COMMODITY PRICES AND TRANSACTION
COORDINATION THROUGH CONTRACTS

A Thesis in
Agricultural, Environmental, and Regional Economics
by
Ming-Chin Chin

© 2003 Ming-Chin Chin

Submitted in Partial Fulfillment
of the Requirements
for the Degree of

Doctor of Philosophy

August 2003
We approve the thesis of Ming-Chin Chin

Robert D. Weaver  
Professor of Agricultural Economics  
Thesis Advisor  
Chair of Committee

James W. Dunn  
Professor of Agricultural Economics

Edward C. Jaenicke  
Assistant Professor of Agricultural Economics

Kalyan Chatterjee  
Professor of Economics

David Blandford  
Professor of Agricultural Economics  
Head of the Department of Agricultural Economics and Rural Sociology
ABSTRACT

My dissertation research is composed of three essays to investigate the role of procurement contracting, market structural features, and market participants’ behavior as determinants of the implications of contracting for spot price determination, market segments, and welfare effects. A key feature of procurement contracting is the partitioning of the market into a contract segment and a residual, open (spot) market segment. This research presents three alternative considerations of the role of procurement contracting in price determination.

For the first essay, a two-sector general equilibrium model is introduced by analyzing the optimizing behavior of agents, who produce and purchase commodities in the presence of forward contracting, and derived a set of individual supply and demand functions under price uncertainty and risk aversion. By setting up a formal optimizing model, we are able to understand how activities of production and consumption should be modified as a consequence of introducing forward contract markets. Assuming clearing markets, equilibrium spot price distributions are solved in the rational expectations framework. We examine the effects of contracts on spot market price behavior. Specifically, both price level and price volatility effects are considered. Simulation results show that as hedge increases mean of spot price falls, and variance increases. These results are intuitive though also dependent on parameterization.

The second and the third essays of this research use intuitive concepts from game theory that are currently useful to formalize and investigate various forms of market structure. For the second essay, the contract market itself is assumed subject to adverse selection and moral hazard in that quality is unknown. We look at how agents effectively
signal their quality using a modified framework *a la* Spence (1973). The results show that the high quality seller receives quality premium on forward contracts, whereas the low quality seller receives lower forward contract price than the expected spot price due to quality discount. Also, under the optimal incentive contracts provided by the buyer the high and the low quality sellers supply their total production to the forward contract market. In other words, the spot market does not exist if all feeders in market are offered optimal contracts.

For the third essay, we set up a bargaining model between buyers and sellers for their contracts in which they bargain over price and/or quantity. The bargaining protocol is a fairly standard Rubinstein bargaining model of alternating offers (see Rubinstein (1982)). The results in this essay show that bargaining is not just increasing prices paid to farmers comparing with the situations in monoposy and in competitive market; the total surplus associated with bargaining are positive. We conclude that the existence of market-wide pooling of revenues mitigates the problem of the processor’s market power that individual producers face. In absence of the introduction of a cooperative, we find it likely that individual producers receive the lowest price and zero profit.
# Table of Contents

List of Figures ........................................................................................................ vii  
List of Table ........................................................................................................ viii  
Acknowledgments ................................................................................................ ix  

**ESSAY 1: FORWARD CONTRACTING: IMPLICATIONS FOR SPOT PRICE LEVEL AND VOLATILITY** ............................................................... 1  
1.1 Introduction ................................................................................................. 2  
1.2 Approach ................................................................................................... 4  
1.2.1 General features of contracting in current U.S. agricultural markets .... 4  
1.2.2 Contract mechanism ............................................................................ 6  
1.2.3 Price volatility theory ......................................................................... 7  
1.2.4 Past results ......................................................................................... 8  
1.2.5 Methods of past studies ..................................................................... 9  
1.3 The Model ................................................................................................. 12  
1.3.1 Overview ........................................................................................... 12  
1.3.2 A two-feeder and one-packer case ..................................................... 14  
1.4 Simulation Model and Results ................................................................ 23  
1.4.1 Analysis of cases .............................................................................. 25  
1.4.2 Simulation setup ............................................................................... 27  
1.4.3 Parameterization .............................................................................. 28  
1.4.4 Numerical illustrations ..................................................................... 30  
1.5 Conclusions .............................................................................................. 33  
References ......................................................................................................... 37  
Appendix 1: Three categories of captive supply .............................................. 42  
Appendix 2: Salient features of contracting in pork, beef, and poultry markets .... 43  

**ESSAY 2: FORWARD CONTRACTING USING A SIGNALING DEVICE TO MANAGE QUALITY** .......................................................... 45  
2.1 Introduction .............................................................................................. 46  
2.2 Approach ................................................................................................ 49  
2.2.1 Salient features of the current fed cattle market ............................... 49  
2.2.2 Signals convey information ............................................................... 53  
2.2.3 Adverse selection and moral hazard in agricultural markets .......... 55  
2.3 The Model ............................................................................................... 57  
2.3.1 Informal description of the model ..................................................... 57  
2.3.2 Simple spot market with asymmetric information ............................ 58  
2.3.3 A signal as Spence (1973) where $x$ is not productive .................... 64  
2.3.4 $x$ is a productive signal ................................................................. 76  
2.4 Conclusions and Discussion ................................................................ 88  
References ........................................................................................................ 92  
Appendix 1: An overview of captive supply and motivations ....................... 95  
Appendix 2: Grading, certification, and inspection systems in current U.S. agricultural markets ................................. 97
List of Figures

Figure 1.1 Mean of spot prices vs. packer’s hedge ratio (delta=-1)……………………..40
Figure 1.2 Mean of spot prices vs. packer’s hedge ratio (lambda=0.1)………………….40
Figure 1.3 Variance of spot prices vs. packer’s hedge ratio (delta=-1)………………….41
Figure 1.4 Variance of spot prices vs. packer’s hedge ratio (lambda=0.1)………………41
Figure 2.1 One of separating equilibria………………………………………………….94
List of Tables

Table 1.1 List the initial value of the parameters and the data sources..........................29
Table 2.1 Incentives for cattle feeders and packers to use captive supply......................96
Table 2.2 Summary of the results of the pure signaling case.................................75
Table 2.3 Differences between the perfect signal model of the Spence’s (1973) and the imperfect signal model.................................................................79
Table 2.4 Summary of the results of the imperfect signaling case..............................88
Table 3.1 The resultant equilibrium quantities and the equilibrium prices from 4 cases........................................................................................................118
Table 3.2 The profits of the processor and the cooperative from 4 cases....................120
Table 3.3 Rank of effects across cases........................................................................133
ACKNOWLEDGMENT

I am most thankful to my thesis advisor, Dr. Robert D. Weaver, for his insightful discussions, helpful suggestions, and unlimited patience during my time working on my thesis. I am also grateful to Spiro E. Stefanou for his warm encouragement in all phases of my graduate study at the Pennsylvania State University. I would like to express my gratitude to Dr. James W. Dunn, Dr. Edward C. Jaenick, and Dr. Kalyan Chatterjee for their kind guidance and discussions on my research and for serving in my doctoral committee. Special thanks to my dear friends at Penn State, Siddhartha Bandyopadhyay, Yanquo Wang, Fang-I Wen, Shih-Tsen Liu, Hisn-hsin Tung, and other friends, for dealing with me through the good times and the bad.

In addition, I want to take this opportunity to express my deepest gratitude to my parents, my aunt, and my sister. They have stood by me when I needed them, offering encouragement and helping out in ways no one else could. Without their love and support throughout my study, it would have been impossible to accomplish my academic goal.

Most importantly, I would like to thank my husband, Wen-Jye Huang, from the bottom of my heart. He has been there and will always be there for me. Now, I am so ready to start another life journey with him together.
**Essay 1: Forward Contracting: Implications for Spot Price Level and Volatility**

**Abstract**

This essay contributes to the understanding of the role of procurement contracting, market structural features, and product characteristics as determinants of the implications of contracting for spot price levels and volatility. We began by analyzing the optimizing behavior of agents who produce and purchase commodities in the presence of forward contracting, and derived a set of individual supply and demand functions under price uncertainty and risk aversion. By setting up a formal optimizing model, we are able to understand how activities of production and consumption should be modified as a consequence of introducing forward contract markets. Assuming clearing markets, equilibrium spot price distributions are solved in the rational expectations framework.

Our results illustrate that contracting can lead to reduced feeder prices received in spot market, not only due to the residual nature of spot markets that operate in conjunction with forward contracting, but also due to the adjusted spot demand by packers. We find that as contracting increases (spot market is thinner), spot price levels decrease and spot price volatility increases.
1.1 Introduction

Contracting as a method for coordination of market transactions is a substitute for anonymous, just-in-time procurement in agricultural markets. In U.S. agriculture, the use of forward contracts in food and agricultural supply chains has spread rapidly during the past decades. The most recent 1998 USDA-ERS Agricultural Resource Management Study (ARMS) found contracting is common among all types of farms, accounting for 35 percent of total production[^1]. The reasons for forward contracting vary across products and economic settings. Ward, et al. (1996) suggested some reasons for the use of contracts. They include income stability, improved efficiency, market security, and access to capital from the farmers’ point of view, whereas processors and other entities enter into contracts to control input supply, improve response to consumer demand, and expand and diversify operations.

The supply procured via contracts in agricultural markets is often referred to as captive supply. The Grain Inspection, Packers and Stockyards Administration (GIPSA) defines captive supply as livestock that is owned or fed by a packer more than 14 days prior to slaughter, livestock that is procured by a packer through a contract or market agreement that has been in place for more than 14 days, or livestock that is otherwise committed to a packer more than 14 days prior to slaughter. In short, the procurement of cattle by packers may be pursued through forward contracts and market agreements and with cattle that are packer-owned or fed. In 2001, GIPSA further defined these procurement categories (See Appendix 1). Typically, contracts define the volume of transactions, other characteristics like type of inputs used, and the rule for determining

the price at which that volume will be transacted. When contracts are costly to renegotiate, the contracted volume is in a sense captured, or taken out of the spot market.

Concern over the potential impact of contracting on price level and volatility led to a series of studies during the 1990s. Most of these studies focused on beef markets, see Schroeder, et al. (1993) and Azzam (1998). Schroeder, et al. (1993) found evidence that contracting could reduce price levels while increasing price variability. Similar results were also found by Ward (1998) and Ward, et al. (1999). However, Hayenga and O’Brien (1992) examined the effects that captive supplies had on weekly average fed cattle prices and price variability during 15 months from 1988 to 1989. They found no conclusive evidence that forward contracting diminished fed cattle prices over the period. They also found no conclusive evidence that forward contracting adversely affected the variability of fed cattle prices.

Given the mixed empirical evidence, we re-examine the implications of forward contracting on cash (or spot) market price and price volatility in this essay. In short, our objectives in this essay are as follows:

1) Analysis of price performance in markets segmented by procurement contracting.
2) Sensitivity analysis of price performance with respect to contract characteristics.
3) Sensitivity analysis of price performance with respect to alternative market structures.

This essay contributes to the understanding of the role of procurement contracting, market structural features, and product characteristics as determinants of the implications of contracting for price levels and volatility. Given that contracting offers an important means of private market coordination, it is essential that its implications be fully understood as a basis for determination of associated price performance. Moreover, such
insights are particularly valuable for the public sector to understand and assess the concerns about captive supply.

1.2 Approach

An optimization model that incorporates the use of forward contracts to manage quality and quantity is set up in this essay. Cattle marketed through forward contracts are priced by quality-based pricing; therefore, those feeders who know their cattle are not high quality market their cattle based on live weight pricing and pricing on average in the spot market. Actual spot supply is specified as price dependent and stochastic. In addition, we can do simulations to examine the sensitivity of price level and volatility to forward contracting, risk aversion, and spot market demand adjustment. We focus on the fundamental analysis of price volatility instead of statistical analysis. Fundamental analysis pertains to understanding the economic factors and relationships that result in price variation, while statistical analysis refers to employing time series techniques to characterize and describe the variation of a price series.

1.2.1 General features of contracting in current U.S. agricultural markets

In U.S. agriculture, two types of contracts are predominant: marketing and production contracts. Marketing contracts are extensions of the spot market in that they specify only market characteristics such as price, quantity, time of delivery, and quality (Hudson 2000). Under marketing contracts, the contractee (farmer) retains ownership of the product and has a large degree of decision-making control over the production process, but has a known market and price. Production contracts require the contractee (producer)

---

1. Fundamental analysis of price volatility is based on the assumption that price movements are the result of changes in exogenous factors such as consumer preferences, changes in market structure, or shifts in the overall economy (Natcher, 2001).

to relinquish most control over production decisions, and the producer does not own the commodity being produced.

In most spot markets, fed cattle are largely sold on the average price and quality (Hayenga, et al. 2000). This is because fed cattle pricing in the spot market has been based predominately on live weight (Schroeder, et al. 1997). However, some research by Ward, et al. (1996) shows that packers pay higher prices in the spot market for pens of cattle with a higher percentage of Choice or Prime quality grade cattle. Even though some cattle feeders sell their cattle by grid pricing in the spot market, spot market purchases by packers are mainly based on their expectations of likely carcass quality (Hayenga, et al. 2000). There are still a large number of cattle feeders who sell their cattle at the same live and carcass prices. In this case, significant welfare losses occur to feeders of high quality cattle who subsidize feeders of poor quality cattle when both are combined in the same sale lot. Obviously, live cattle pricing cannot accurately send pricing signals to producers regarding cattle quality attributes (Schroeder, et al. 1998). Although some large feedlots or packers prefer trading on average because they are volume driven and cost oriented, most feeders and packers agree that the industry needs to move toward pricing fed cattle according to value (Schroeder, et al. 1997).

In fact, many efforts have been made to move toward value-based marketing and pricing. Among them are exclusive marketing agreements, strategic alliances, formula pricing, and grid pricing (Schroeder, et al. 1997). Marketing agreements and alliances are variations of contract integration. Cattle marketed through marketing agreements and forward contracts (by formulas or grids) are part of what industry calls captive supplies. Generally, cattle feeders agree to provide cattle on a regular basis to a packer with price
based on some type of formula arrangement. The formulas may specify an acceptable quality range of cattle, e.g. yield, quality grade, and carcass weight. Typically, valued-based pricing requires pricing fed cattle on carcass traits, not live animal characteristics. Most contracts involve formula pricing and, since most price cattle on a carcass weight basis, they are variations of a grid pricing system (Schroeder, et al. 1997). The pricing formula consists of a base price with specified premiums and discounts for carcasses above and below the base quality specifications. Several base prices have been used. One example is the average price of cattle purchased. Other base prices can include the reported futures market price for live cattle or a negotiated price. As a result, once cattle are slaughtered, there is no opportunity for price negotiation because the final price has been predetermined by the agreed upon formula.

Appendix 2 introduces some salient features of contracting in particular agricultural markets, including pork, beef, and poultry.

