatively compared. According to the arbitrary nature of utility scales, one utility value cannot be directly compared to another utility value, which makes it impossible to analyze risk decisions among different risk correlation coefficients (Hardaker, Lien, Anderson and Huirne, 2015). On the other hand, CEs is more understandable and acceptable, because CEs can directly reflect changes in wealth effected by risk management decisions, which is what most producers are concerned about. When the utility function is known, it is often feasible to convert the expected utility to CEs (Hardaker, Lien, Anderson and Huirne, 2015).

CHAPTER III

Conceptual Framework

Before comparing and determining the price risk management tools, we define our assumption, production objectives, and risk attitude. The main audience for this research is the small feeder cattle producer since many small feeder cattle producers are not interested in price hedging given that it may not increase revenue (Hill, 2015). We assume that producers are utility maximizers. An empirical study showed most small feeder cattle producers are risk averse (Young, 1979). In summary, we define the general form of expected utility (EU) and end of period profit (π) for a feeder cattle producer as:

$$\max_{\widetilde{RM}} E(u) = f(W_0, \tilde{\pi}, c); \qquad (1)$$

$$\tilde{\pi} = f(\tilde{P}, \tilde{Q}, C, \widetilde{RM}); \qquad (2)$$

where, W_0: $begining\ of\ period\ wealth,$

$\tilde{\pi}$: $profit\ (negative\ profit\ implies\ a\ loss),$

c: $coefficient\ of\ risk\ aversion,$

$\tilde{P}$: cash price at the end of the period,

$\tilde{Q}$: $output\ at\ the\ end\ of\ the\ period,$

C: $production\ cost,$

$\widetilde{\mathrm{RM}}$: $revenue/loss\ and\ cost\ from\ risk\ management,$

Because, as mentioned earlier, the individual producers of the feeder cattle are considered price takers in this study, in the general profit function $\tilde{P}$ is the cash price or market price at the end of the period. The tildes represent uncertain outcomes. In addition to price risk we also consider output quantity risk during the production period. The output function is:

$$\tilde{Q} = f(\widetilde{ADG}, \widetilde{DL},\ Q_0, Days) \qquad (3)$$

$\widetilde{ADG}$*: average daily gain;*

$\widetilde{DL}$*: death loss;*

Q_0*: beginning weight;*

Days: days backgrounded.

Figure 3.1 defines the decision tree a producer faces when considering risk management options. This was used to guide the simulation process of optimal price risk management decisions. The price risk management decision tree is:

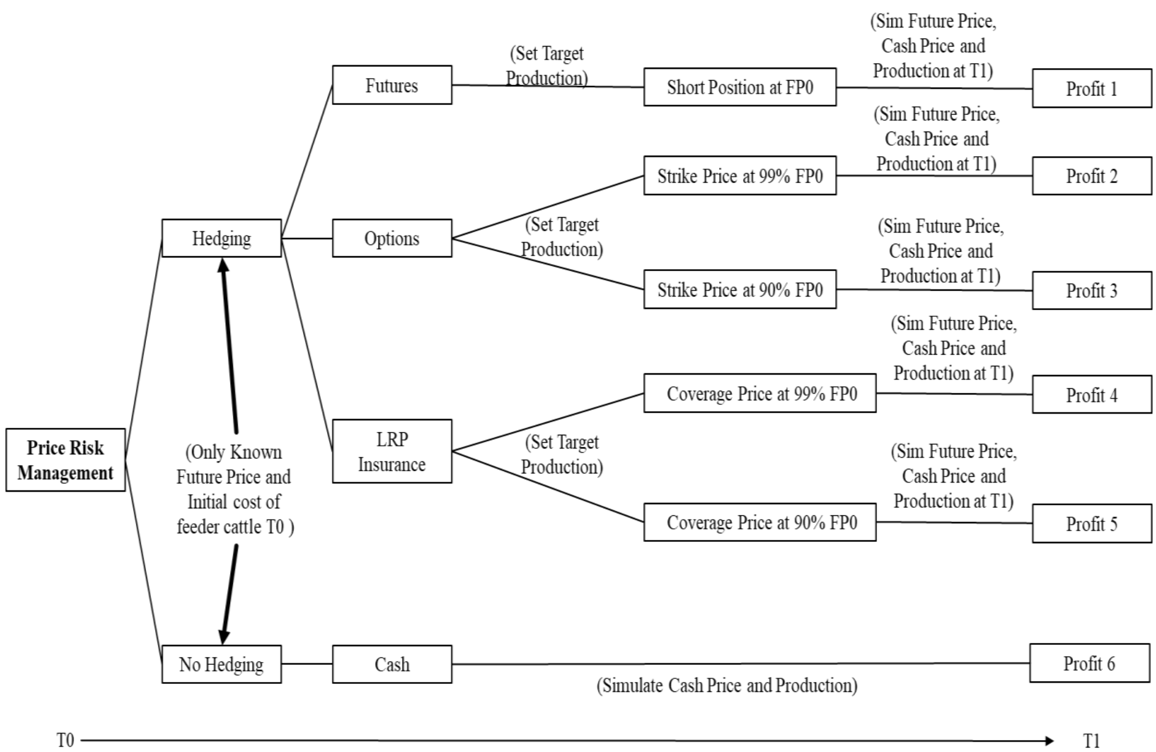


Figure 3.1. Decision Tree

T_0: *beginning of the production period,*

T_1: $end\ of\ the\ production\ period,$

FP_0: $feeder\ cattle\ futures\ price\ at\ beginning\ of\ the\ period\ (known\ at\ T),$

FP_1: $feeder\ cattle\ futures\ price\ at\ end\ of\ the\ period.$

CHAPTER IV

Method and Data

We set strike price and LRP coverage price at 99% and 90% of FP_0 given that the hedging mechanism of options and LRP insurance was similar. Therefore, the strike price and coverage price are often similar. In order to compare expected utility, the risk coverage level of options and LRP insurance should be consistent. For example, comparing the expected utility of put option with strike price at 99% of FP_0 and LRP insurance with coverage price at 85% of FP_0 is would be unjustified because they require different premium amount. We used 99% and 90% of beginning future price to represent two strategies of hedging: At the money and out of the money. The United States Department of Agriculture's Risk Management Agency (RMA) Online Livestock Reports (2019) shows that the upper limit of the coverage price is 99% of the FP_0. The out of the money situation was set 90% of FP_0, which was approximately near the breakeven price of feeder cattle production based on Oklahoma Cooperative Extension Service budgets (Oklahoma Cooperative Extension Service, 2019).