1.2.2 Contract mechanism

Competitive market theory says that agents acting independently result in an efficient allocation. In reality, it is often the case that the competitive environment does not hold, because information is not instantaneously and freely available; thus, there are externalities. Therefore, substantial incentives may exist for internalization of such costs through re-organization of the behavior of atomistic agents. This ex post inefficiency gives the parties incentives to re-organize their behavior ex ante to avoid or limit this inefficiency (Tirole, 1997). One approach to such re-organization is offered by contracting. By contrast, if the parties’ information is common knowledge and no transaction cost is considered, contracting in general offers no improvement in outcomes.
As a means of coordination of transactions, there are two main functions that contracts provide. First, contracts can be regarded as an insurance/risk-smoothing scheme to mitigate the inefficiency that results from uncertainty prevailing in an economy composed of risk-averse agents. Second, contracts play a role in reducing transaction costs if asymmetric information exists before a transaction is completed. In a contracting setting, two parties can write ex ante contracts specifying the process through which the amount of trade and the transfer are determined ex post. In other words, contracts change the pattern and nature of trade. Intuitively, if a market allows the existence of contracting, which replaces cash transactions in the open market, the given market supply cannot adjust immediately. This implies that captive supply may leave a thinner market to those who are not contracting, and this may, in turn, affect their welfare.

1.2.3 Price volatility theory

When uncertainty exists a market, the determination of prices is not the only concern of market participants; price volatility becomes another one. Kurz (1997) defines the term “persistence” as the property according to which the probability at time $t$ of an event occurring at time $t + 1$ is higher when the event has occurred at time $t$ compared with the probability given that the event did not occur at time $t$. Therefore, if volatility is persistent, once a shock occurs to the system, it is likely the repercussions from the shock will continue into the future. Price volatility is an estimate of the range within which prices might vary at a future time; therefore, when prices are said to be volatile, the range in which prices might fall at a future date is widened. The volatility persists.

Price volatility and price variation are not equivalent. Price volatility is a statistical concept based on a constant data generation process, while price variation is simply the
historical range of prices. Therefore, using the range of historical price variation to measure price volatility is misleading. Various approaches have been proposed to estimate historical and expected volatility in prices. Weaver and Natcher (1999) summarized that measuring historic price variation most often involves time series inference, while estimating expected volatility entails time series forecasting or computing the volatility implied by an option-pricing model.

1.2.4 Past results

Past literature has focused on empirical evidence of relationships between transaction price levels (spot market prices) and the extent of contracting as measured by inventories of forward contracting. Ward, et al. (1999) explains that reductions in the supply of available fed cattle due to contracting have led to a change in the distribution of available cattle from feedlots to packers and could potentially change the relative bargaining position of feedlots and packers. If this claim were true, these changes would affect spot price variation, most likely reducing price levels if packers hold price power. Schroeder et al. (1993) proposed that the main factors determining spot price levels when contracting occurs are the packers’ competitiveness, the extent of inelasticity of supply in the short run, and quality attributes.

Quite a few studies found empirical evidence that is consistent with the hypothesis that the spot price is inversely related to the incidence of contract use. Ward et al. (1998) found negative relationships between spot prices and percentage deliveries from the inventory of forward contracted cattle. Azzam (1998) examined another method of captive supply (vertical integration) and drew the same conclusion.
The results of Ward et al. (1998) also indicated that the price paid for cattle procured through forward contracting is lower than the spot market price. The economic intuition of this result is straightforward. Forward contracting provides risk sharing. It follows that if the packer or processor does not have complete control over production decisions, feeders or producers may be willing to accept a lower price to have some of the production risk assumed by the processors (Love and Burton, 1999). Ward et al. (1999) drew another conclusion that the prices and variability of non-contracted cattle were high during the contract period, and that feeders with contracts had lower, less variable forward contract prices than feeders without contracts.

Few studies focus on price volatility. Hayenga (1979) mentioned that, as spot markets become thin due to contracting, it is expected that mean prices would not change, but that price volatility would increase and pricing efficiency would decline. Lyford et al. (2001) examined the effects of systematic variations in contracting levels on prices using an experimental model of the fed cattle market. Results indicated that pricing dynamics changed considerably with increased contracting, but the mean price level was found to be unrelated to contracting levels.

1.2.5 Methods of past studies

Five methods have been used to analyze the impact of captive supply. The first was to test for the existence of marginal cost-pricing conduct in the relevant market or industry. Most of the literature has focused on the degree of non-competitive behavior that is caused by contracting. By doing so, evidence of market power, either in oligopoly or in oligopsony, can be used to explain why market prices deviate from competitive prices. Azzam and Pagoulatos (1990) and Schroeter (1988) provide examples for this
type of analysis. Both studies indicated small but statistically significant price distortions in slaughter cattle and wholesale beef markets. In particular, Azzam and Pagoulatos (1990) suggested that the degree of market power in the livestock market is significantly higher than in the meat market.

The second approach was direct estimation of market price functions to examine the role of shipments of contract cattle as a determinant of price level. Elam (1992), Schroeder et al. (1993), and Ward et al. (1998, 1999) provide examples. In each case, the results indicated a negative impact of forward contracting on the level of cash transaction prices. Schroeder et al. (1993) also concluded that changes in forward contract shipments had a larger impact on spot transaction prices during the periods when shipments were high.

The third approach taken in the literature has been the use of survey data. These studies provide first-hand, practical information that serves as background for theoretical specification and analysis. For instance, Hennessy and Lawrence (1999) surveyed the opinions of hog industry participants. Questions were asked about the advantages and disadvantages of production contracts from the perspective of the production farm. Three top advantages, including increased financial leverage, reduced regulatory problems, and improved access to motivated labor, are mentioned by the hog producers, whereas loss of control, increased production costs, and disagreement are seen as three main disadvantages of contracts for them. Rhodes (1995) administered a sequence of surveys to the U.S. hog industry from 1974 to 1992. These surveys showed a swift evolution taking place in hog production; each surveyed firm marketed 5,000 head on average in 1974 and up to 792,000 head in 1993. Perry et al. (1999) used USDA survey data to
provide background on industry organization, management, and performance of the broiler industry.

The fourth approach was to use experimental economics. The most merit of using this approach is that it overcomes data limitations. Both Ward et al. (1996) and Lyford et al. (2001) used the Fed Cattle Market Simulator (FCMS). Ward et al. (1996) analyzed the effects of contracting on price discovery: a negative relationship has been found. Lyford et al. (2001) focused on the effects of changing contracting levels on cash price levels and pricing dynamics. Results have shown that the response of price to a given supply will increase as contracting increases. Price volatility would be lower followed by significantly large price changes in the presence of contracting.

The final approach found in the past literature is the use of game theoretic models to explain market behavior. Game theory has been used to specify market participant characteristics and describe the strategic interaction between them. Conditional on behavioral specifications, different responses of players can be predicted for different economic environments. For example, in an oligopoly or oligopsony setting, firms are specified as profit maximizing subject to the behavior of other firms in the market. Game theory indicates that various types of outcomes are possible: firms can devolve into price wars or end up exercising market power. Jaenicke and Dimitri (2000) set up a principal-agent problem and concluded that agricultural contracts are a response to reduced transaction costs caused by technical innovation and changing consumer demand. Zhang and Sexton (2000) developed a duopsony game model with a spatial market to show that exclusive contracts can be used in some market settings to diminish competition between
buyers; hence, contracts represent a device to enhance oligopsony coordination. Their result partially explains rising concentration and vertical control in the livestock sector.

Although the literature with regard to the relationship between contracting and spot price is vast, no work has addressed its implications on price volatility. For example, price volatility may be different if the contracts convey different information to market participants. Information that is transferable across markets can be quality, quantity, or prices. For market participants to effectively manage price uncertainty, they must understand the need to incorporate information about price risk into economic decisions and, also, the fundamental factors that result in price variation.

1.3 The Model

1.3.1 Overview

Two kinds of players are specified in the fed cattle market: feeders and packers. The feeders play the role of the suppliers of animals, whereas the downstream packers are buyers. Two type of transactions, forward contract and spot/cash market, are assumed to occur between feeders and packers. Three assumptions, which have also been used in some past literature, e.g., Grossman (1977), Kawai (1983), etc., are as follows: First, the commodity being transacted is the same both under the contracts and under the spot transaction. Second, a forward contract is settled by actual delivery of the commodity. Third, a contract market reopens every period and delivery takes place only once in each period.

We use a four-stage model to describe this environment. At the first stage, Nature generates a random draw that decides the type for each of the feeders. Here, type indicates the quality of output produced by the feeder. We assume that the information of
feeders’ types is public and is known to both the packer and the feeders. In the second period of the process, feeders and packers make their investment decisions, setting their planned supply and demand of animals, respectively. We assume each quality of meat has a market outlet.

In the third period, the forward contract market opens. We assume that the packer uses forward contracts to manage his quantity and quality needs. This would especially be the case in the cash market where animals are traded on auction markets or purchased by roving buyers that would have little insight into the condition of the animals. A forward contract offered by the packer to the feeder is assumed to specify quantity, quality, price, delivery time, etc. On the other hand, the value of the forward contract market to feeders is assumed to include the improvement of financing potential and the locking in of buyers. Within this specification, the existence of the forward contract market follows from its ability to differentiate prices by quality. It follows that the packer will be assumed to be able to verify the quality of cattle after delivery.

In the fourth period, all animals have been fed to their market weight and the uncertainty over available total supply is resolved. The quantity that is not contracted is expected to be traded in the spot market. The packer might adjust his planned demand as information, such as the spot price, evolves. We assume that the production of quantity is stochastic. In this simplest version of the model, we assume the probability of either quality animal going to the spot market is equal. The packer cannot distinguish the meat quality in the spot market. The spot market is assumed to be an anonymous auction market where animal quality is not observable at a reasonable cost.
1.3.2 A two-feeder and one-packer case

We simplify the model to a two-feeder-one-packer problem, in which one feeder is high quality and the other is low quality. Feeders are distinguished by their costs. We introduce the feeder’s and the packer’s choice problem as follows.

**Feeder behavior**

After each feeder knows his type, we suppose that the feeder selects the market to allocate his production. He can choose to enter into a forward contract to deliver a specified quantity of the commodity at a specified future time at a known contract price, or he can supply his production to the spot market and receive an expected competitive price. We assume that feeders’ preferences are represented by a constant absolute risk aversion (CARA) utility function\(^4\) of the form \(U(\pi) = -\exp(-\lambda \pi)\), where \(\pi\) is a feeder’s profit and \(\lambda\) is a coefficient of absolute risk aversion; and that the random spot price \(p_s\) is normally distributed. Under these conditions, the expected utility problem can be equivalently represented by a mean-variance specification (Lvey and Markowitz 1979). Further, it is noted that CARA implies the mean-variance objective is monotonically decreasing in risk as measured by variance.

The objective of a feeder is to maximize his expected utility of profit by optimally choosing his planned supply to each market and can be represented as:

\[
\max_{q_f, q_s} EU(\pi | p_f, p_s) = p_f q_f + p_s q_s - \frac{1}{2} \lambda \text{var}(p_f q_f) - C(q_f, q_s),
\]

where \(i \in [h, l]\) is feeder’s cattle quality. \(p_f\) and \(q_f\) are the price and quantity, respectively, based on the feeder’s type in the forward contract market. \(q_s\) is the quantity

---

\(^4\) For detail discussions, see Chambers and Quiggin 2000, p.82
supplied to the spot market, and \( p_s \) is the price in spot market. In order to obtain a linear form of commodity production, assume that the cost function, \( C'() \), is quadratic. Define \( C'() \equiv c'(q_f^i + q_s^i)^2 \), where \( c' \) is a parameter. We assume that feeders hold subjective expectations about \( p_s \) with mean \( \bar{p}_s \) and variance \( \sigma_s^2 \). The expected utility of profit is defined as the total expected revenue from the sale of cattle by contract and on the spot market, less a quadratic production cost function and the costs associated with spot price volatility, as reflected by risk aversion, which is characterized by \( \lambda \), the absolute risk aversion parameter. Later in the empirical part of the essay, we will simulate different levels of risk aversion by varying the risk aversion parameter \( \lambda \) in the range of 0.01 to 1.

Solution of the first-order conditions for (1) yields the optimal supply to contract and spot markets:

\[
(2) \quad q_f^i = -\frac{\bar{p}_s - p_f^i}{\lambda \sigma_s^2} + \frac{p_f^i}{2c^i} \quad \text{(Planned supply to the forward contract market)}
\]

\[
(3) \quad q_s^i = \frac{\bar{p}_s - p_f^i}{\lambda \sigma_s^2} \quad \text{(Planned supply to the spot market)}
\]

Forward contracts and spot markets are alternative market outlets. Equations (2) and (3) state that the supply is positively related to the own price, and inversely related to the alternative price. That is, \( \frac{\partial q_f^i}{\partial p_f^i} > 0 \), \( \frac{\partial q_f^i}{\partial p_s} < 0 \), \( \frac{\partial q_s^i}{\partial p_s} > 0 \), and \( \frac{\partial q_s^i}{\partial p_f^i} < 0 \). Moreover, if a feeder is more risk averse and/or the spot price is more volatile, then he is willing to supply more production to the forward contract instead of the spot market, \( \frac{\partial q_f^i}{\partial \lambda} > 0 \), and
\[
\frac{\partial q^i}{\partial \tilde{\sigma}_s} > 0.
\]
Note that the production decision is made dependent upon attitudes toward risk and the probability distribution of uncertain spot prices and, in this sense, it is completely related to the forward market.

Thus, equations (2) and (3) give us the ratio of type \(i\)'s quantity in the forward contract and the spot market. Given the population distribution of the two types, which we assume to be \(x\) for high quality meat and \(1 - x\) for low quality meat, the ratios of high and low quality in the spot market can be calculated. For example, if high quality and low quality are in equal proportion in the spot market, then

\[
\frac{xq^h_s}{xq^h_s + (1 - x)q^l_s} = \frac{(1 - x)q^l_s}{xq^h_s + (1 - x)q^l_s}.
\]

A deeper understanding of the supply to the spot market can be gleaned from equation (3). The expected spot price (\(\tilde{p}_s\)) must be greater than the forward contract price (\(p^i_f\)) for a spot market to exist. Therefore, if feeders could contract cattle at prices consistently equal to or greater than spot prices, they would contract all production. However, this does not imply that the actual realized spot price is always greater than the forward price, only that expected value is.

Forward contract supply \(q^i_f\) is divided into two parts. The first term on the right-hand side of (2), \(-\frac{\tilde{p}_s - p^i_f}{\lambda \tilde{\sigma}_s^2}\), is the negative of the exact quantity that should be sold in the forward market if the feeder wants to completely hedge against price risk; hence, this term represents the “hedging component”. In addition, this term reflects the difference between the feeder’s anticipated spot price and the corresponding forward price, which is
an anticipated gain per unit on the commodity sold to the spot market. Hence, this term should also be called the “speculation component”. Thus, the feeder enters into a forward contract not only to hedge against price risk but also to exploit speculative opportunities. This is a direct consequence of the risk-averse agent’s expected utility maximizing behavior (Kawai 1983).

**Packer behavior**

The packer decides his planned demand in the forward contract and spot markets by maximizing the expected utility of profit. In the model, the reasons for the packer to use forward contracting are due to the price differential on processed market prices and/or the differential on conditional marginal productivities, i.e., higher quality can sell at a higher price. This is reflected in the processor’s production function for the final product in the model setting. The packer’s choice problem is represented as follows:

\[
\begin{align*}
\text{(4)} \quad & \max_{q_b^i, q_b^f, q_s^p} \quad E(U_P) = p_b^h q_b^h + p_b^i q_b^i + p_f^h q_f^h - p_f^i q_f^i - p_f^q q_f^q - \tilde{p} q_s^p - \frac{1}{2} \lambda \var{p_s q_s^p} \\
\text{subject to } \quad & \text{Production function: } q_b = f(q) = \alpha_1 q^2 + \alpha_2 q, \quad \alpha_1 < 0, \alpha_2 > 0,
\end{align*}
\]

where \( p_b^i \) is the wholesale price of processed meat over quality when cattle are slaughtered, \( q_b^i \) is the quantity of processed meat over quality, \( p_f^i \) is the price of cattle over quality procured using forward contracts, and \( \tilde{p} \) is the expected spot price. We also assume that the packer holds subjective expectations about \( p_s \) with mean \( \tilde{p} \) and variance \( \tilde{\sigma}_s^2 \), and that he is risk-averse. Thus, the packer’s expected utility is the expected wholesale value of processed meat less input costs from the contracts market \( (p_f^i q_f^p) \) and from the spot market \( (\tilde{p}, q_s^p) \) minus the costs associated with the spot price volatility as
reflected by risk aversion, which is characterized by $\lambda^p$, the relative risk aversion parameter.

Incorporating the production function, equation (4) becomes:

$$
(4) \Rightarrow \max_{q_f^b, q_f^i, q_s} EU(\pi^p) = p_b^h(\alpha_1(q_f^b)^2 + \alpha_2 q_f^b) + p_i^j(\alpha_1(q_f^i)^2 + \alpha_2 q_f^i) + p_s^i(\alpha_1(q_s^i)^2 + \alpha_2 q_s^i) - p_f^b q_f^b - p_f^i q_f^i - p_f^s q_f^s - \frac{1}{2} \lambda^p \sigma_s^2 (q_f^p)^2
$$

Solution of the first-order conditions for (4) yields the optimal planned forward contract demand over quality and spot demand:

$$
(5) \quad q_f^b = \frac{p_f^b - \alpha_2 p_b^h}{2\alpha_1 p_b^h} \quad \text{(Planned demand on high quality to the forward contract market)}
$$

$$
(6) \quad q_f^i = \frac{p_f^i - \alpha_2 p_b^i}{2\alpha_1 p_b^i} \quad \text{(Planned demand on low quality to the forward contract market)}
$$

$$
(7) \quad q_s^p = \frac{-\bar{\sigma}_s - \alpha_2 p_b^i}{2\alpha_1 p_b^i - \lambda^p \sigma_s^2} \quad \text{(Planned demand to the spot market)}
$$

Equations (5) and (6) show that the planned forward contract demand increases when the wholesale price increases, with respect to forward contract purchasing ($p_b^h, p_b^i$), but decreases when the price of forward contract purchasing ($p_f^b, p_f^i$) increases. That is,

$$
\frac{\partial q_f^b}{\partial p_b^h} > 0 \quad \text{and} \quad \frac{\partial q_f^i}{\partial p_f^i} < 0, \ i = h, i. \quad \text{Equation (7) is the planned spot demand as a function of wholesale price and forward price conditioned on production technology, the packer’s risk aversion, and the expected spot volatility. It shows that the planned spot demand decreases when a packer is more risk averse and/or the expected spot volatility increases. That is,}
$$

$$
\frac{\partial q_s^p}{\partial \lambda^p} < 0 \quad \text{and} \quad \frac{\partial q_s^p}{\partial \sigma_s^2} < 0. \quad \text{In addition, if the packer is risk-neutral, i.e.} \quad \lambda^p = 0, \text{then}
$$
the expected spot demand will increase. The reason is straightforward. As the packer is risk-neutral, he is indifferent between supplying to forward contracts and supplying to the spot market. Thus, the planned spot demand by (7) with $\lambda^p = 0$ is bigger than it is with $\lambda^p > 0$.

Moreover, define $\beta = \frac{q_{ph}^f + q_{pl}^f}{q_{ph}^f + q_{pl}^f + q_s^p}$ as the packer’s optimal hedge ratio. That is, the packer will purchase the proportion $\beta$ of cattle from the contract market and the proportion $1 - \beta$ trades in the spot market. In addition, $\beta$ can play a role as an indicator of the extent of contracting in the later simulation study. In the model, the processor’s optimal hedge ratio is:

$$\beta = \frac{(2\alpha_1p_s^b - \lambda^p \tilde{\sigma}^2_s)(p_s^i(p_s^b - \alpha_2p_s^h) + p_b^h(p_s^i - \alpha_2p_s^b))}{(2\alpha_1p_s^b - \lambda^p \tilde{\sigma}^2_s)(p_s^i(p_s^b - \alpha_2p_s^h) + p_b^h(p_s^i - \alpha_2p_s^b)) + 2\alpha_1p_s^b p_b^h(p_s - \alpha_2p_s^b)}$$

Furthermore, we assume that the packer adjusts his planned demand as the spot price is revealed. We define a term, $\delta p_s$, to reflect the packer’s adjusted spot demand, i.e. $\delta$ is used here as an adjustment mechanism. We hypothesize that the packer is price responsive to actual spot demand. The interpretation of $\delta$ is as follows:

$$\bar{q}_s^p = q_s^p + \delta p_s = q_s^p (1 + \frac{\partial q_s^p}{\partial p_s} p_s)$$

where $\delta = \frac{\partial q_s^p}{\partial p_s}$, and $\delta < 0$. $\bar{q}_s^p$ is packer’s actual spot demand, and $q_s^p$ is packer’s planned spot demand. Thus, as spot market demand is more sensitive to current spot price, and $|\delta|$ increases. Later in the empirical part of the essay, we will simulate different levels of $\delta$ in the range of -1.5 to -0.5.
Market equilibrium

Individual agent’s supply and demand functions for forward contracts and spot markets can be aggregated in order to obtain the market supply and demand schedules and to determine equilibrium prices. It is assumed that there is no asymmetry in the amount of information available to the agents\(^5\).

To proceed, note that the spot market equilibrium must be considered both from an expectational perspective, as well as from an actual perspective. That is, during the forward market transactions period, the actual spot price is not resolved. An expectational spot market equilibrium occurs, determining the expected spot price that represents the mean of actual spot prices.

We consider the forward contract market equilibrium first. Suppose that the packer demands both quality types by forward contracts, as well as in spot market. Thus, the forward contract market equilibrium equates planned supply from equation (2), and demand from equations (5) and (6) for either quality in a forward contract. The resulting contract prices are:

\[ p^h_f = \frac{c^h (2\alpha_1 \tilde{p}_s + \alpha_2 \lambda \tilde{\sigma}^2_s) p^h_b}{c^h \lambda \tilde{\sigma}^2_s - \alpha_1 (\lambda \tilde{\sigma}^2_s - 2c^h) p^h_b} \quad \text{(Forward contract price for high quality meat)} \]

\[ p^l_f = \frac{c^l (2\alpha_1 \tilde{p}_s + \alpha_2 \lambda \tilde{\sigma}^2_s) p^l_b}{c^l \lambda \tilde{\sigma}^2_s - \alpha_1 (\lambda \tilde{\sigma}^2_s - 2c^l) p^l_b} \quad \text{(Forward contract price for low quality meat)} \]

Note that these forward contract prices are anticipated equilibrium values in the sense that they are conditional on \( \tilde{p}_s \) and \( \tilde{\sigma}^2_s \).

\(^5\) This essay does not consider the implication of information asymmetry, but focuses on other important functions of a forward contract market.
Next, we solve the actual equilibrium for the spot price, $p_s$. After forward contracts are signed and the delivery date approaches, the total supply of the product becomes certain. We assume that the production shock, $v$, is realized when the spot market opens and that it affects spot supply only. Besides, $v$ is assumed to have no effect on quality. Therefore, the actual spot price is derived from the structural form of the spot market clearing:

\[
(10) \quad \frac{\hat{p}_s - \alpha_s p'_s}{2\alpha_i p'_i - \lambda^2 \hat{\sigma}^2_s} + \delta \hat{p}_s = \frac{\hat{p}_s - p_f^b}{\lambda \hat{\sigma}^2_s} + \frac{\hat{p}_s - p_f^f}{\lambda \hat{\sigma}^2_s} + v
\]

Equation (10) is the actual spot market equilibrium. The left hand side and the right hand side are the actual spot demand and the actual spot supply, respectively.

In order to solve this stochastic equation, the following strategy is adopted. To proceed, an assumption of rationality of the first moment of subjective distribution is maintained. That is, expectations formation is presumed to follow from the agents’ knowledge of (10) and their use of (10) to form their expectation. Applying the conditional expectation operator $E$ to both side of (10) and using the assumption that $E(p_s) = \tilde{p}_s$ and $E(v) = 0$, the agent can compute:

\[
(10) \Rightarrow \quad \tilde{p}_s = \frac{\alpha_s \lambda \hat{\sigma}^2_s p'_s - (2\alpha_i p'_i - \lambda^2 \hat{\sigma}^2_s)(p_f^b + p_f^f)}{\lambda \hat{\sigma}^2_s + (2\alpha_i p'_i - \lambda^2 \hat{\sigma}^2_s)(\delta \lambda \hat{\sigma}^2_s - 2)}
\]

Thus, the expected spot price, conditional on price volatility, is derived as follows:

\[
(11) \quad \tilde{p}_s = \frac{\alpha_s \lambda \hat{\sigma}^2_s p'_s - (2\alpha_i p'_i - \lambda^2 \hat{\sigma}^2_s)(p_f^b + p_f^f)}{\lambda \hat{\sigma}^2_s + (2\alpha_i p'_i - \lambda^2 \hat{\sigma}^2_s)(\delta \lambda \hat{\sigma}^2_s - 2)}
\]

From equation (10), the actual spot price is written conditional on $\hat{\sigma}^2_s$ though consistent with rational expectation:
(12) \[ p_s = \frac{\alpha_2 p^2_b}{\delta(2\alpha_1 p^2_b - \lambda^2 \sigma^2_s)} - \frac{p^h + p^f}{\delta \lambda \sigma^2_s} + \frac{2(2\alpha_1 p^2_b - \lambda^2 \sigma^2_s) - \lambda \sigma^2_s}{\delta \lambda \sigma^2_s (2\alpha_1 p^2_b - \lambda^2 \sigma^2_s)} \tilde{p}_s + \frac{\nu}{\delta} \]

A theoretical difficulty emerges when we deal with the second moment of subjective distribution under the assumption of rational expectation. The difficulty arises from the fact that an indicator of price uncertainty \( \sigma^2_s \) is one of the structural coefficients, which in turn determines the equilibrium spot price and its conditional variances including \( \sigma^2_s \) itself, so that complicated nonlinear relationships exist among the structural parameters. McCafferty and Driskill (1980) have pointed out that such nonlinearity may lead to problems of nonexistence and nonuniqueness of a rational expectations solution. Exactly the same theoretical difficulty emerges in our model.

Taking the second moment on \( p_s \) of (10) and using the assumption that \( \text{Var}(p_s) = \tilde{\sigma}^2_s \) and \( \text{Var}(\nu) = \sigma^2_v \), the agent needs to compute:

\[ (10)' \quad \tilde{\sigma}^2_s = (p_s - \tilde{p}_s)^2 = \left( \frac{2 \tilde{p}_s - (p^h + p^f)}{\delta \lambda \sigma^2_s} + \frac{\nu}{\delta} - \frac{\tilde{p}_s - \alpha_2 p^f}{\delta(2\alpha_1 p^2_b - \lambda^2 \sigma^2_s)} - \tilde{p}_s \right)^2 \]

Considering the analytical difficulty in solving for \( \tilde{p}_s \) and \( \tilde{\sigma}^2_s \) simultaneously from (10) and (10)', a general solution is virtually impossible. Furthermore, such solution may not exist. Even when existence is assured, multiple solutions may be obtained. In order to make a manageable parameter, therefore, simplifying setup should be added to the model. In the simulation section, we will further address how we handle this problem.

The major purpose of this essay is to assess the effects on the spot price level of the introduction of a forward market. As a measure of price volatility, we analyze the conditional variance of the spot price. Due to the functional complexity we mentioned
previously, a simulation exercise is needed to get a better understanding of the relationships, even though the results are influenced by the parametric set-up.

We are particularly interested in the signs of \( \frac{\partial p_s}{\partial \beta}, \frac{\partial \sigma^2_s}{\partial \beta} \), \( \frac{\partial p_s}{\partial \lambda}, \frac{\partial \sigma^2_s}{\partial \lambda} \), and \( \frac{\partial \sigma^2_s}{\partial \delta}, \frac{\partial \sigma^2_s}{\partial \delta} \). We imbed the processor’s optimal hedge ratio \( \beta \) into (12) and rewrite equation (12) as:

\[
(13) \quad p_s = \frac{AB + C}{AB} \left( \frac{\alpha \sigma^2_s}{\delta \sigma^2_s} - \frac{\alpha p^b_s + p^f_s}{\lambda \sigma^2_s} + \frac{2A - \lambda \sigma^2_s}{\delta \sigma^2_s} \tilde{p}_s + \frac{v}{\delta} \right) \beta,
\]

where \( A = (2\alpha p^b_s - \lambda \sigma^2_s) < 0, B = p^b_s (p^b_s - \alpha p^b_s) + p^f_s (p^f_s - \alpha p^f_s) > 0, \) and \( C = 2\alpha p^b_s p^f_s (\tilde{p}_s - \alpha p^b_s) < 0 \).

Some relationships can be explained intuitively. For example, if a feeder becomes more risk averse (\( \lambda \) increases), then he may want to sell more to forward contracts instead of the spot market. Given the packer does not change the spot demand, reduced supply will drive the spot price up. Moreover, if the expected spot volatility increases, both the feeder and the packer want to trade on forward contracts. The result of decreased demand and supply on the spot price is undetermined.

1.4 Simulation Model and Results

In this essay, it is of interest to consider how spot price level and volatility change with the hedge ratio, \( \beta \). Many empirical studies have suggested \( \frac{\partial p_s}{\partial \beta} < 0 \). As for the sign of \( \frac{\partial \sigma^2_s}{\partial \beta} \), intuition may provide some conjecture. When the packer’s hedges increase, more forward demand will reduce spot demand. Since the spot market becomes thin
because of decreased demand, the effect on variance may be increased volatility. Based on simulation, we hope to determine the robustness of this type of result. To do so, we have to parameterize $\beta$.

In the simulation model, the market supply (feeder’s behavior) is same as that in the theoretical model, but the specification of market demand (packer’s behavior) needs to be changed. $\beta$ now is treated as a parameter to allow for simulation over different values.