The research utilized simulation procedures to determine optimal hedging strategies for feeder cattle producers of three sizes and cattle risk levels. The profit function from equation (2), considered within the expected utility framework expressed in equation (1) with the different price risk management tools defined the simulation outcomes. In this research the behavior of small feeder cattle producers were considered as price risk managers, rather than as speculators -- except for a hedger using futures and options whose contract size exceeds the amount of production.

Expected Utility

We compare the expected utility using constant absolute risk aversion (CARA) due to its desirable properties across payoff measures. CARA should be applied when assessing risk choices expressed in terms of losses and gains (Hardaker, Lien, Anderson and Huirne, 2015). The specific functional form employed in this study, was defined as:

$$U = 1 - e^{-cw}, c > 0 \tag{4}$$

which is the negative exponential and were *c*, the coefficient of risk aversion, and *w* is the end of period wealth. When the coefficient of risk aversion is great than zero given, feeder cattle producers are risk averse (Young, 1979). The coefficient of risk aversion defined the risk attitude of the individual and aided in the analysis in the determination of an individual's preference for the alternatives examined (Meyer, 2010). An approximate classification for the degree of risk aversion was proposed by Anderson and Dillon (1992) and based on these producers in the current study were divided into three different risk attitude groups:

c = 0.5, hardly risk averse at all;

c = 2, rather risk averse;

c = 4, extremely risk averse.

However, the coefficient of risk aversion, *c*, here represents the coefficient of relative risk aversion (CRRA) as opposed to CARA. When fitting to CARA, a conversion is necessary. Hardaker, Lien, Anderson and Huirne (2015) provide the calculation as:

$$c_{CARA} = \frac{c_{CRRA}}{W_0} \qquad (5)$$

The specific functional from of profit with the price risk management outcomes was:

$$\widetilde{\pi_{i,t}} = \widetilde{P_t Q_t} - C\left(\widetilde{Q_t}\right) + x\left[\left(f_0 - \widetilde{f_1}\right) - H_F\right] + y\left[Max\left(K - \widetilde{f_1},\ 0\right) - H_O\right] +$$
$$z\left[Max\left(I - \widetilde{f_1}, 0\right) - H_I\right] \qquad (6)$$

x: $number\ of\ futures\ contracts$;

y: $number\ of\ option\ contracts$;

z: $number\ of\ head\ insured\ with\ LRP$;

f_0: $futures\ price\ at\ the\ begining\ of\ the\ production\ period$;

$\widetilde{f_1}$: $futures\ price\ at\ end\ of\ the\ production\ period$;

K: $option\ strike\ price$;

I: $LRP\ insurance\ coverage\ price$;

H_F: $futures\ contract\ commission$;

H_O: $option\ contract\ premium$;

H_I: $LRP\ insurance\ producers\ premium.$

We assumed K at two different levels, K_1 and K_2, implying a strike price at 99% of f_0 and 90% of f_0, respectively. Similarly, we assumed I at two different levels, LRP99%

and LRP90%, implying LRP insurance with coverage price at 99% of f_0 and 90% of f_0, respectively.

Option premiums stem from the Black (1976) option pricing formula, which was defined as:

$$H_O = e^{-rT}KN(d_2) - e^{-rT}FP_0N(d_1), \quad (7)$$

$$d_1 = \frac{Ln\frac{FP_0}{K} + \frac{\sigma^2}{2}T}{\sigma\sqrt{T}}, \quad (8)$$

$$d_2 = d_1 - \sigma\sqrt{T}, \quad (9)$$

r: $risk\ free\ rate\ of\ return\ (the\ 90 - day\ Treasury\ bill\ rate)$;

T: $length\ of\ time\ until\ option\ expiration$;

σ: $annualived\ variance\ of\ f_0\ (implied\ volatility)$.

According RMA, the LRP insurance producers' premium calculation is based on the rate from daily actuarial documents (RMA, 2019). The total premium is equal to the insured value multiplied by the rate, and the insured value is equal number of heads multiplied by the target weight (live weight) multiplied by the coverage price multiplied by ownership share (RMA, 2019). However, RMA's calculation of the rate is not publicly available. Therefore, as mentioned above, the LRP insurance premium without the subsidy will also be calculated using the Black option pricing model. Given recent changes to brokerage structures which has seen commissions decline sharply, we do not consider the commission associated with futures and option trading outcomes.

For the subsidy level, we used a 27.5% discount for LRP99% and a 20% discount for LRP90%, which means the total premium of LRP99% is 72.5% of the premium of options at K_1 and the total premium of LRP90% is 80% of the premium of options at K_2. Subsidies were not public information the time of this study, but the subsidy range of 20% to 35% was associated with coverage levels that were typically 99% to85%. So, we matched the coverage level with the subsidy where a higher coverage level (99%) was associated with lower subsidy (20%), which follows the crop insurance format.

To determine the profit, output must be defined. At the beginning of the production period the final weight and number of heads sold is not known with certainty. Therefore, output, Q_t, was determined as:

$$\widetilde{Q_t} = \sum_{i=1}^{n} (Q_0 + \widetilde{ADG_i} * Days) - Q_{i,DL}, \qquad (10)$$

$Q_{i,DL}$: *animal lost to death*;

Q_0: *beginning weight at* T_0;

$\widetilde{ADG}_i$: *random average daily gain specific to each animal*, i;

Days: days of feeding the feeder cattle;

n: the total number of head.

Because of the small production scale, which is limited due to the size of the operation, and given the indivisibility of both futures and option contracts, which seldom match production quantities due to their rigidity, x and y usually are zero (no futures or options hedge) or one, where one may imply over hedging. This profit function could consider the case of combining different price risk instruments by assigning x, y and z different values, but we only analyze the singular use of each tool (i.e. only futures, only options, or only LRP insurance).

Production Scenarios

We set up small (20 head), medium (50), and large (250) sizes of farms that represent three different levels of output. The minimum purchase quantity for options and futures contracts is one contract, and the size of one contract is 50,000 pounds. This means that if the producer uses futures or options to manage price risk, the small farm is over-hedged, the medium farm is close to full hedging, and the large farm may utilize more than one contract (a final weight, Q_t, of approximately 800 pounds would imply four contracts, 800 pounds times 250 head divided by 50,000 pounds per contract).

In additionally, farms are classified into three levels of cattle production risk: low-risk animal farms, average-risk animal farms, and high-risk animal farms and we assumed different risk level animal with different level Average Daily Gain (ADG).

Moreover, we assume that production is from the second week of October to the first week of April, which is about 170 growth days and 124 trading days. The growth day is used to calculate the output, *Days* in equation (10), and the trading day is used to calculate the premium for the option, T in equations (7) – (9).

Purchase price and beginning weight, Q_0, of feeder cattle are known at the beginning of the production period along with f_0. Based on the Stocker Enterprise Budget developed by Oklahoma State University (Oklahoma Cooperative Extension Service, 2019), we assume that the purchase cost of feeder cattle is $169.9822/cwt (in the base year) and the variable cost is $245/cwt. We also assume that every animal purchased would not have the exact same weight[1]. Therefore, the uniform distribution was used for the feeder cattle beginning weight (Steel and Torrie, 1980). Furthermore, we assume the range of purchase weights of feeder cattle increases as the size of the operations increases since the opportunity to buy a larger volume of cattle at a similar weight would be more challenging. Specifically, the range of initial weights for the different farm sizes were: small farm was 388 to 412 pounds; medium farm was 380 to 420 pounds; large farm was 370 to 430 pounds.

To compare whether the expected utility of the price risk management strategy differed depending on the feeder cattle price cycle, we evaluated a five-year period of price increases and a five-year period of prices decline. Specifically, the beginning of period price for each subsequent year increased (decreased) by 10% over the previous

[1] A feeder cattle buyer at a sale barn is not likely to purchase multiple animals all with the same weight, nor is a cow-calf producer likely to raise multiple calves that have the same weight.

year for the price increase (decline) cycle. The sum of the five-year profit based on equation (6) was calculated and included in expected utility, equation (4). The total profit function is:

$$\pi_{total} = \sum_{t=1}^{5} \pi_t \quad (12)$$

Futures price change is the change in the price of the feeder cattle future contract at beginning of the production period and the end of the period, and expressed as:

$$\Delta F = f_1 - f_0 \quad (13)$$

Basis is the difference between the cash price and futures price. For example, basis of the steers weighting 400 and 500 pounds is:

$$\text{Basis}_{S4} = \text{Cash Price}_{S4} - f_1 \quad (14)$$

The feeder cattle price and output are influenced by many complex factors and they are difficult to predict precisely (Feuz 2014; Hall et al, 2003 and Burdine 2013). Simulation offers a technique to mimic the risks that producers face. In the feeder cattle price risk situation, simulation was used to generate data for the following variables: average daily gain, death loss, change in futures price, and basis. We then used these to, respectively, determine output quantity (Q_t) using equation (5), final future price using equation (12) and output cash price (P_t) using equation (13). The procedure maintains correlations across simulated variables (Anderson, Harri, and Coble, 2009).

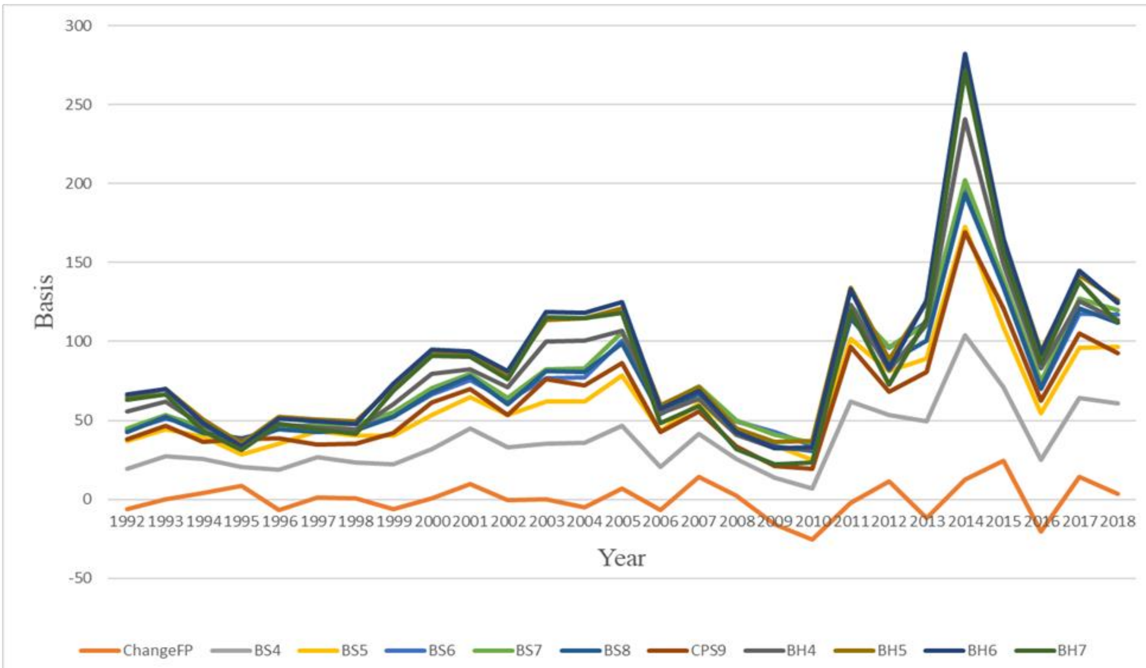
After the simulation, the outcomes are used to determine profit, equation (5) and then to determine expected utility, equation (4).

Simulation Procedures

All the conditions that are known with certainty at the start of the production period were generated using simulation. The basic principle of simulation is to generate data through a random process based on the distribution of the original data, so the simulation data should have the same, or very similar, distributional properties as the original data. We first determine the shape of the original data.

For cash price data, basis links cash price to futures price. Feeder cattle futures price represents a specific cattle type defined by the futures exchange like contract space that includes contract unit (50,000 pounds) and listed contracts (8 monthly contracts of Jan, Mar, Apr, May, Aug, Sep, Oct, Nov.) et., but cash prices are present for many different types. Cash price encompasses the gender, weight, and location of an animal. For example, the cash price of a 425-pound steer in Oklahoma City, OK, may be different than a 625-pound heifer in Tulsa, OK. Figure 4.1 depicts change in futures price and basis for the prices used in this study. From this, the trends of ΔF is roughly consistent with basis. After obtaining final futures price by simulation, we can calculate the cash price of feeder cattle of different gender and different weight groups through simulation of basis.