**Packer behavior**

Define $q^p = q^{ph} + q^{pl}$ as the total optimal level of slaughter for a given time period, and $q^{pi}, i = h, l$ as the packer’s demand over quality. The packer is assumed to purchase the proportion $\beta$ of cattle from the contract market for high and low quality meat. In other words, the proportion $1 - \beta$ trades in the spot market. Thus, the packer’s demand in forward contracts for either quality and in the spot market can be presented as:

14) $q^{ph}_i = \beta q^{ph}$, $i = h, l$

15) $q^{pl}_i = (1 - \beta)(q^{ph} + q^{pl})$

**Market equilibrium**

The expectational market equilibrium occurs, determining the expected prices that equate supply from equation (2) and demand from equation (14) for either quality in forward contracts and in the spot market, as shown in equations (16) and (17).

16) $\beta q^{pi}_i = \frac{(2c^i + \lambda \sigma^i_s) p^i_j}{2c^i \lambda \sigma^i_s} - \frac{\bar{p}_s}{\lambda \sigma^i_s}, i = h, l$ (Forward contract market equilibrium)

17) $E[(1 - \beta)(q^{ph} + q^{pl}) + \delta p_j] = E[\frac{\bar{p}_s - p^p_j}{\lambda \sigma^i_s} + \frac{\bar{p}_s - p^p_j}{\lambda \sigma^i_s} + v_j]$ (Anticipated spot market equilibrium)

The resulting contract price function for either quality meat is:
The partial reduced form for the rational expected spot price derived from equation (17) is:

\[
\tilde{p}_i = \frac{p_{i}^h + p_{i}^l + \lambda \sigma_s^2 (1 - \beta)(q^{ph} + q^{pl})}{2 - \delta \lambda \sigma_s^2}
\]

The actual spot price is derived from the physical balance of the spot market:

\[
(1 - \beta)(q^{ph} + q^{pl}) + \delta p_s = \frac{\tilde{p}_s - p_{i}^h}{\lambda \sigma_s^2} + \frac{\tilde{p}_l - p_{i}^l}{\lambda \sigma_s^2} + v
\]

In actual spot market equilibrium, the spot price is:

\[
p_s = \frac{2\tilde{p}_s - (p_{i}^h + p_{i}^l)}{\delta \lambda \sigma_s^2} - (1 - \beta)(q^{ph} + q^{pl}) + v
\]

Substituting equation (18) into (21) yields:

\[
p_s = \frac{2\tilde{p}_s}{\delta \lambda \sigma_s^2} (1 - \frac{c^h}{2c^h + \lambda \sigma_s^2} - \frac{c^l}{2c^l + \lambda \sigma_s^2}) - \frac{2\beta}{\delta} (\frac{c^h q^{ph}}{2c^h + \lambda \sigma_s^2} + \frac{c^l q^{pl}}{2c^l + \lambda \sigma_s^2}) - \frac{(1 - \beta)(q^{ph} + q^{pl}) + v}{\delta}
\]

The general form can be presented as:

\[
p_s = p_s(q^{ph}, q^{pl}, \beta, \sigma_s^2, c^h, c^l, \lambda, \delta, v)
\]

1.4.1 Analysis of cases

In this section three cases are considered, each of which assumes the existence of an equilibrium solution and assigns a specific value to the given parameter in the model. These simple cases suggest that the spot market may or may not exist, depending upon some agent’s or market’s characteristics.
**Case 1: Risk neutral feeders**

When feeders are risk neutral (i.e., \( \lambda = 0 \)), equation (18) shows that the forward prices for each quality tend to equal the expected spot price. That is, \( p_j^h = p_j^l = \bar{p}_s \). In this case, the introduction of a forward contract cannot play its function of quality management, but play a role as an alternative to the spot market. Thereby, the feeders are indifferent between a forward contract and a spot transaction.

**Case 2: Infinitely risk averse feeders**

When feeders are infinitely risk averse (i.e., \( \lambda \rightarrow \infty \)), transactions take place only in the presence of a forward market and not in its absence. In this case, the forward prices are \( p_i^j = \theta^i q_i^{pi} \), where \( \theta^i = \lim_{\lambda \rightarrow \infty} \frac{2c^i \lambda \sigma^i \beta}{2c^i + \lambda \sigma^i} \), \( i = h, l \). Moreover, the spot price by equation (21) is \( p_s = \frac{(1 - \beta)(q_i^{ph} + q_i^{pl}) + \nu}{\delta} \). This suggests that the equilibrium spot price is determined by the planned spot demand, the packer’s adjusted spot demand term, and the production disturbance. In addition, spot volatility in this case comes from the stochastic spot supply that resulted from \( \nu \). Therefore, the introduction of a forward market in this case stabilizes the prices paid to the feeders in the spot market.

**Case 3: Infinitely adjusted spot demand**

When the packer’s spot demand can be adjusted without a restriction (i.e., \( \delta \rightarrow -\infty \)), the packers are expected to have the absolute market power in the spot market. In this case, both the expected spot price and actual spot price are the lowest. That is, \( \bar{p}_s \rightarrow 0 \) and \( p_s \rightarrow 0 \). Thus, no feeder will supply to the spot market and only forward contract markets based on quality exist. In this case, the forward contract prices for each quality
are derived from clearing the total supply and total demand. That is, \[ p_i^j = \frac{2c^j \lambda \sigma^2_s}{2c^j + \lambda \sigma^2_s} q^{pi}, \]
\[ i = h, l. \]

### 1.4.2 Simulation setup

To simplify the model, 500 simulated trading periods are considered. The main focus here is to examine the spot price level and its variance and the relationship of these factors to hedge ratio, \( \beta \). To consider the robustness of these results, we also consider sensitivity to the risk aversion parameter, \( \lambda \), and the spot demand adjustment term, \( \delta \).

The simulation procedure is as follows. At the beginning, say period 1, appropriate initial values for the parameters \((\bar{P}_{s0}, \sigma^2_{s0}, c^h, c^l, q^{ph}, q^{pl}, \lambda, \delta, \beta)\) are set. The forward price based on quality for period 1 can be derived from equation (18), with time frame as a consideration.

\[(18) \Rightarrow p_i^1 = \frac{2c^j \lambda \sigma^2_s \beta}{2c^j + \lambda \sigma^2_s} q^{pi} + \frac{2c^j}{2c^j + \lambda \sigma^2_s} \bar{P}_{s0}, \ i = h, l \]

Further, 500 values of random shock, \( v \), are drawn from the standard normal distribution. These 500 random values generate 500 possible spot prices by equation (21):

\[(21) \Rightarrow p_{s1} = \frac{2\bar{P}_{s0}}{\delta \lambda \sigma^2_{s0}} \left(1 - \frac{c^h}{2c^h + \lambda \sigma^2_{s0}} - \frac{c^l}{2c^l + \lambda \sigma^2_{s0}}\right) - \frac{2B}{\delta} \left(\frac{c^h q^{ph}}{2c^h + \lambda \sigma^2_{s0}} + \frac{c^l q^{pl}}{2c^l + \lambda \sigma^2_{s0}}\right) - \frac{(1-\beta)(q^{ph} + q^{pl}) + v}{\delta} \]

Thus, these 500 samples of spot price in period 1 give us the mean and variance of spot price in period 1. That is, \( E(p_{s1}) = \bar{P}_{s1} \) and \( Var(p_{s1}) = \sigma^2_{s1} \).

From period 2 on, the anticipated spot price variance is defined as:

\[ \sigma^2_{s1} = (\bar{P}_{s,t-1} - \bar{P}_{s,t-1})^2. \] This shows that the agents adopt most new information related to subjective spot price. From period 2 to period 500, in general,
\[ \tilde{p}_{st} = \frac{p_{f,s-1}^h + p_{f,s-1}^l + \lambda \sigma_{st}^2 (1 - \beta)(q_{ph}^{fs} + q_{pl}^{fs})}{2 - \delta \lambda \sigma_{st}^2} \]

\[ p_{i} = \frac{2c^i \lambda \sigma_{st}^2 \beta}{2c^i + \lambda \sigma_{st}^2} q_{pi} + \frac{2c^i}{2c^i + \lambda \sigma_{st}^2} \tilde{p}_{st}, \quad i = h, l \]

\[ p_{st} = \frac{2 \tilde{p}_{st}}{\delta \lambda \sigma_{st}^2} (1 - \frac{c^h}{2c^h + \lambda \sigma_{st}^2} - \frac{c^l}{2c^l + \lambda \sigma_{st}^2}) - \frac{2 \beta}{\delta} (\frac{c^h q_{ph}^{fs}}{2c^h + \lambda \sigma_{st}^2} + \frac{c^l q_{pl}^{fs}}{2c^l + \lambda \sigma_{st}^2}) - \frac{(1 - \beta)(q_{ph}^{fs} + q_{pl}^{fs}) + \nu}{\delta} \]

After 500 periods, the mean and the variance of spot price over the time series are collected.

**1.4.3 Parameterization**

This subsection considers numerical illustrations by assigning plausible values to the parameters in the system. The price levels and variances can be computed for each set of chosen values, and the effects of changes in numerical values upon price levels and variances can be observed.

First, the setting of the behavioral parameters such as \( \lambda, \delta, \beta \) is described. \( \beta \) represents the packer’s hedge ratio and is defined as the percentage of contract portion out of total trade. Thus, we simulate different levels of \( \beta \) in the range of 0.1 to 1. Note that there is no planned demand in the spot market when \( \beta = 1 \). \( \lambda \) is the feeder’s absolute risk aversion parameter and represents the costs associated with the spot price volatility. We simulate different levels of \( \lambda \) in the range of 0.01 to 1 based on reasonable conjecture. \( \delta \) represents an adjustment mechanism in the spot market used by the packer and is defined as \( \delta = \frac{\partial q^p_s}{\partial p_s} \), and \( \delta < 0 \). We simulate different levels of \( \delta \) in the range of -1.5 to -0.5 based on reasonable conjecture.
Next, we introduce the starting values of the parameters and their source. Table 1.1 lists the initial value of the parameters and their corresponding data sources.

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Initial value</th>
<th>Data source</th>
</tr>
</thead>
<tbody>
<tr>
<td>Expected spot price (dollars per cwt)</td>
<td>( \hat{p}_{s0} = 60 )</td>
<td>USDA-NASS Agricultural Prices 2001 Summary</td>
</tr>
<tr>
<td>Expected spot variance (dollars per cwt)</td>
<td>( \sigma^2_{x_0} = 25 )</td>
<td>Computation</td>
</tr>
<tr>
<td>Total demand (1000 pounds)</td>
<td>( q_t^p = 100600 )</td>
<td>USDA-NASS Agricultural Statistics 2002</td>
</tr>
<tr>
<td>Feeders’ production cost (dollars per cwt)</td>
<td>( c^h = 38, c^l = 19 )</td>
<td>USDA-ARMS 2001</td>
</tr>
<tr>
<td>Production shock (10000 pounds)</td>
<td>( \nu \sim N(-38, 15) )</td>
<td>Pennsylvania 1998-99 Annual Statistical Summary</td>
</tr>
</tbody>
</table>

To set the expected spot price, we choose the average value of the monthly prices of slaughter cattle received by Pennsylvania farmers in 2001. The expected spot variance results from the variance of this price series. As for the packer’s optimal demand, we use the total weight of commercial cattle slaughter data in Pennsylvania in 2001 and take the monthly value. As for the feeder’s production cost, the data we use is provided by the 2001 USDA Agricultural Resource Management Study⁶. This study divided cow-calf feeders into three cost groups: low, middle, and high. The data we use is the production costs per cow. For low-cost ranches, per cow costs are $240, where for high cost ranches, per cow costs are $830. According to the study, the average live weight per cow in Pennsylvania in 2001 is 1,265 pounds. After computation, we determine that the production cost for the high quality feeder is $38 per cwt, and for the low quality feeder it is $19 per cwt. In addition, we have to estimate the percentage of cattle that are of high and low quality. This number is computed based on the different production cost groups

shown above. We assume that the low-cost and mid-cost ranches provide low quality cattle and the high-cost ranches provide high quality cattle. Given this assumption, 75 percent of the cattle available in the market are of low quality. The variable we did not specify so far is production shock $v$. We use death loss data in Pennsylvania from 1990 to 1998 to set a distribution for $v$. Since we only have the death loss by head, the numbers we determine are based on the average live weight of 1,265 pounds per head. The estimated distribution is that $v \sim N(-38, 15)$.

**1.4.4 Numerical illustrations**

The numerical results show, in general, that as hedging increases the mean of the spot price may fall and spot volatility may increase. The sensitivity analysis of the effects of $\lambda$ and $\delta$ is as follows:

**Example 1:** $\lambda = 0.01 , 0.1 , 1.0$ and $\delta = -1$ vs. spot prices

Figure 1.1 shows that the spot price decreases as the packer’s hedge ratio increases. Also, there is an effect on spot price when the feeder’s risk aversion, $\lambda$, is changed. Intuitively, since the spot market is a residual market, the higher the packer’s hedge ratio, the less spot demand will be. From (19), $\tilde{p}_s$ decreases as $\beta$ increases due to decreased spot demand. Further, we see that the second term of the right-hand side of (21), which is represented by $-\frac{(1-\beta)(q^{ph} + q^{pf}) + v}{\delta}$, determines the movement of spot prices. Thus, this negative relation is due to the fact that decreased spot demand drives the spot price down.

In addition, this negative effect is amplified as $\lambda \to 1$. As the feeder’s risk aversion, $\lambda$, increases from 0.01 to 1, the feeder becomes more risk averse, and, in turn,
the feeder wants more to be hedged until \( p_f = \tilde{p}_s \). (21) provides the information about the movement of \( p_s \). The first term of (21) becomes smaller as \( \lambda \) increases. Also, \( p_f \rightarrow \tilde{p}_s \) as \( \lambda \rightarrow 1 \). The first term of (21) vanishes as \( p_f = \tilde{p}_s \), and thus \( p_s = -\frac{(1-\beta)(q^{ph} + q^{pn}) + v}{\delta} \). That is, given the packer’s hedge ratio, the spot price decreases faster as \( \lambda \) increases.

**Example 2:** \( \delta = -1.5, -1, -0.5 \) and \( \lambda = 0.1 \) vs. spot prices

Figure 1.2 confirms the negative, but less sensitive relationship, between the spot price and the packer’s hedge ratio, as the adjusted spot demand \( |\delta| \) changes. In addition, it shows that spot prices decrease as \( |\delta| \) increases given a packer’s hedge ratio. Note that \( |\delta| \) reflects the spot demand sensitivity to current spot price, so as \( |\delta| \) decreases, the packer is less flexible to change the planned spot demand. In one sense, \( |\delta| \) can represent an instrument used by the packer to manipulate the spot market. The higher \( |\delta| \) the more possible it becomes for the packer to manipulate the spot market to drive the spot price down.