Figure 4.1: $Change\ in\ Futures\ Price\ and\ Basis, 1992 - 2019.$



Note: Change FP is equivalent to ΔF; BS4 implies the basis of 400-500 lbs. steers; BS5 implies the basis of 500-600 lbs. steers; BS6 implies the basis of 600-700 lbs. steers; BS7 implies the basis of 700-800 lbs. steers; BS8 implies the basis of 800-900 lbs. steers; BS9 implies the basis of 900-1000 lbs. steers; BH4 implies the basis of 400-500 lbs. heifers; BH5 implies the basis of 500-600 lbs. heifers; BH6 implies the basis of 600-700 lbs. heifers; BH7 implies the basis of 700-800 lbs. heifers

However, the empirical distribution of ΔF was approximately that of the normal distribution, while basis was either normal or log-normal depending on the specific gender and weight. To overcome the different distributional issues, and to maintain the correlation of ΔF and basis, the Iman-Conover (IC) method was employed. The IC method is a distributional free simulation technique that maintains correlations and does not require any unusual mathematical derivations (Iman and Conover, 1982).

First, we obtained the correlation coefficient of the ΔF and basis. These are provided in the Table 4.1. Next, the correlations were transformed using Choleskey decomposition. After this, a sample size of 1,000 randomized, correlated standard normal deviates (N~(0,1)) were generated. These outcomes were multiplied by the mean of the underlying, empirical data as the final step in obtaining the simulated outcomes for a specific production period. The simulated data's rank correlation matrix is provided in Table 4.2. This process provided each random variable (ΔF, BS4, BS5, BS6, BS7, BS8, BS9, BH4, BH5, BH6, and BH7). For example, in Table 4.3, we use the standard deviation of DeltaFP, multiply by the random sample of DeltaFP and add the mean of DeltaFP, then we can get the simulate result for DeltaFP. According equation (12) and assuming f_0, we can calculate the simulated outcome of f_1 by f_0 plus DeltaFP.

Table 4.1. Historical Correlation of Change in Futures Price and Basis,1992-2019.

	DeltaFP	BS4	BS5	BS6	BS7	BS8	BS9	BH4	BH5	BH6	BH7
DeltaFP	1.0000										
BS4	0.1422	1.0000									
BS5	0.2221	0.9728	1.0000								
BS6	0.2694	0.8604	0.8927	1.0000							
BS7	0.3099	0.2292	0.2633	0.4916	1.0000						
BS8	0.0144	-0.6800	-0.6478	-0.5716	0.2254	1.0000					
BS9	-0.1763	-0.8420	-0.8222	-0.7588	-0.0296	0.9073	1.0000				
BH4	0.1474	0.8916	0.9208	0.7491	0.2272	-0.4477	-0.6280	1.0000			
BH5	0.2763	0.8583	0.8940	0.8074	0.4304	-0.3979	-0.6092	0.9506	1.0000		
BH6	0.2711	0.4446	0.4899	0.4792	0.5027	0.1188	-0.0643	0.6804	0.7650	1.0000	
BH7	-0.0035	-0.5916	-0.5714	-0.4985	0.2201	0.8727	0.8580	-0.3237	-0.2454	0.2940	1.0000

Table 4.2. New Rank Correlation Matrix

	DeltaFP	BS4	BS5	BS6	BS7	BS8	BS9	BH4	BH5	BH6	BH7
DeltaFP	1.0000	-0.0366	-0.0944	-0.1482	-0.2467	-0.0963	0.0647	-0.0166	-0.1407	-0.2182	-0.0650
BS4	-0.0366	1.0000	0.9728	0.8604	0.2292	-0.6800	-0.8420	0.8916	0.8583	0.4446	-0.5916
BS5	-0.0944	0.9728	1.0000	0.8927	0.2633	-0.6478	-0.8222	0.9208	0.8940	0.4899	-0.5714
BS6	-0.1482	0.8604	0.8927	1.0000	0.4916	-0.5716	-0.7588	0.7491	0.8074	0.4792	-0.4985
BS7	-0.2467	0.2292	0.2633	0.4916	1.0000	0.2254	-0.0296	0.2272	0.4304	0.5027	0.2201
BS8	-0.0963	-0.6800	-0.6478	-0.5716	0.2254	1.0000	0.9073	-0.4477	-0.3979	0.1188	0.8727
BS9	0.0647	-0.8420	-0.8222	-0.7588	-0.0296	0.9073	1.0000	-0.6280	-0.6092	-0.0643	0.8580
BH4	-0.0166	0.8916	0.9208	0.7491	0.2272	-0.4477	-0.6280	1.0000	0.9506	0.6804	-0.3237
BH5	-0.1407	0.8583	0.8940	0.8074	0.4304	-0.3979	-0.6092	0.9506	1.0000	0.7650	-0.2454
BH6	-0.2182	0.4446	0.4899	0.4792	0.5027	0.1188	-0.0643	0.6804	0.7650	1.0000	0.2940
BH7	-0.0650	-0.5916	-0.5714	-0.4985	0.2201	0.8727	0.8580	-0.3237	-0.2454	0.2940	1.0000

Table 4.3. Historical Mean and Standard deviation for each Variable

	DeltaFP	BS4	BS5	BS6	BS7	BS8	BS9	BH4	BH5	BH6	BH7
Mean	0.4136	36.6987	24.7842	12.9364	2.3107	-4.6381	-10.6545	18.0932	9.6241	0.1135	-6.9318
St dev	10.8630	16.4703	12.0647	6.6091	2.5704	2.7603	5.6318	12.6960	6.6635	2.8972	3.4042
Max	24.2900	91.5500	68.8450	26.9350	9.8900	1.7170	-0.9080	71.3350	34.6350	7.2600	-2.0930
Min	-25.5700	11.8420	8.2170	4.5720	-1.4350	-10.4250	-24.2350	-0.7180	-1.9030	-5.5050	-13.9188

Production Data

The realized total output is dependent on the cattle ADG and DL. The growth of each animal is random, so the ADG of a single feeder calf is randomly generated based on a triangular distribution of ADG using the triangular parameters defined in table 4.1. Hardaker, Lien, Anderson and Huirne (2015) give a similar example with a triangular distribution when explaining how to use stochastic simulation as a decision analysis tool.

The level of cattle risks directly impacted output, which was reflected in the ADG and mortality (death loss) of the final output, Q_t. We used an average feeder cattle ADG that stemmed from OSU stocker cattle research trials (Peel, 2006) and mortality rates (USDA APHIS, 2008) as the base for average-risk farms. No data were available for low and high-risk cattle operations, so we assumed a 15% increase (decrease) in ADG and a 15% decrease (increase) in mortality from the base for the low (high) risk. Table 4.4 provides the specific parameters of the triangular distribution for ADG used to determine final output.

Table 4.4. Triangular Distribution Parameters of Cattle Average Daily Gain for the Three Cattle Risk Levels and Dead Loss Number of Head.

	20	50	250
Low Risk Animal	Min = 1.725 Max = 3.91 Mode = 2.4725 Dead = 1 Head	Min = 1.725 Max = 3.91 Mode = 2.4725 Dead =1 Head	Min = 1.725 Max = 3.91 Mode = 2.4725 Dead = 5 Head
Average Risk Animal	Min = 1.5 Max = 3.4 Mode = 2.15 Dead = 1 Head	Min = 1.5 Max = 3.4 Mode = 2.15 Dead = 1 Head	Min = 1.5 Max = 3.4 Mode = 2.15 Dead = 6 Head
High Risk Animal	Min = 1.275 Max = 2.89 Mode = 1.8275 Dead = 1 Head	Min = 1.275 Max = 2.89 Mode = 1.8275 Dead = 1 Head	Min = 1.275 Max = 2.89 Mode = 1.8275 Dead = 7 Head

For the death loss, the same weight is used to obtain the weight of the dead animal using a triangular distribution. For example, if one animal dies in a 20 head herd, we set the weight range between the 388 pounds to 412 pounds and proceed simply with a one head less. For the gender of feeder cattle, a simple stochastic process is used to determine which animals were steers and heifers. We use the simple random number to judge the gender. We set steer when the random number is grader than 0.5 and set heifer when the random number small than 0.5.

Historical Data

Simulated price data stemmed from historical data for futures and cash prices. In terms of futures price data, the CME© Wednesday price of the April feeder cattle futures from week 42 (approximately October 15) and then week 15 of the contract expiration year (approximately April 5) from 1991- 2019 were collected. The cash price from Oklahoma National Stockyards, which includes steers weighting from 400-500 pounds, 500-600 pounds, 600-700 pounds, 700-800 pounds, 800-900 pounds, 900-1000 pounds, and heifers weighted from 400-500 pounds, 500-600 pounds, 600-700 pounds, and 700-800 pounds (USDA-AMS, 1990-2019).

Certainty Equivalent

After the expected price and the expected output are obtained through simulation, end of period wealth was calculated based on the summation of beginning of period wealth and profits (losses) from each year within the five-year time frame using equation

(6). With this, and the coefficient of risk aversion, equation (5), the producer's utility was calculated by equation (4). The mean utility over the 1,000 random outcomes were used to calculate a producer's certainty equivalent. We derived the equation for CE by solving equation (4) for ending wealth but excluding beginning of period wealth. The specific formula for certainty equivalent was:

$$CE = -W_0 - \frac{\mathrm{Ln}(1-\overline{U})}{c} \qquad (15)$$

W_0: $inital\ wealth\ of\ the\ farm$;

$\overline{U}$: $mean\ utility$.

The maximum of expected utility is considered the optimal choice. The expression of the maximum of expected utility is:

$$\max_{x,y,z} U = 1 - e^{-c\left(W_{0,diff}+\pi_{total}\right)}, \qquad (16)$$

$W_{0,diff}$: $different\ inital\ wealth\ for\ different\ size\ farm$.

CHAPTER V

Result

Optimal Choice

In this section, we summarize the outcomes from the methods defined in chapter 4. Tables 5.1 to 5.9 provide the expected utility and certainty equivalent of the various marketing schemes for each of the different cattle risk and farm size when prices increase. The maximum of expected utility is considered the optimal choice. In each table, the optimal choice denoted by the highlighted values

Table 5.1. Low Risk & 20 Head Feeder Cattle Farm

Tools	*c* = 0.5		*c* = 2		*c* = 4	
	Mean E(u)	CE	Mean E(u)	CE	Mean E(u)	CE
Cash	0.5466	$21,530.2392	0.9569	$21,185.2355	0.9981	$20,726.7553
Futures	0.5541	$22,772.1842	0.9577	$21,510.4074	0.9979	$19,853.5277
OptionK1	0.5205	$17,393.9515	0.9462	$17,053.3168	0.9970	$16,637.9931
OptionK2	0.5343	$19,548.7929	0.9522	$19,268.7829	0.9976	$18,904.2241
LRP99%	0.5443	$21,159.8677	0.9565	$21,015.3647	0.9981	$20,830.0845
LRP90%	0.5447	$21,223.6509	0.9563	$20,929.0972	0.9980	$20,544.8189

Table 5.2. Low Risk & 50 Head Feeder Cattle Farm

Tools	*c* = 0.5		*c* = 2		*c* = 4	
	Mean E(u)	CE	Mean E(u)	CE	Mean E(u)	CE
Cash	0.6257	$63,877.0511	0.9796	$252,914.6758	0.9995	$498,963.2086
Futures	0.6312	$64,844.1548	0.9814	$259,089.9749	0.9997	$517,414.5249
OptionK1	0.6144	$61,944.2475	0.9776	$246,807.4333	0.9995	$491,173.8302
OptionK2	0.6208	$63,027.9777	0.9786	$249,955.2298	0.9995	$494,365.9746
LRP99%	0.6231	$63,429.8030	0.9795	$252,646.7966	0.9996	$502,593.1773
LRP90%	0.6235	63,487.4274	0.9792	251,743.5789	0.9995	497,801.5799

Table 5.3. Low Risk & 250 Head Feeder Cattle Farm

Tools	*c* = 0.5		*c* = 2		*c* = 4	
	Mean E(u)	CE	Mean E(u)	CE	Mean E(u)	CE
Cash	0.6586	$271,864.5614	0.9855	$1,071,289.9162	0.9998	$2,099,970.4176
Futures	0.6603	$273,153.1852	0.9861	$1,082,587.1918	0.9998	$2,138,611.6418
OptionK1	0.6483	$264,365.6198	0.9843	$1,050,717.7199	0.9997	$2,084,728.5890
OptionK2	0.6553	$269,457.1461	0.9851	$1,064,493.2131	0.9997	$2,094,968.3354
LRP99%	0.6558	$269,805.3893	0.9856	$1,072,702.5649	0.9998	$2,129,268.5781
LRP90%	0.6560	$269,968.6891	0.9852	$1,066,216.0498	0.9997	$2,097,661.9108