Then we check this result from the simulation model. (19) shows that \( \tilde{p}_s \) decreases as \( |\delta| \) increases due to increases in the packer’s manipulation of the spot market. Further, the movement of spot price is determined by the term, \( -\frac{(1-\beta)(q^{ph} + q^{pn}) + v}{\delta} \), of (21). Thus, \( p_s \) decreases as \( |\delta| \) increases.
Example 3: $\lambda = 0.01, 0.1, 1$ and $\delta = -1$ vs. the variance of spot prices

Figure 1.3 shows that the spot volatility (contemporary variance) of the spot prices increases with $\beta$. This effect is amplified as $\lambda$ increases. That is, as more is hedged out of the spot market, spot prices become more volatile. Intuition cannot draw any conclusion, but we explain this result from the simulation model. In the simulation, the anticipated spot price variance is defined as $\sigma^2_{st} = (\bar{p}_{s,t-1} - \bar{p}_{s,t-1})^2$, and the resulting values of $\sigma^2_{st}$ are quite stable. Thereby, (21) shows that the variance of spot prices mainly depends on the stochastic spot supply, $\nu$. We characterize the spot supply shock as the death loss of cattle, i.e., $\nu < 0$. As the packer’s hedge ratio increases, the planned spot demand decreases. Combined with a smaller planned spot demand, the spot price is more volatile because the random supply plays a relatively large role in the spot trade quantity. This is consistent with the general comment that the spot volatility may increase when the spot market becomes thinner.

Moreover, for a given $\beta$, the spot price volatility decrease as $\lambda$ increases. First, we rewrite (21) as $p_s = \frac{2 \bar{p}_s - (p_f^b + p_f^l) - \lambda \sigma^2_{sf} \nu}{\delta \lambda \bar{\sigma}^2_s} - \frac{(1-\beta)(q^p + q^m)}{\delta}$. Intuitively, as the feeders’ risk aversion increases, more supply would be hedged until $p_f = \tilde{p}_s$. This situation results in $2 \bar{p}_s - (p_f^b + p_f^l) \to 0$, and in turn decreases the magnitude of the stochastic spot supply that resulted from $\nu$. Therefore, the variance of the spot prices decreases as the feeders become more risk averse.
**Example 4**: $\delta = -1.5, -1, -0.5$ and $\lambda = 0.1$ vs. the variance of spot prices

Figure 1.4 shows a result that is analogous to those found in Example 3. First, as $\beta$ increases, the variance of spot prices increases. Second, the sensitivity of the variance to $\beta$ decreases as $|\delta|$ increases. The second result can be intuitively explained by the following. As $|\delta|$ increases, a packer may flexibly adjust spot demand to manage the spot market. This may result in decreased spot prices as shown in Example 2. Hence, the decreased variance of spot price also can be explained by the strategic actions of the packer. This effect decreases as the packers trade little in the spot market, i.e., the hedge ratio is high. In other words, if most transactions for the packer were traded in the spot market and if he is allowed to change a large proportion of spot demand, i.e., $|\delta|$ increases, then the spot price may fall and become stable.

From the simulation model, (19) shows that $\tilde{p}_s$ decreases as $|\delta|$ increases. Further, in (21) the magnitude of the stochastic spot supply $v$ decreases as $\tilde{p}_s$ decreases, $|\delta|$ increases, and in turn the variance of the spot prices decreases.

**1.5 Conclusions**

Contracting as a means of vertical coordination in the fed cattle industry, commonly referred to as captive supply, has increased in response to a failed pricing system, which means that the product is not priced according value at the producer level. However, most fed cattle producers believe that captive supply reduces their selling prices. The typical reasoning is built upon the argument that processors do not have to aggressively bid for what they demand as they would in the competitive spot market. In this essay, we clarify the important issue that the demand and supply determine prices, and that this rule
does not change because some cattle are contracted. Indeed, captive supply may change the elements of demand and supply, and, in turn, a price impact may be found.

We began by analyzing the optimizing behavior of agents, who produce and purchase commodities in the presence of forward contracting, and derived a set of individual supply and demand functions under price uncertainty and risk aversion. By setting up a formal optimizing model, we are able to understand how activities of production and consumption should be modified as a consequence of introducing forward contract markets. Assuming clearing markets, equilibrium spot price distributions are solved in the rational expectations framework. The forward market provides an important venue for distributing products into forward contracts and the spot market; hence, the forward market may have the potential to increase price fluctuations over time. Although the nonlinear relationships among the structural parameters make the analytical solution of rational expectations virtually impossible, the aid of numerical examples provides some insights.

The results of this essay are summarized as follows: First, our model shows that procurement contracting indeed plays an important role in spot price discovery and spot price volatility. In our model setting, forward contracting is used as an insurance/risk-smoothing instrument to facilitate market transactions that deal with quantity uncertainty and risk-averse agents. The existence of forward contracting enhances transaction performance by pricing differential quality and by reduction of spot transaction risks. Furthermore, our results illustrate that contracting can lead to reduced feeder prices received in the spot market. This result is not only due to the residual nature of spot markets that operate in conjunction with forward contracting, but also to the market
power of packers, which is represented by the adjusted spot demand $\delta$ in this essay. We find that as contracting increases (spot market becomes thinner), spot price levels decrease and spot price volatility increases. This negative relationship is consistent with some past studies, e.g., Schroeder, et al. (1993) and Ward, et al. (1996).

Secondly, we consider risk aversion, $\lambda$, and the adjusted spot demand term, $\delta$, as they represent market structure, to examine the sensitivity of spot price performance. According to the simulation outcomes, the negative relationship between the spot price and forward contracting is amplified as $\lambda$ increases, whereas the positive relationship between the variance of spot price and forward contracting is amplified as $|\delta|$ decreases. These results are intuitive, though also dependent on parameterization. The above illustrations have also revealed that the origin of production disturbance in the model is a critical determinant of whether a forward market increases conditional spot price variance. Therefore, we conclude that the nature of the contract, such as hedge ratio, risk attitude, market power, and uncertainty, may affect the movement of spot prices.

Finally, some policy implications are drawn from this essay. According to the result of negative relationship between captive supply and spot price, we can expect that if trade through contracting is high in a particular industry, then those producers that do not enter into contracts suffer low spot prices. Therefore, it is very important to make market access easier for producers. In addition, value-based pricing would be adopted. It is so important to have the entire industry move to a quality-controlled, consumer-driven system. The live-based pricing cannot improve production and marketing efficiency. Buying cattle on average does not coordinate consumer demand. Further, value-based
pricing allows cattle feeders to get paid the value of their cattle. As a result, high-quality cattle are guaranteed, and feeders and packers can better target their markets.
References


Figure 1.1

Mean of spot prices vs. packer’s hedge ratio

Delta = -1

Figure 1.2

Mean of spot prices vs. packer’s hedge ratio

Lambda = 0.1

Delta = -1.5, -1, -0.5
Figure 1.3

variance of spot prices vs. packer's hedge ratio

$\delta = -1$

$dollars\ per\ cwt$

$0.1 0.2 0.3 0.4 0.5 0.6 0.7 0.8 0.9 1$

hedge ratio

$\lambda = 0.01$

$\lambda = 0.1$

$\lambda = 1$

Figure 1.4

variance of spot prices vs. packer's hedge ratio

$\lambda = 0.1$

$dollars\ per\ cwt$

$\delta = -1.5$

$\delta = -1$

$\delta = -0.5$

$0.1 0.2 0.3 0.4 0.5 0.6 0.7 0.8 0.9 1$

hedge ratio
Appendix 1: Three categories of captive supply

Captive supply is divided by GIPSA into three categories:

1. Marketing agreements

   This is an agreement to purchase livestock at a future date with the price to be determined at or after the time of slaughter. In a typical marketing agreement, the feedlot will notify the packer that they are ready to deliver a specified number of head for slaughter under the agreement the following week. The packer may make a visual estimate of cattle quality and agree on a delivery day.

2. Forward contracts

   A packer and a seller who enter into a forward contract agree upon future delivery of a specific quantity of fed cattle to the packer. Price may be fixed when the contract is entered into, but usually the parties agree to use a pricing formula. Premiums and discounts are applied for differences in animal quality or other non-quality-related factors.

3. Packer feeding

   Packer feeding includes all company-owned cattle fed for slaughter, whether custom fed or fed in a company owned or operated lot or in partnership, joint venture, or other feeding agreement. Typically, when packer-owned cattle are ready for slaughter, the feedlot manager notifies the packer of the number of head and the week of delivery, and the packer schedules the delivery date.
Appendix 2: Salient features of contracting in pork, beef, and poultry markets

**Pork industry**

In the pork industry, pork packer’s marketing contract volumes have risen dramatically in the last decade, now reaching over 50 percent of industry volume. The major incentives for packers to contract are to assure consistent high quality supplies of hogs and to utilize their full capacity in order to keep costs down. Hence, according to the GIPSA/USDA (1996) investigations in several Midwest states, there are significant differences in hog quality sourced from contracts compared to those sourced from spot market transactions. Small volume, spot market transactions have more of the lower quality hogs. Packers were forced to capture the highest quality animals via contracts, leaving the lower quality animals in the spot market. In addition, the financial crisis in pork production in 1998-99 further stimulated pork producers to seek contracts to stabilize their financial situation. Consequently, less than 30 percent of hogs were purchased via the spot market in 2000.

**Beef industry**

In the beef sector, about 25 percent of slaughter cattle come from contracts and market agreements. Traditionally, fed cattle have been sold on a live weight basis in spot markets. However, live cattle pricing has been inadequate in sending appropriate pricing signals to producers regarding cattle attributes. This poor information flow, resulting in poor beef quality, contributed to demand declining by nearly 50 percent from 1980 to 1998 (Hayenga et al. 2000). Therefore, the most important reasons for packers to enter into contracts are to secure high and consistent quality.
Despite this shift to contracting, at least 35 percent of cattle were still purchased from the spot market based on carcass merit in 1999. The reason for spot market existence is supported by Schroeder, et al. (1997). Their survey of cattle feeders and packers indicated that there is a large market for lower quality, cheaper beef products and that the entire industry should not be encouraged to produce the same high quality, high priced products. Thus, cattle feeders striving for low cost and quality were forced to be more willing to sell cattle on average in the spot market.

**Poultry industry**

The broiler industry is a significant competitor for the pork and beef industries, expanding market share dramatically over the last 30 years. Compared to the beef sector, with over one-third of trade in spot market, the broiler industry has been entirely vertically coordinated through ownership or contract. The significant economies of scale in poultry processing and the large proportion of value added in processing are major drivers leading processors to coordinate the industry. Overall, the extensive use of contracts with growers has facilitated the industry’s efficiency, lowered the financial risk for farmers, increased technology adoption, quickened the response to changing consumer demand, and improved grower access to capital.

---

7 According to the beef packer survey (complied by Hayenga et al. 2000) accounting 72 percent of 1999 cattle slaughter, 5 percent of cattle slaughtered were packer-fed, 35 percent used marketing agreements, 25 percent were formula-priced or forward contracted, and 35 percent were in the spot market.
Essay 2: Forward Contracting Using a Signaling Device to Manage Quality

Abstract

The goal of this essay is to develop an understanding of how contract design in the presence of asymmetric information can influence price level, quantity, and quality. We consider the second-best situation, where there is asymmetric information and the principal can only observe a variable correlated with the agent’s action. We show what optimal incentive contracts require as adverse selection and/or moral hazard occur.

Our results show that the high quality feeder receives a quality premium on forward contracts, whereas the low quality feeder receives a forward contract price that is lower than the expected spot price due to quality discount. In addition, when both type feeders are risk averse, under the optimal incentive contracts offered by the packer, the high and the low quality feeders supply their total production to the forward contract market. However, when the feeders are risk-neutral, the low quality feeders can bear all the risks. They are indifferent to supply between forward contracts and spot markets. Since the high quality still are fully hedged because of quality pricing in forward contracts, only low quality meat is traded in the spot market.
2.1 Introduction

The analyses of captive supply have been a steady topic of academic and government research for many years. Some issues have been clarified, but some issues are not yet resolved. One of the known effects is that captive supply can contribute to overall efficiency in the agricultural marketing system (Schroeder et al. 1997). Usefulness of captive supply to meatpackers or processors includes secured slaughter needs, secured quality supply, reduced procurement costs, and reduced price risk (Ward 1998). On the other hand, primary benefits to cattle feeders may include improved price risk management, improved opportunity for quality premiums, secure demand for cattle, and reduced marketing cost (Ward 1998). Another known effect of captive supply from past studies is captive supply prices. Prices for cattle purchased using different captive supply methods vary according to the particular procurement method. Ward et al. (1996) used an econometric approach to show spot prices for fed cattle tend to be less than prices for marketing agreement cattle, but higher than prices for forward contracting cattle. These results suggest that cattle feeders pay a risk premium to packers for forward contracting, and that packers pay a premium for the higher quality or quantity of fed cattle on marketing agreements.

As for the unresolved questions about captive supply, one is the cause-and-effect relationship between the use of captive supplies and spot prices paid for cattle. A negative statistical relationship between the use of captive supplies and the spot price of fed cattle has been identified in several studies (e.g., Schroeder et al. (1993) and Elam (1992)), but researchers have not concluded that an increase in captive supply causes a decrease in spot prices. A more complete behavioral model is needed to test for causal
effects. In our previous essay, we described one such model. The other issue, which has not been well documented in previous studies, is the amount of information reported about captive supply. With voluntary price reporting prior to April 2001, the use of captive supply was linked to a reduced amount of market information, because fewer prices were publicly reported. Thus, less market information can inhibit efficient price discovery and determination.

Moreover, accurate determination of cattle value is essential to coordinate the marketing system. Price is the most important signal to encourage demand by consumers. Price has to be present for producers and processors to target production and marketing decisions. In order for the pricing system to provide appropriate incentives to producers, accurate measurements of desired beef quality attributes are necessary. One important characteristic of fed cattle markets is that the quality of a live animal is hard to observe or verify. Usually, grid pricing (a variation of value-based pricing) has a carcass weight base price with premiums and discounts. However, there still exists a high possibility to inaccurately estimate carcass characteristics when cattle are still alive. Thus, meatpackers, who are demanders in the market, are not sure of the quality of cattle at the time of purchase. Nor will this information necessarily become available to them immediately after contracting or before delivery. In addition, fed cattle pricing traditionally has been based on live weight (Schroeder, et al. 1997). This kind of informational gap in the cattle market leaves packers without perfect information about feeders (adverse selection occurs). On the other hand, feeders are also imperfectly informed about the market demand. Both packers and producers make decisions under their own expectations, due to uncertainty.
Furthermore, due to asymmetric information, the problem is not only that the spot market-clearing prices fail to be Pareto optimal, but also that producers might be discouraged by the absence of a quality premium. This could reduce production or produce low quality instead (moral hazard occurs). Furthermore, packers would face uncertain quality and risk holding calves of unsatisfactory quality. Obviously, this failure follows from the inability of packers to distinguish a producer’s quality and from a market that is unable to efficiently supply different quality meat. Therefore, a well-designed contract mechanism is very important to market participants for mitigating risks and reducing transaction costs. In this essay, we analyze the asymmetric information problem and how agents mitigate this problem by contracting. From there, we can draw some implications of market information provided by captive supply and its effect on the market.

The goal of this essay is to develop an understanding of how contract design in the presence of asymmetric information can influence price level, quantity, and quality. A complete behavioral model is set up to examine how impacts vary across different characteristics of forward contracting. We investigate three different market environments: 1) trade only occurs in spot market, 2) forward contracts price quality to overcome adverse selection problem, and 3) moral hazard problem is involved. Overall, this essay is about the endogenous market process, whereby the packer requires information about the potential producer, which ultimately determines the offered contract price and, in the end, the allocation of purchases to markets (contract and spot).

We address the issue of forward contracting design by pursuing the following objectives:
1). Analyze the behavior of agents and of market supply and demand.

2). Analyze the problem of adverse selection and moral hazard in markets segmented by procurement contracting.

3). Analyze the effect of quality management in forward contracting on spot market.

2.2 Approach

Two models are established in this essay. One deals with the adverse selection problem, which shows that signaling (Spence’s (1973) job market signaling model) can be used to overcome the asymmetric information problem. The other deals with adverse selection and the moral hazard problem, where a modified Spence (1973) model is introduced.

2.2.1 Salient features of the current fed cattle market

A salient feature in the current fed cattle industry is increased value-based marketing. Traditionally, fed cattle have been sold on a live-weight basis (Hayenga, et al. 2000). Some studies (e.g. Stout and Thomas (1970), Feuz, et al. (1993), and Ward, et al. (1996)) have clearly showed that pricing accuracy increases as cattle pricing moves from live weight to dressed weight and grade (value-based pricing).

Jones et al. (1992) found that differences in live weight transaction prices paid for fed cattle in western Kansas during 1990 reflected only 25% of estimated wholesale value differences. Schroeder and Graff (2000) examined an empirical model and concluded that using traditional live-weight or dressed-weight pricing methods, high-quality cattle subsidize low-quality cattle by an average of $30/head. In addition, Hayenga, et al. (2000) reported that 36 percent of cattle were purchased on the spot market on a live weight basis, and 29 percent on a carcass weight or grid basis in 1999. However, value-based
pricing has a base price and involves premiums and discounts to estimate carcass characteristics. Estimation of carcass attributes may be unreliable when the cattle are still alive.

Pricing accuracy increases as cattle pricing moves from live weight pricing to value based pricing. Value based pricing requires fed cattle to be priced on a carcass merit basis. Thus, the price is determined after the animal is slaughtered and the carcass is inspected by federal graders. However, resistance to pricing on a carcass merit basis exists. For example, feeders are concerned that packer will not accurately measure carcass weights and that USDA graders will not accurately determine quality grades (Schroeder, et al.).

Several efforts have been made to move toward value based pricing. These include formula pricing and grid pricing. Using formula pricing, the price paid for cattle by the packer is based on some other market price or packing plant average price. For example, long-term (more than 14 days) formula-priced contracts link to spot market (live cattle or wholesale beef prices reported by USDA) or futures market prices. Grid pricing is usually a formula in the sense that the final price is only discovered after animals have been graded. The pricing formula usually uses a base price with specified premiums and discounts for carcasses above and below the base quality specifications. According to Hayenga et al. (2000)’s report, in 1999, at least 35 percent of cattle purchased on contract were priced based on carcass merit. In addition, 20 percent of cattle were purchased on formula-priced contracts in 1999. The formula was based on either reported live spot market price, reported dressed price, plant average, CME cattle futures price, quoted boxed beef, or retail beef price.
Most contracts involve formula pricing, and, since most of these contracts price cattle on a carcass weight basis, they are variations of a grid pricing system (Schroeder, et al. 1997). For example, Certified Angus Beef pays premiums for cattle that qualify for the program, and other grids have premiums for yield grade 2, High Choice cattle. Usually, the grids are not uniform, often have heavy penalties for inferior cattle, and are hard to compare across processors of cattle. Still, they are an attempt to encourage producers in ways the price system does not (Purcell 2001). Strictly speaking, both formula pricing and grid pricing do not accurately reflect cattle quality.

Another salient feature is that cattle producers and beef packers become linked through means other than direct spot market negotiations. The concern of market access arises. Cattle sold under contracts might receive higher quality-adjusted prices than cattle purchased on the spot market. This is because quality standards usually are specified in forward contracts, so higher quality cattle bring better prices. By contrast, usually average quality is priced in spot markets, so higher quality cattle may be weighted with some low quality cattle and make average prices. Therefore, contracting that attempts to encourage quality through incentive design, such as individual rationality (IR) and incentive constraints (IC) to sustain contract equilibrium, results in the use of quality-based grid pricing. Thereby, producers of high quality cattle prefer quality-based pricing or contracting to the average live-weight pricing on spot markets1. However, this logic implies a possibility of the disappearance of spot markets and harm to farmers who do not enter into contracting.

---

1 This would especially be the case in the cash market where animals are traded on auction markets or purchased by roving buyers that would have little insight into the condition of the animals.
The other salient feature is that reported spot prices become less representative of market conditions at times when they represent only a small portion of transactions. Hayenga et al. (2000) suggested that contracts convey clear signals and incentives to the producer regarding quality that best meet consumer demands, and may result in faster response to consumer demands than spot market signals. This, however, further discourages the function of spot markets. Moreover, some captive supply is not available to smaller volume producers, and the packers’ use of such arrangements may diminish the demand for cattle in the spot market, where the smaller volume producers sell their cattle. There is also concern that packers may use captive supply as a mechanism for discriminating among producers (USDA, 2002).

Apart from the issues discussed above, there are some new issues, such as grading, certification, and inspection systems in current U.S. agricultural markets, which have created incentives for producers and packers to increasingly enter into contractual relationships. Grading for quality means the evaluation of traits related to tenderness, juiciness, and flavor of meat. USDA grades are based on nationally-uniform Federal standards of quality. For example, beef is graded as whole carcasses in two ways: 1) quality grades- for tenderness, juiciness, and flavor; and 2) yield grades- for the amount of usable meat on the carcass. However, Schroeder, et al (1997) claimed that current quality grading methods need to be reexamined, because they are too subjective and they do not accurately predict consistent quality. In addition to problems in measuring beef quality, difficulty in predicting red meat yields from live cattle or even from carcasses presents a significant obstacle. Therefore, packers may face risks of uncertain quality, which increases their costs and leads to lower prices for fed cattle. To solve this problem,

2 Details see Food Safety and Inspection Service report, June 2002.
feasible quality identification processes have to be developed. Certification programs provide an opportunity to recover these costs. For example, USDA beef carcass certification programs are provided for carcasses that have been identified with an official USDA grade. Certification programs for breed of cattle (e.g. Angus), based on phenotypic characteristics or genetics, must meet the specific requirements promulgated by the appropriate U.S. breed association. Moreover, the inspection program within the USDA is mandatory and ensures that meat products are safe, wholesome, and correctly labeled and packaged. In earlier days, the primary concern of inspection was animal diseases. Today’s concerns include unseen hazards, such as microbiological and chemical contamination.

A detailed description of the current grading, certification, and inspection systems may be found in Appendix 2, which provides the foundation for the theoretical model.

2.2.2 Signals convey information

The formal signaling model was developed by Spence (1973) to describe how efficient workers can signal their ability to employers by engaging in (possibly wasteful) education expenditures. In Spence’s model, signals are defined as those observable characteristics, which attach to the worker and are subject to manipulation by him. Also, the signal that is sent by the informed agent has a cost that depends on its type, so higher types are more likely to send higher signals. This signal may then help the uninformed principal to distinguish the different types. In addition, Spence assumed that a signal does nothing for the agent’s type. Therefore, the signal represents a social cost and merely serves as a useful signal to help overcome asymmetric information. However, the
signaling instrument might have functions other than that of a pure signal according to Spence.

Transposed to other signaling product quality problems, a producer who knows the quality of his goods signals it through his choice of price, advertising, and so on. The signal of quality usually relies on market prices (See Outlaw, et al. (1997) and Baggett, et al. (2002)). It is clear that market price signals work, and work well if the characteristics of quality are distinguishable. However, the signal of quality need not actually be an introductory price. Any conspicuous initial expenditure that the producer can make to prove he will produce good quality will do. Nelson (1974) argued that uninformative advertising could be a signal of quality. However, the advertising of a product has strong psychological and sociological aspects that go beyond optimal inferences about objective quality. If advertising were solely concerned with distributing direct information, such as the existence and its price, then there should be much more advertising for goods whose quality can be assessed before a purchase.

Sporleder and Goldsmith (2002) identified alternative signaling strategies regarding quality in the food system and claimed that those alternatives can be evaluated on a relative basis. The choice set of strategies for signaling includes: strategies that rely on government or third-party procedures, such as standards, quality control, and signaling services; differentiation through branding and reputation; indemnification strategies, such as insurance, warranties, etc.; and coordination strategies such as vertical integration. They also suggested that there is no globally optimal strategy, which exists for the supply chain in general. Each mechanism for signaling is likely to provide different outcomes.
2.2.3 Adverse selection and moral hazard in agricultural markets

Bonroy and Laborde (2002) examined the problem created when the government plays a role to signal the product quality to consumers by using labeling policy, and the government’s decisions depend on an expert who is hired by the government. There are four players in the model: a monopoly, a consumer, a government, and an expert. No one knows the true quality. In the model, the role of the government is to conquer the problem of adverse selection due to the incomplete information. The adverse selection problem comes when a risky product is signaled as healthy and then causes the consumer an illness. The objective of the government is to maximize an *ex post* social welfare, including the firm’s profit and consumer’s surplus minus the expert expense and the expected costs of a “wrong signal”. Their results suggested: 1) when the expected cost of a wrong signal is low, there is a pooling equilibrium: the government always labels the product as healthy and does not call an expert, 2) when this cost is high, there is also a pooling equilibrium: the government chooses to not guarantee the product and not call an expert, and 3) in between, the government will call an expert and label/not label according to the expert’s opinion.

Inderst (2002) considered a contractual game of signaling, where an informed sender proposes a contract, which can only be accepted or rejected by the receiver. Rejection by the receiver leads to the end of the game, while the sender can still choose whether to withdraw or implement an accepted proposal. In the model, there is an outside option to the sender, which is that the sender can switch to another receiver in case of rejection. The results showed that, under an additional assumption, the set of contracts, which were
implemented in equilibrium, converged to the set of least-cost separating contracts. This logic is similar with the Intuitive Criterion of Cho and Kreps (1987).

Bourgeon and Coestier (2001) studied the management of a marketing cooperative, which is operated by a producer organization. Producers can sell their products either to a competitive market or through a quality label provided by the cooperative. The problems of moral hazard and adverse selection arise because of asymmetric information about product quality. The results suggested that high quality producers have the opportunity to set up an organization and act as a monopoly to make a quality premium in an environment of asymmetric information. In addition, the cooperative sets the optimal monitoring and pricing policies to alleviate the adverse selection of its members. Furthermore, when combined with public intervention through credit facilities and subsidized monitoring costs, the market price may decrease and consumers may benefit.

In this essay, packers offer forward contracts for quality management, due to the inability of spot markets to price based upon quality. Forward contracts are offered before product quality is known, so high quality feeders have the incentive to signal their quality to packers in order to distinguish themselves from low quality feeders. We consider two cases, according to the ability of a feeder to control quality. In the first case, quality is exogenous: a pure signaling case may involve the adverse selection problem. The second case is that the quality is endogenously determined after the contracts are signed. This ex post action for feeders creates a prior signal that is impure, and the moral hazard problem arises.
2.3 The Model

2.3.1 Informal description of the model

In the model, two kinds of players are specified in the fed cattle market: the feeder and the packer. Feeders play the role of the suppliers of animals, whereas the downstream packers are buyers. Two markets, the forward contract market and the spot/cash market, are assumed to support all transactions between feeders and packers. The contract market here is subject to adverse selection and/or moral hazard, and is based on imperfect information concerning meat quality. Forward contracting is designed for quality management in favor of the packer. We suppose that feeders are agents that are differentiated by type. They can signal their type through investment in a certificate. The packer is presumed to hold the market power to define forward contract prices, which are conditional on signals. Packers prefer to forward contract, since the forward contract market in quality differentiated. The spot market is assumed to be competitive. This would especially be the case in the cash market where animals are traded on the average. This implies both an average price and an average quality (Schroeder et al. 1997). Moreover, packers offer forward contracts based on their expectations about spot prices and their knowledge of the distribution of feeder types, as well as typical individual rationality and incentive compatibility constraints. Feeders choose optimally to supply to forward contracts and spot markets, as determined by the signal and quality investment.

We consider a situation where a player named “Nature” determines a producer’s type: either high type or low type. We assume that a producer’s type is equal to the quality of his product. This assumption will be changed later. The packer does not know this
information, so each feeder signals his type to the packer through offering a farm certificate. This policy is, of course, not cost free. This is what we call signaling cost, which is assumed to be negatively correlated with feeder’s type. In other words, given a certificate level, it costs less to a higher type feeder. The optimal certificate level is determined by the feeder’s optimization behavior. The quality of products is not stochastic during the transaction period.

The analysis in this essay can be divided into three cases by the following schematic setting:

Case 1: Only the spot market exists. We will show spot prices and quality implications with productive or nonproductive signals/certifications. By so doing, we suggest the packer’s demand for the quality signal and his willingness to pay for that signal.

Case 2: Forward contracting with a nonproductive signal is introduced. We will show how adverse selection is resolved and why the spot market continues to operate.

Case 3: Forward contracting with a productive signal is introduced. We will show how to overcome the adverse selection and moral hazard problems at the same time.

Indemnity instrument plays a role in contract design.

2.3.2 Simple spot market with asymmetric information

**Feeder/producer behavior**

“Nature” determines feeder’s type $w^i$. $w$ is type and $i$ is a binary indicator. That is, $i \equiv [i^h, h]$ and $w^h > w^i > 0$. We interpret type as an indicator of exogenously produced meat quality. Denote $q^i$ as the feeder’s total production of quality $w^i$ and $q^i : R^+ \to (0, \infty)$. Since the packer does not know the feeder’s type, the high type feeder
has an incentive to reveal his type to receive higher prices. \( x \) is certification training, which can serve as a signal from the feeder to the packer.

The feeder’s production technology, \( q^i = q^i(y; x) \), is a vector of inputs that result in \( q^i \). For the case when \( x \) is nonproductive, the basic properties are \( q^i(0, x) = 0 \) and \( q^i(y, 0) = q^i > 0 \). On the other hand, if \( x \) is productive, then \( 0 < q^i(0, x) < q^i(y, x) \) and \( 0 < q^i(y, 0) < q^i(y, x) \). The production cost can be derived by minimizing \( c = r_y y \) subject to \( q(y; x) \leq q \), where \( r_y \) is the unit price of \( y \). Then we get \( c = c(q, x) \), where \( \frac{\partial c}{\partial q} > 0 \). Further, if \( x \) is productive, then \( \frac{\partial c}{\partial x} < 0 \). Otherwise, \( \frac{\partial c}{\partial x} = 0 \).

The certification technology is \( x = x(v; w^i) \), where \( v \) is a vector of inputs that results in \( x \). The cost function of certification can be derived by minimizing \( g = r_v v \) subject to \( x(v; w^i) \leq x \), where \( r_v \) is the unit price of \( v \). Then we get \( v^*(x, w^i) \) and \( g = g(x, w^i) \).