Table 5.4. Average Risk & 20 Head Feeder Cattle Farm

Tools	*c* = 0.5		*c* = 2		*c* = 4	
	Mean E(u)	CE	Mean E(u)	CE	Mean E(u)	CE
Cash	0.4905	$24,949.7917	0.9316	$99,271.2049	0.9951	$197,139.7266
Futures	0.4985	$25,536.5662	0.9318	$99,377.0294	0.9943	$191,500.3056
OptionK1	0.4610	$22,865.2777	0.9139	$90,751.8882	0.9922	$179,795.2591
OptionK2	0.4783	$24,077.1305	0.9251	$95,904.5445	0.9942	$190,762.2500
LRP99%	0.4881	$24,772.5783	0.9309	$98,883.8072	0.9952	$197,238.6763
LRP90%	0.4884	$24,799.9669	0.9307	$98,751.5955	0.9950	$196,332.3317

Table 5.5. Average Risk & 50 Head Feeder Cattle Farm

Tools	*c* = 0.5		*c* = 2		*c* = 4	
	Mean E(u)	CE	Mean E(u)	CE	Mean E(u)	CE
Cash	0.5481	$51,633.7822	0.9570	$204,580.4638	0.9980	$403,986.8500
Futures	0.5544	$52,548.3672	0.9604	$209,914.9625	0.9984	$419,087.2457
OptionK1	0.5343	$49,675.5248	0.9525	$198,053.8417	0.9977	$394,474.8618
OptionK2	0.5422	$50,779.7226	0.9550	$201,530.5823	0.9978	$398,973.8524
LRP99%	0.5452	$51,214.8732	0.9567	$204,109.8022	0.9981	$406,333.9894
LRP90%	0.5456	$51,276.2783	0.9563	$203,457.7222	0.9980	$402,662.5888

Table 5.6. Average Risk & 250 Head Feeder Cattle Farm

Tools	*c* = 0.5		*c* = 2		*c* = 4	
	Mean E(u)	CE	Mean E(u)	CE	Mean E(u)	CE
Cash	0.5858	$222,978.2056	0.9690	$878,912.0032	0.9989	$1,723,508.2536
Futures	0.5883	$224,551.9113	0.9705	$891,614.6686	0.9991	$1,765,621.3187
OptionK1	0.5678	$212,229.2504	0.9643	$842,960.6555	0.9986	$1,670,886.7040
OptionK2	0.5802	$219,607.5394	0.9676	$867,540.7178	0.9988	$1,707,262.6642
LRP99%	0.5825	$221,000.7093	0.9690	$879,017.0844	0.9990	$1,745,688.8585
LRP90%	0.5829	$221,203.0422	0.9684	$873,886.4312	0.9989	$1,719,849.7405

Table 5.7. High Risk & 20 Head Feeder Cattle Farm

Tools	*c* = 0.5		*c* = 2		*c* = 4	
	Mean E(u)	CE	Mean E(u)	CE	Mean E(u)	CE
Cash	0.4549	$22,451.9538	0.9107	$89,387.6042	0.9918	$177,658.7473
Futures	0.4631	$23,010.7855	0.9099	$89,050.5779	0.9900	$170,281.7536
OptionK1	0.4231	$20,354.2752	0.8870	$80,664.9397	0.9866	$159,536.6402
OptionK2	0.4419	$21,576.6415	0.9021	$85,977.4708	0.9902	$171,102.1856
LRP99%	0.4525	$22,285.2282	0.9097	$88,984.2814	0.9918	$177,567.1737
LRP90%	0.4529	$22,318.5308	0.9096	$88,919.0615	0.9916	$176,909.1246

Table 5.8. High Risk & 50 Head Feeder Cattle Farm

Tools	*c* = 0.5		*c* = 2		*c* = 4	
	Mean E(u)	CE	Mean E(u)	CE	Mean E(u)	CE
Cash	0.4923	$44,061.1710	0.9319	$174,680.6411	0.9951	$345,217.1215
Futures	0.4991	$44,935.5407	0.9367	$179,372.9218	0.9959	$357,764.7140
OptionK1	0.4766	$42,083.6176	0.9244	$167,839.1667	0.9942	$334,425.3630
OptionK2	0.4856	$43,202.9811	0.9286	$171,557.6407	0.9946	$339,877.3796
LRP99%	0.4891	$43,651.6582	0.9313	$174,035.8055	0.9952	$346,634.3934
LRP90%	0.4896	$43,721.0307	0.9308	$173,569.8557	0.9949	$343,736.0641

Table 5.9. High Risk & 250 Head Feeder Cattle Farm

Tools	*c* = 0.5		*c* = 2		*c* = 4	
	Mean E(u)	CE	Mean E(u)	CE	Mean E(u)	CE
Cash	0.5061	$178,493.1007	0.9381	$704,053.6697	0.9958	$1,381,942.7093
Futures	0.5084	$179,666.4098	0.9404	$713,508.7122	0.9963	$1,413,365.6248
OptionK1	0.4787	$164,820.5489	0.9247	$654,345.7983	0.9940	$1,296,182.4792
OptionK2	0.4979	$174,306.7718	0.9342	$688,594.2586	0.9953	$1,354,921.8628
LRP99%	0.5024	$176,600.1353	0.9378	$702,806.7300	0.9960	$1,396,700.5903
LRP90%	0.5029	$176,845.0590	0.9369	$699,093.5816	0.9957	$1,376,948.9927

From Table 5.1 to 5.9, the mean expected utility increased as the degree of risk aversion increased for each risk management tool. In other words, the results are reliable because they are consistent with the previously mentioned theory that expected utility under a high degree of risk aversion is higher than expected utility with low degree of risk aversion, or even risk neutral, under the same wealth conditions.

Moreover, after comparing the certainty equivalent between the different price risk management tools with the different risk-aversion coefficients we found hedging with futures was frequently the optimal choice with the exception of low and average risk cattle, with a farm size of 20 head with an extremely risk averse producer (*c* = 4); high risk cattle with a farm size of 20 head with a risk aversion of coefficient of two (rather risk averse) and four (extremely risk averse). For low and average risk cattle with a farm size of 20 head and with extremely risk aversion producer (*c* = 4) the optimal choice was LRP insurance with coverage price at 99% of f_0. For high risk cattle with a farm size of 20 head and with a rather risk aversion producer (*c* = 2) and extremely risk aversion (*c* = 4), the optimal choice was a cash strategy.

Table 5.10 to Table 5.18 show the expected utility and CE of price risk management tools for the different risk farm and farm size when prices decline.

Table 5.10. Low Risk & 20 Head Feeder Cattle Farm

Tools	c = 0.5		c = 2		c = 4	
	Mean E(u)	CE	Mean E(u)	CE	Mean E(u)	CE
Cash	0.4178	$20,014.9507	0.8820	$79,064.9270	0.9850	$155,457.6982
Futures	0.4269	$20,600.3013	0.8808	$78,690.9101	0.9816	$147,770.5012
OptionK1	0.4255	$20,507.2844	0.8884	$81,137.4680	0.9868	$160,128.9348
OptionK2	0.4232	$20,358.3367	0.8874	$80,791.7177	0.9867	$159,930.1115
LRP99%	0.4258	$20,523.8167	0.8901	$81,713.2798	0.9876	$162,461.0788
LRP90%	0.4210	$20,221.4424	0.8854	$80,162.7208	0.9862	$158,472.7646

Table 5.11. Low Risk & 50 Head Feeder Cattle Farm

Tools	c = 0.5		c = 2		c = 4	
	Mean E(u)	CE	Mean E(u)	CE	Mean E(u)	CE
Cash	0.4515	$39,036.2289	0.9041	$152,401.1774	0.9893	$294,734.9956
Futures	0.4606	$40,129.8559	0.9149	$160,144.5389	0.9926	$319,296.1472
OptionK1	0.4573	$39,728.9753	0.9116	$157,699.0127	0.9918	$312,379.7016
OptionK2	0.4549	$39,442.3560	0.9082	$155,228.9968	0.9907	$304,104.7529
LRP99%	0.4631	$40,423.6115	0.9151	$160,304.2797	0.9924	$317,178.0356
LRP90%	0.4563	$39,603.2434	0.9089	$155,747.1234	0.9908	$304,804.8896

Table 5.12. Low Risk & 250 Head Feeder Cattle Farm

Tools	c = 0.5		c = 2		c = 4	
	Mean E(u)	CE	Mean E(u)	CE	Mean E(u)	CE
Cash	0.4655	$158,481.3338	0.9102	$609,871.8618	0.9896	$1,155,586.1336
Futures	0.4688	$160,057.5617	0.9156	$625,376.0754	0.9917	$1,210,898.6214
OptionK1	0.4721	$161,618.4065	0.9195	$637,313.2256	0.9929	$1,252,605.7321
OptionK2	0.4700	$160,627.3579	0.9155	$625,292.9955	0.9916	$1,207,900.2037
LRP99%	0.4804	$165,658.0074	0.9245	$653,799.7501	0.9938	$1,286,367.2840
LRP90%	0.4717	$161,414.2192	0.9167	$628,712.3768	0.9918	$1,215,974.5042

Table 5.13. Average Risk & 20 Head Feeder Cattle Farm

Tools	c = 0.5		c = 2		c = 4	
	Mean E(u)	CE	Mean E(u)	CE	Mean E(u)	CE
Cash	0.3863	$18,062.9073	0.8550	$71,455.2612	0.9777	$140,775.0268
Futures	0.3952	$18,605.4593	0.8508	$70,402.6498	0.9705	$130,426.5346
OptionK1	0.3940	$18,534.5363	0.8617	$73,211.0200	0.9797	$144,240.0073
OptionK2	0.3918	$18,398.6457	0.8612	$73,057.3141	0.9800	$144,735.7039
LRP99%	0.3941	$18,538.2563	0.8642	$73,865.7240	0.9812	$147,003.3624
LRP90%	0.3894	$18,251.8165	0.8588	$72,436.1490	0.9793	$143,405.1162

Table 5.14. Average Risk & 50 Head Feeder Cattle Farm

Tools	c = 0.5		c = 2		c = 4	
	Mean E(u)	CE	Mean E(u)	CE	Mean E(u)	CE
Cash	0.4163	$34,989.3578	0.8784	$136,943.8634	0.9832	$265,800.5048
Futures	0.4255	$36,022.7842	0.8904	$143,712.9681	0.9878	$286,422.7491
OptionK1	0.4222	$35,652.0330	0.8870	$141,731.0303	0.9868	$281,267.8643
OptionK2	0.4198	$35,383.6963	0.8832	$139,551.4511	0.9853	$274,129.9649
LRP99%	0.4277	$36,272.5775	0.8910	$144,041.1680	0.9876	$285,486.8174
LRP90%	0.4209	$35,513.2249	0.8838	$139,930.4995	0.9854	$274,520.2171

Table 5.15. Average Risk & 250 Head Feeder Cattle Farm

Tools	c = 0.5		c = 2		c = 4	
	Mean E(u)	CE	Mean E(u)	CE	Mean E(u)	CE
Cash	0.4102	$133,587.6546	0.8695	$515,224.1568	0.9792	$979,252.9573
Futures	0.4146	$135,469.6548	0.8781	$532,492.7168	0.9836	$1,039,758.0340
OptionK1	0.4171	$136,560.1912	0.8816	$539,815.2184	0.9851	$1,064,077.5555
OptionK2	0.4142	$135,285.3809	0.8759	$527,911.9582	0.9825	$1,023,223.8445
LRP99%	0.4253	$140,134.5674	0.8880	$553,964.7016	0.9867	$1,092,025.2802
LRP90%	0.4164	$136,258.7570	0.8777	$531,705.6073	0.9830	$1,030,541.2430

Table 5.16. High Risk & 20 Head Feeder Cattle Farm

Tools	c = 0.5		c = 2		c = 4	
	Mean E(u)	CE	Mean E(u)	CE	Mean E(u)	CE
Cash	0.3640	$16,743.6684	0.8335	$66,333.1352	0.9710	$130,945.7567
Futures	0.3726	$17,248.1059	0.8259	$64,672.7745	0.9590	$118,200.9471
OptionK1	0.3709	$17,146.0432	0.8224	$63,945.8470	0.9615	$120,501.6693
OptionK2	0.3717	$17,192.5885	0.8392	$67,628.6284	0.9726	$133,072.3053
LRP99%	0.3715	$17,185.5214	0.8431	$68,527.0708	0.9750	$136,506.1568
LRP90%	0.3671	$16,923.2511	0.8375	$67,238.7251	0.9728	$133,305.1571