Incorporating those specifications, the feeder’s profit function is:

\[
\pi^F \equiv p_y q(y, x) - r_y y - r_v v \equiv p_y q - c(q, x) - g(x; w),
\]

where \( p_y \) is spot market price. We assume that spot prices do not price based upon quality. The feeder’s profit is defined as the revenue minus the sum of production and certification costs.

Two cases are considered. The first is that \( x \) is not productive. In this case, the feeder’s profit function becomes \( \pi^F \equiv p_y q - c(q) - g(x; w) \). Thus, the optimal certificate level is \( x^* = 0 \). The second is that \( x \) is productive. The first order conditions derive the optimal supply and certificate level as follows:
\[
\frac{\partial \pi^F}{\partial q} = p_{x} - c_{q} = 0 \Rightarrow q^*
\]
\[
\frac{\partial \pi^F}{\partial x} = -c_{x} - g_{x} = 0 \Rightarrow x^{*} \geq 0 \quad \text{(recall } c_{x} < 0 \text{ and } g_{x} > 0)\]

Note that since spot prices do not price based upon quality, \( x^* > 0 \) only because it reduces production costs more than \( g(0; w) \), that is \( c(q) - c(q, x^*) - g(x^*; w) \geq g(0; w) \).

In addition, \( x^* \) is not a signal to the packer, just an optimal choice for a feeder.

**Processor/packer behavior**

In considering the packer’s side, we would like to show that the packer is willing-to-pay (WTP) for increased \( x \), which is \( \frac{\partial \pi^p}{\partial x} > 0 \). This motivates the packer to offer a higher price for \( q^b \). We consider a representative packer here. To establish a market for quality, we need to define its value to packers. Denote \( q_b \) as the packer processed output and \( q^{pi}, i \equiv [l, h] \) as the packer’s demand over quality. Three alternative processing technologies are as follows:

1. Perfect substitutes: \( f(q^p) \), where \( q^p = q^{ph} + q^{pl} \).

Suppose that a packer’s revenue is \( p_b f(q^p) \) and \( p_b \) is the market price for the processed product. In this case, a packer’s profit is \( \pi^p = p_b f(q^{ph} + q^{pl}) - p_s (q^{ph} + q^{pl}) \).

It is obvious that since the market price of the processed product is not differentiated based on quality, there is no demand for a quality differential in the spot market, and in turn, no need for signaling.
2. Imperfect substitutes: $f(q^{ph}, q^{pi})$

A packer’s profit function is $\pi^p = p_h f(q^{ph}, q^{pi}) - p_s (q^{ph} + q^{pi})$. The first order conditions show that $p_b = \frac{p_s}{f_h'} = \frac{p_s}{f_i'}$. Although the $p_b$ is the same, the need for a quality differential may not exist because of the same marginal productivity.

3. Separable processing: $f(q^{ph})$, $f(q^{pi})$

A packer’s profit function is: $\pi^p = p_h^h f(q^{ph}) + p_i^i f(q^{pi}) - p_s (q^{ph} + q^{pi})$. Taking the derivative with respect to $q^{ph}$ and $q^{pi}$, we can derive:

$$\frac{\partial \pi^p}{\partial q^{ph}} = p_h^h f_h' - p_s = 0 \Rightarrow p_h^h = \frac{p_s}{f_h'},$$

$$\frac{\partial \pi^p}{\partial q^{pi}} = p_i^i f_h' - p_s = 0 \Rightarrow p_i^i = \frac{p_s}{f_i'}.$$

We can consider two situations. The first situation is $p_h^h = p_i^i$. We have already discussed this in case 2. There is no demand for signaling since the market prices are the same. This will force the marginal productivity to be the same. The second situation is $p_h^h \neq p_i^i$. If $f_h' = f_i'$, then the differential spot market prices can sustain the need for signaling. On the other hand, if $f_h' \neq f_i'$, then the need for signaling is definite.

In total, we conclude that packers prefer high quality, either as a result of a price differential on processed market prices, i.e., higher quality can sell at higher prices, or due to differential marginal productivity, i.e., higher quality cattle have a higher marginal productivity. Schroeder, et al. (1997) claimed that targeting meat products to specific consumer demands requires careful meat sorting and identification in beef packing plants.
That is, if there is no information about cattle quality before slaughtering, packers need to increase costs for additional sorting. By contrast, if signaling provides packers with information about meat quality, these increased costs of additional sorting would be offset by improved prices for higher quality meat products.

**Akerlof’s (1970) Model**

Akerlof’s (1970) lemon market model is introduced here to show that asymmetric information about the quality of a good may hinder the functioning of the market. Suppose high quality cattle are worth $F_{hv}$ to a feeder and $F_{hv} > F_{vh}$ to a packer, while low quality cattle are worth $F_{lv}$ to a feeder and $F_{lv} > F_{vl}$ to a packer. The proportion of high quality cattle is $\theta$ and that of lemons (low quality cattle) is $1 - \theta$. If both the feeder and the packer are ignorant of cattle quality, then the equilibrium price will be $\theta F_{hv} + (1 - \theta) F_{vl}$.

We assume that the feeder knows the quality of his cattle, but the packer cannot observe the quality. What then will be the equilibrium price $p$?

a) If $p < F_{vl}$, then there is no supply in the market.

b) If $F_{vl} < p < F_{hv} < F_{vh}$, then only low type cattle are supplied to the market, and the equilibrium price will go to $p = F_{vl}$ provided there are many buyers.

c) If $F_{vl} < F_{hv} < p < F_{vh} < F_{vh}$, then only low type cattle are supplied to the market, but the packer does not want to pay $p$ for low quality meat. No equilibrium exists.

d) If $F_{vl} < F_{hv} < F_{vh} < p < F_{vh}$, then both types of cattle will be supplied to the market, and the equilibrium price is $p = \theta F_{vh} + (1 - \theta) F_{vl} \geq F_{vh}$.
Thus, there are 2 possible equilibria:

1) \( p = v^{Pl} < v^{Fh} \), and only lemons are sold.

2) \( p = \theta v^{Fh} + (1 - \theta)v^{Pl} \geq v^{Fh} \), and both types of cattle are sold.

Applied to the fed cattle market, Akerlof’s model implies that informational asymmetries can reduce the functioning of a market where all types of cattle are traded to the point where only low-quality cattle are traded. This is one example of adverse selection. In addition, the dysfunction of the cattle market comes from the inability of feeders of high quality to signal the quality of their cattle. Effective signaling strategies within the supply chain are needed so that investments, made ex-ante, correspond to the correct supply of products and quality on offer ex-post. Therefore, due to information asymmetry, significant externalities, such as inferior products being oversupplied or high quality products being undersupplied, can be created by market failure. In conclusion, given the above results from the simple spot market, there exists scope for signaling, i.e. the demand by the packer for cattle quality information, and the high quality feeder receives a benefit for sending this signal.

**Forward contracting**

To date, most fed cattle sold in the spot market are largely sold on a live/carcass weight basis and priced on average (Schroeder et al. 1997). Research has found that pricing accuracy, i.e., how closely fed cattle prices reflect actual wholesale values, increases as fed cattle pricing moves from a carcass weight basis to a dressed weight basis with grade (Feuz, et al. 1993). Since both feeders and packers need more accurate quality identification and greater pricing accuracy, forward contracting is one of the methods to provide quality management in fed cattle market.
In practice, the forward contracts used for cattle sold by feeders to packers are generally basis or flat price contracts (Ward 1998). A packer and seller who enter into a forward contract agree upon future delivery of a specific lot or quantity of fed cattle to the packer. Price may be fixed when the contract is entered into, but usually the parties agree to use a pricing formula. The pricing formula in most contracts consists of a base price with specified premiums and discounts for carcasses above and below the base or standard quality specifications (Schroeder et al. 1997).

In the next two sections, we analyze how the packer can observe a signal and use it to completely or incompletely infer cattle quality.

2.3.3 A signal as Spence (1973) where $x$ is not productive.

Spence’s (1973) job market signaling model provides a way to overcome the asymmetric information problem. Signals are defined in Spence’s model as 1) observable, 2) unrelated to the outcome valued by principal, and 3) correlated with a determinant of the outcome. In other words, these are characteristics of an individual that are subject to manipulation by the individual, but that are unrelated to an outcome valued by the principal. This is why it is called a pure signal. The potential worker sends an education signal to the employer, and then the employer infers this worker’s productivity from his signal. An education signal does nothing for a worker’s productivity. Thus, a pure signal represents a social cost and merely serves as a useful signal to help overcome asymmetric information. A critical assumption in Spence’s model for a signal that effectively distinguishes one worker from another is that signaling costs are negatively correlated with a worker’s type. That is, the higher the worker’s type the easier it is for him or her to acquire education. By comparison to Spence’s problem, we replace the
worker's type with the feeder’s type, the diploma signal with a farm certificate, and the employee’s wage with the forward contract price of the meat.

The model is a general multi-stage game with observed actions and incomplete information. There are four successive periods. The following is the time line of the story:

<table>
<thead>
<tr>
<th>$t = 1$</th>
<th>$t = 2$</th>
<th>$t = 3$</th>
<th>$t = 4$</th>
</tr>
</thead>
<tbody>
<tr>
<td>“Nature” decides the feeders’ types</td>
<td>The feeders select certification and their planned supply. The packers select planned demand across quality.</td>
<td>The forward contract market is opened.</td>
<td>A competitive spot market clears the market.</td>
</tr>
</tbody>
</table>

This is a game of incomplete information in that, when making their decisions, packers do not know the type of the feeder. The equilibrium concept used in Spence’s model is a weak Perfect Bayesian Equilibrium (PBE). It requires that at any point in the game, a player’s strategy prescribe optimal actions from that point on given her opponents’ beliefs are consistent with the strategies being played (Mas-Colell, et al. 1995, ch.9). The following section explains how this concept of equilibrium is applied to our model.

**The perfect Bayesian equilibria**

Assume that the packer thinks that the feeder is $w^h$ with probability $\hat{\theta}(x)$. Denote $\hat{\theta}_0$ the a priori of packers on the feeder’s type. $x$ is a signal from feeder to packer.

---

3 Fudenberg and Tirole (1993, Ch.3, p70) define this which must satisfy that (1) all players knew the actions chosen at all previous stages before making their decisions at current stage, and that (2) all players move “simultaneously” in each stage.

4 PBE results from combining the ideas of subgame perfection, Bayesian equilibrium, and Bayesian inference: Strategies are required to yield a Bayesian equilibrium in every continuous game given the posterior beliefs of the players, and the beliefs are required to be updated in accordance with Bayes’ law whenever it is applicable (Fudenberg and Tirole, 1993, Ch.8).
A perfect Bayesian equilibrium in pure strategies consists of a vector of strategies 
\((x^{i*}, x^{h*}, p_f^*)\) and a system of beliefs \(\hat{\theta}^*\) such that:

1. Each feeder chooses the level of certification he will invest \(x\) based on an anticipated or expected pricing function \(p_f^*(x)\) that prevails on the cattle market,
   \[\forall i = l, h, \quad x^{i*} \in \arg\max_x p(x)q - c(q) - g(x, w^i)\]

2. Each packer purchases cattle with a certification \(x\) at a price
   \[p_f^*(x) = \hat{\theta}^*(x)p_f^b + (1 - \hat{\theta}^*(x))p_f^h\]

3. This is a “forward pricing rule”. That is, the packer is willing to pay differentiated prices for quality; however, without pure strategy that the packer pays an expected price.

4. The beliefs \(\hat{\theta}^*(x)\) are consistent with the strategies \(x^*\) (observed signal) for a set of feeders, where individuals signal either \(x^{h*}\) or \(x^{i*}\):
   
   if \(x^{i*} \neq x^{h*}\),
   and if \(x = x^{i*}: \hat{\theta}^*(x) = 1\)
   or if \(x = x^{h*}: \hat{\theta}^*(x) = 0\)

   else if \(x^{i*} = x^{h*}\),
   and if \(x = x^{i*} = x^{h*}: \hat{\theta}^*(x) = \hat{\theta}_0\)

   Note that this definition does not restrict the beliefs \(\hat{\theta}^*(x)\) when certification \(x\) is not chosen in equilibrium \((x \neq x^{i*} \text{ and } x \neq x^{h*})\). Recall that we assume a feeder chooses a signal rationally. However, in the absence of a rational signal, \(x\) could be not optimal. In this case we only know that the equilibrium price \(p^*(x) \in [p_f^l, p_f^h]\). Hence, the existence
of this degree of freedom, which gives rise to a great multiplicity of perfect Bayesian equilibria.

Applied to our model, for any certificate level the feeder chooses, the offered contract should be reasonable in the sense of being consistent with equilibrium play in the continuation game. The reasonable contract to offer will typically depend on the packer’s beliefs about the feeder’s quality production, which in turn can depend on the feeder’s observed level of certificate. If this level is one to which the equilibrium assigns positive probability, the posterior distribution of the feeder’s quality production can use Bayes’ rule, and the reasonable contract will depend on which posterior distribution is specified.

**A feeder’s behavior**

To conceptualize the feeder’s problem, we suppose that a feeder’s type, $w^i$, represents cattle quality and is determined by Nature’s probability density function. Further, we suppose that a feeder can invest in a scalar signal, $x$, through a certification program, though the cost of certification $g(x, w^i)$ is also a function of type. We assume $x$ is the publicly observable signal, though $w^i$ is only known to feeders. Investment in the signal may be rational given that forward contract prices are conditional on the signal, i.e.

$$p_f = p_f(x) \quad \text{where} \quad \frac{\partial p_f}{\partial x} > 0.$$  
$p_f$ is the forward contract price and is paid based on the signal. We assume that it is the signal that determines the quality segment in the forward contracting market.

Moreover, we define $q_f^i$ as the quantity supplied to the forward contract market with respect to quality $i$; $q_s$ as the quantity supplied to the spot market; and $p_s$ as the price in spot market. Note that $p_s$ is not conditioned on quality because we assume that the spot
market does not provide for quality-based differentiation. The cost function for production $c'(q_f + q_s)$ is a function of total cattle quantity and is not affected by the certificate signal. A feeder’s profit can be represented as:

$$\pi \equiv p_f(x)q_f + p_s q_s - c'(q_f + q_s) - g(x, w')$$

To complete the specification of the feeder choice problem, we specify mean-variance representations for the feeder’s expected utility functions.

$$\max_{q_f, q_s, x} \text{EU}(\pi|w') = p_f(x)q_f + \tilde{p}_s q_s' - \frac{1}{2} \lambda \var(p_s q_s') - c'(q_f', q_s') - g(x, w'),$$

where $c'(q_f, q_s) = \varphi(q_f + q_s)^2$ and $g(x, w') = \frac{x^2}{w'}$.