Table 5.17. High Risk & 50 Head Feeder Cattle Farm

Tools	c = 0.5		c = 2		c = 4	
	Mean E(u)	CE	Mean E(u)	CE	Mean E(u)	CE
Cash	0.3598	$28,987.5506	0.8259	$113,613.1492	0.9666	$220,965.5952
Futures	0.3692	$29,951.9777	0.8404	$119,271.2024	0.9740	$237,114.9958
OptionK1	0.3660	$29,616.4386	0.8368	$117,837.1746	0.9727	$234,073.7024
OptionK2	0.3635	$29,368.7001	0.8321	$115,981.0635	0.9701	$228,187.7450
LRP99%	0.3711	$30,146.1092	0.8417	$119,813.6143	0.9742	$237,703.5358
LRP90%	0.3644	$29,459.2170	0.8327	$116,202.0820	0.9702	$228,263.3766

Table 5.18. High Risk & 250 Head Feeder Cattle Farm

Tools	c = 0.5		c = 2		c = 4	
	Mean E(u)	CE	Mean E(u)	CE	Mean E(u)	CE
Cash	0.3502	$109,081.1009	0.8110	$421,464.9042	0.9582	$803,124.6823
Futures	0.3538	$110,487.3197	0.8203	$434,233.1930	0.9649	$847,698.0259
OptionK1	0.3588	$112,452.9105	0.8282	$445,581.5602	0.9692	$880,746.8402
OptionK2	0.3631	$114,158.8382	0.8303	$448,688.5898	0.9688	$877,571.5436
LRP99%	0.3667	$115,571.7477	0.8362	$457,665.5160	0.9719	$904,001.8535
LRP90%	0.3659	$115,269.1322	0.8332	$453,122.4275	0.9699	$886,530.1118

From Table 5.10 to 5.18, after comparing the certainty equivalent between the different price risk management tools with the different risk-aversion coefficients we found LRP insurance with coverage price at 99% of f_0 was frequently the optimal choice except for low, average, and high risk cattle, with a size of 20 head for a slight risk averse producer (*c* = 0.5); low and average risk cattle with a farm size of 50 head with a risk aversion of coefficient of four (extremely risk averse). For low, average, and high-risk cattle with a farm size of 20 head and with light risk aversion producer (*c* = 0.5) the optimal choice was hedging using futures. For low and average risk cattle with a farm size of 50 head and with extremely risk averse (*c* = 4), futures was also the optimal strategy choice.

For the parameter of the mean of DeltaFP, we also tested with it equal to zero, which implies market efficiency, but the results were similar to those of applying the historical mean.

In general, in the period of cattle cash prices increasing, futures should be the optimal price risk management tool for most producers, but for small producers who are extremely risk-averse the optimal price risk management tool prefers LRP insurance with coverage price at 99% of f_0. It is worth noting that cash is the optimal price risk management tool for producers with limited output if they are risk averse or extremely risk averse. In a period of cash feeder cattle price declines, LRP insurance with coverage price at 99% of $f_0$will become the preferred price risk management tool. The sensitivity of small and medium producers to risk aversion is likely to be reversed, because for small producers with light risk aversion, they prefer futures when prices is in price decreased period. But for medium-size producers, who are extremely risk-averse, they prefer futures to price insurance.

Subsidy Adjustment

The second part of the objective of this study is to examine possible adjustments to the subsidy level of LRP insurance that make it more beneficial for small producers when LRP insurance is not optimal choice for hedging. We measured what subsidy level can make the expected utility of LRP 99% insurance match the expected utility of futures after subsidy adjustment. In the cash feeder cattle price increasing period, Table 5.19 shows that if the subsidy was adjusted to about 75.47%, 60.54%,and 62.35%, small producers (20 head) with low, average, or high-risk cattle would prefer to choose the LRP 99% for hedging, respectively. In cash feeder cattle price decline period, as shown in

Table 5.20, for producers with 20 head low, average, or high-risk cattle, raising the subsidy to about 30% might prompt them to choose LRP 99% as price risk management tools.

Table 5.19. Subsidy Adjustment Trial Sheet in Price Increasing Period

	Target Tool	Target Utility	Adj. Subsidy	Adj. Utility	
LR20	Future	0.5541	75.47%	LRP99%	0.5541
MR20	Future	0.4985	60.54%	LRP99%	0.4985
HR20	Future	0.4631	62.35%	LRP99%	0.4631

Table 5.20. Subsidy Adjustment Trial Sheet in Price Decreasing Period

	Target Tool	Target Utility	Adj. Subsidy	Adj. Utility	
LR20	Future	0.4269	34.93%	LRP99%	0.4269
MR20	Future	0.3952	30.53%	LRP99%	0.3952
HR20	Future	0.3726	31.58%	LRP99%	0.3726

The above results from the Table 5.19 and 5.20 are examples obtained when $c = 0.5$. When $c = 2$ or $c = 4$, the subsidy levels that need to be adjusted are similar or even need not be adjusted to match the expected utility of futures.

CHAPTER VI

Conclusion

Futures and LRP insurance with coverage price at 99% of f_0 are likely to be optimal price risk management tools under different market conditions. The one potential reason that futures is the optimal choice in a period where cash feeder cattle price is increasing is that, as the cash price continually moves toward a high point, the risk of a potential price drop is gradually increasing. As mentioned in the literature review, futures have a strong ability to control price risks. At the same time, when the spot price or cash prices are at high levels, the potential payout opportunity from futures is larger. However, selling on the cash market is the optimal choice for small producers who are within extreme risk aversion due to the initial wealth effect. And vice versa, in cash feeder cattle price decreasing period, producers' financial outcomes are improved with price risk management tools through hedging price risks.

Another possible reason why LRP insurance with coverage price at 99% of f_0 is the optimal choice in the price decreasing period is the risk of moral hazard. If the price cycle of feeder cattle is reliable, the utility or demand of LRP insurance with a coverage price at 99% of f_0 is strong for producers because they believe the price will decrease.

Based on these results, we suggest that feeder cattle producers use futures to manage the price risk if prices have experienced a relatively long period of price inflation. When the cash price has experienced a relatively long period of price decline, feeder cattle producers should consider LRP insurance with a coverage price at 99% of f_0.Policy makers may need to consider a floating subsidy rate for LRP insurance in future farm bill cycles to avoid moral hazard issues and ensure the effective operation of agricultural insurance and agricultural reinsurance.

Future research may address whether a market index can be developed to guide the reasonable level of LRP insurance subsidy. Some of the existing studies have focused on actuarial approaches without considering how to set appropriate subsidy levels, which is a point of concern for the future.

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