The objective function for a feeder is defined as total expected revenue from the sale of cattle by contract and on the spot market less a quadratic production cost function $c'(\cdot)$, signaling cost $g(\cdot)$, and the costs associated with the spot price volatility as reflected by risk aversion characterized by $\lambda$, the relative risk aversion parameter. Equation (2) indicates a feeder maximizing his expected utility with type $w'$ by choosing $q_f, q_s, x$ three variables. We assume that feeders hold a subjective distribution about $p_s$ with mean $\tilde{p}_s$ and variance $\sigma_s^2$. In addition, we assume that the marginal production cost increases as production increases and the marginal signaling cost increases as signal increases. That is $\frac{\partial c}{\partial q} > 0$, $\frac{\partial^2 c}{\partial q^2} > 0$, and $\frac{\partial g}{\partial x} = \frac{x}{w'} > 0$, $\frac{\partial^2 g}{\partial x^2} = \frac{1}{w'} > 0$, respectively. In addition, the activity of signaling costs low type feeders more, i.e. $\frac{\partial g}{\partial x}|_{w'} > \frac{\partial g}{\partial x}|_{w^*}$. Thus, the feeder’s objective function is a concave function.
A packer’s behavior

According to optimal incentive contract design, the packer has to offer the feeder a menu of contracts \(( q_f(w'), p_f(w') )\) indexed by an announcement of the feeder’s type \( w' \) that must be truthful at the equilibrium. We thus need to characterize the menu of contracts such that incentive constraint (IC) is for the feeder choosing the \(( q_f(w'), p_f(w') )\) that the processor designed for him, and rationality constraint (IR) is for the feeder receiving a utility level as large as his reservation utility. In the model, a feeder receives the reservation utility when he sells his cattle to the spot market. In addition, the menu of contract \(( q_f(w'), p_f(w') )\) maximizes the expected utility of the packer among all menus that satisfy IR and IC.

Assume that the packer adopts the technology of separable process to produce total output \( q^p \). Equation (3) is a packer’s profit.

\[(3) \quad \pi^p = p'_b q'_b - p'_f q'_f - p_s q_s \]

Suppose the packer’s subjective probability of contracting with a high type feeder is \( \theta \), which means \( \text{prob}(w^h) = \theta \) and \( \text{prob}(w^l) = 1-\theta \). We assume that the packer is risk-neutral. The packer’s choice problem can be represented as:

\[(4) \quad \max_{\theta} \ E(\pi^p | w^h) \theta + E(\pi^p | w^l)(1-\theta) \]

\[= \max_{\theta} \ \theta(p'_b f(q'^h_b) - p'_b q'^h_b) + (1-\theta)(p'_f f(q'^l_f) - p'_f q'^l_f) + p'_b f(q'^p_b) - \bar{p}_f q'^p_s \]

subject to

Capacity constraint: \( q^h_f + q^l_f + q^p_s \leq \bar{q}^p \)

---

5 In equilibrium, this is the same as Nature’s intensity distribution on feeder’s type.
IR for high quality feeder: $IR^h$

$$\bar{p}_s q_s^h + p_f^h (x^h) q_f^h - \frac{1}{2} \lambda \sigma^2_s (q_s^h)^2 - g(x^h; w^h) \geq \bar{p}_s (q_s^h + q_s^h) - \frac{1}{2} \lambda \sigma^2_s (q_s^h + q_s^h)^2$$

$$\Rightarrow (p_f^h - \bar{p}_s) q_f^h + \frac{1}{2} \lambda \sigma^2_s (q_f^h)^2 - \frac{(x^h)^2}{w^h} \geq 0$$

IR for low quality feeder: $IR^l$

$$\bar{p}_s q_s^l + p_f^l (x^l) q_f^l - \frac{1}{2} \lambda \sigma^2_s (q_s^l)^2 - g(x^l; w^l) \geq \bar{p}_s (q_s^l + q_s^l) - \frac{1}{2} \lambda \sigma^2_s (q_s^l + q_s^l)^2$$

$$\Rightarrow (p_f^l - \bar{p}_s) q_f^l + \frac{1}{2} \lambda \sigma^2_s (q_f^l)^2 - \frac{(x^l)^2}{w^l} \geq 0$$

IC for high quality feeder: $IC^h$

$$\bar{p}_s q_s^h + p_f^h (x^h) q_f^h - g(x^h; w^h) \geq \bar{p}_s q_s^h + p_f^l (x^l) q_f^l - g(x^l; w^l)$$

$$\Rightarrow p_f^h q_f^h - \frac{(x^h)^2}{w^h} \geq p_f^l q_f^l - \frac{(x^l)^2}{w^l}$$

IC for low quality feeder: $IC^l$

$$\bar{p}_s q_s^l + p_f^l (x^l) q_f^l - g(x^l; w^l) \geq \bar{p}_s q_s^l + p_f^h (x^h) q_f^h - g(x^h; w^h)$$

$$\Rightarrow p_f^l q_f^l - \frac{(x^l)^2}{w^l} \geq p_f^h q_f^h - \frac{(x^h)^2}{w^h}$$

Equation (4) is the packer’s expected utility weighted by the packer’s subjective expectation about the feeder’s type, where $p_f^h$, $p_f^l$, and $p_f^s$ are the wholesale prices of the processed product with respect to high quality, low quality, and mixed quality in the spot market. $f(q^i)$ is the production function of wholesale meat and byproducts. In addition, we assume that the packer is risk neutral. Roughly, the packer’s expected profit is the

---

6 The packer’s production function is the same as that of Schroeder, et al. (1993).
expected wholesale value of processed meat less input costs from the contracts market \( (p_j^i, q_j^i) \) and from the spot market \( (\tilde{p}_i, q_i^s) \).

**Four propositions and forward contract prices**

At the optimum, four properties hold.

**Property 1**: \((IR^i)\) is binding equality, then it is rewritten as \(p_j^i = \tilde{p}_i - \frac{\lambda \sigma^2_{ij}(q^i_j)}{2} + \frac{(x^i_j)^2}{w^i_j q^i_j} \).

Proof: We use \((IC^h)\) to prove property 1.

\[
p_j^i q^h_j - \frac{(x^h_j)^2}{w^h_j} > p_j^i q^h_j - \frac{(x^i_j)^2}{w^i_j} \geq p_j^i q^h_j - \frac{(x^i_j)^2}{w^i_j} + \frac{\lambda \sigma^2_{ij}(q^i_j)}{2} \geq p_j^i q^h_j - \frac{(x^i_j)^2}{w^i_j} + \frac{\lambda \sigma^2_{ij}(q^i_j)}{2}
\]

We add \(\frac{\lambda \sigma^2_{ij}(q^i_j)}{2}\) into both sides of \(IC^h\) and have the left hand side relationship hold.

The right hand side relationship holds because \(q^h_j \geq q^i_j \geq 0\) and \(w^h_j > w^i_j\). Besides, the last term is \(IR^i\). If \((IR^i)\) were not binding, that is \(IR^i > 0\), neither would the first two terms. Thus, the packer could decrease \(p_j^h\) and \(p_j^i\) by the same amount, but this would increase the packer’s profit without any effect on incentive compatibility.

**Property 2**: \((IC^h)\) is binding, whence \((p_j^h - p_j^i) q^h_j = \frac{(x^h_j)^2}{w^h_j} - \frac{(x^i_j)^2}{w^i_j}\).

Proof: Assume that \((IC^h)\) is not binding, then

\[
p_j^h q^h_j - \frac{(x^h_j)^2}{w^h_j} > p_j^i q^h_j - \frac{(x^i_j)^2}{w^i_j} \geq p_j^i q^h_j - \frac{(x^i_j)^2}{w^i_j}
\]

\[
\Rightarrow p_j^h q^h_j - \frac{(x^h_j)^2}{w^h_j} - \tilde{p}_j q^i_j + \frac{\lambda \sigma^2_{ij}(q^i_j)}{2} > p_j^i q^h_j - \frac{(x^i_j)^2}{w^i_j} - \tilde{p}_j q^i_j + \frac{\lambda \sigma^2_{ij}(q^i_j)}{2} \geq p_j^i q^h_j - \frac{(x^i_j)^2}{w^i_j} - \tilde{p}_j q^i_j + \frac{\lambda \sigma^2_{ij}(q^i_j)}{2} = 0
\]
We can therefore reduce \( p_f^h \) without breaking incentive compatibility or the individual rationality constraint \((IR^h)\). This obviously increases the packer’s profit, and the original mechanism cannot be optimal.

**Property 3:** \( q_f^h \geq q_f^l \).

Proof: Let us add \((IC^h)\) and \((IC^l)\) and we get \((p_f^h - p_f^l)(q_f^h - q_f^l) \geq 0\), and \( q_f^h \geq q_f^l \), since \( p_f^h > p_f^l \).

**Property 4:** We can neglect \((IC^l)\) and \((IR^h)\).

Proof: \((IC^l)\) can be neglected since \((IC^h)\) is active, so using property 3,

\[
\frac{(x^h)^2}{w_f^l} - \frac{(x^l)^2}{w_f^l} \geq \frac{(x^h)^2}{w_f^h} - \frac{(x^l)^2}{w_f^h} = (p_f^h - p_f^l)q_f^h \geq (p_f^h - p_f^l)q_f^l.
\]

The proof of property 1 shows that \((IR^h)\) can be neglected.

From property 1 and property 2, the forward contract prices for high quality cattle and low quality cattle are

\[
p_f^h = p_f^l + \frac{(x^h)^2 - (x^l)^2}{w_f^h q_f^h} \quad \text{and} \quad p_f^l = \tilde{p}_x - \frac{\lambda \bar{\sigma}^2 q_f^l}{2w_f^l q_f^l} + \frac{(x^l)^2}{w_f^l q_f^l},
\]

respectively.

**Feeder choice problem**

To analyze separating equilibrium, let \( x^*(w) \) be the feeder’s equilibrium certification choice as a function of his type, and \( p_f^*(x) \) be the packer’s equilibrium forward price offer as a function of the feeder’s certification level. Figure 2.1 depicts one of separating equilibria. In this equilibrium, the packer believes that the feeder is certain to be of high quality if \( x \geq \bar{x} \) and is certain to be of low quality if \( x < \bar{x} \). The resulting forward price schedule has \( p_f^*(x) = p_f^h \) if \( x \geq \bar{x} \) and \( p_f^*(x) = p_f^l \) if \( x < \bar{x} \).
Figure 2.1 depicts an indifference curve for each of two types of feeders (with forward prices offered on the vertical axis and certification levels measured on the horizontal axis). This property of preference is known as the single-crossing property. It arises here because the feeder’s marginal rate of substitution between forward price and certification at any given \((p_f, x)\) pair is \(\frac{dp_f}{dx} > 0\), which is decreasing in \(w\). Also,

\[
\left(\frac{d^2 p_f}{dx^2}\right)_E > 0
\]

Moreover, we apply the "intuitive criterion" of Cho-Kreps (1987) to rule out the dominated separating equilibria and all pooling equilibria. The basic idea of the intuitive criterion with two types is that there is type who has a deviation that is assured of yielding her a payoff above her equilibrium payoff, as long as all the other players do not assign a positive probability to the deviation having been made by any type for whom this action is equilibrium dominated. Therefore, there is only one separating equilibrium survived to this two-type signaling model, which is also the most efficient separating equilibrium: the high-type feeder chooses the minimum certification level that allows him to signal his type without attracting the low-type feeder; whereas, the low-type feeder does not signal at all \((x^l = 0)\).

Substituting the forward contract prices in the expression of the feeder’s utility, we solve the high quality feeder’s optimization problem first.

(2) \[\max_{q_f, q_s} \mathbb{E}U(q_f^h, q_s^h | x^h, w^h) = \]

\[
(\tilde{p}_s + \frac{(x^h)^2 - (x^l)^2}{w^hq^h_f} + \frac{(x^l)^2}{w^lq^l_f})q^h_f + \tilde{p}_sq^h_s - \frac{1}{2} \lambda \sigma^2 (q^h_s)^2 - \varphi^h (q^h_f + q^h_s)^2 - \frac{(x^h)^2}{w^h}
\]

First-order differentiation yields the planned supply for contract and spot markets.

\[(5) \quad q_f^h : \tilde{p}_s + \frac{(x')^2}{w' q_f'} - 2\phi^h (q_f^h + q_s^h) = 0 \]

\[(6) \quad q_s^h : \tilde{p}_s - \lambda \tilde{\sigma}_s^2 q_s^h - 2\phi^h (q_f^h + q_s^h) = 0 \]

According to equations (5) and (6),

\[(7) \quad q_f^h = \frac{\tilde{p}_s}{2\phi^h} - \frac{(2\phi^h + \lambda \tilde{\sigma}_s^2)(x')^2}{2\phi^h \lambda \tilde{\sigma}_s^2 w' q_f'} \]

\[(8) \quad q_s^h = \frac{(x')^2}{\lambda \tilde{\sigma}_s^2 w' q_f'} \]

Since \( x' = 0 \), then we get \( q_f^h = \frac{\tilde{p}_s}{2\phi^h} \) and \( q_s^h = 0 \). This means that the high quality feeder chooses to supply to the forward contract market only and not the spot market. The reason is straightforward: the forward contract market prices differentiated quality.

Then, we solve the low quality feeder’s optimization problem. The low quality feeder faces the forward contract price \( p_f' = \tilde{p}_s - \frac{\lambda \tilde{\sigma}_s^2 q_f'}{2} \) without signaling.

\[(2) \Rightarrow \max_{q_f',q_s'} EU(q_f', q_s' | x' = 0, w') = \]

\[ (\tilde{p}_s - \frac{\lambda \tilde{\sigma}_s^2 q_f'}{2})q_f' + \tilde{p}_s q_s' - \frac{1}{2} \lambda \tilde{\sigma}_s^2 (q_s')^2 - \phi^f (q_f' + q_s')^2 \]

Followed by the first-order conditions.

\[(9) \quad q_f' : \tilde{p}_s - 2\phi^f (q_f' + q_s') = 0 \]

\[(10) \quad q_s' : \tilde{p}_s - \lambda \tilde{\sigma}_s^2 q_s' - 2\phi^f (q_f' + q_s') = 0 \]

Equation (9) and (10) derive that \( q_f' = \frac{\tilde{p}_s}{2\phi^f} \) and \( q_s' = 0 \).
Conclusion

Table 2.2 summaries the results.

<table>
<thead>
<tr>
<th></th>
<th>High quality feeder ((w^h))</th>
<th>Low quality feeder ((w'))</th>
</tr>
</thead>
<tbody>
<tr>
<td>Forward contract price ((p^i_f))</td>
<td>(p^h_f = \tilde{p}_s + \frac{(x^h)^2}{w^h q^h_f})</td>
<td>(p'^f = \tilde{p}_s - \frac{\lambda \tilde{\sigma}^2 q^{i_f}}{2})</td>
</tr>
<tr>
<td>Forward contract supply ((q^i_f))</td>
<td>(q^h_f = \frac{\tilde{p}_s}{2\phi^h})</td>
<td>(q'^f = \frac{\tilde{p}_s}{2\phi'})</td>
</tr>
<tr>
<td>Spot market supply ((q^i_s))</td>
<td>(q^h_s = 0)</td>
<td>(q'^s = 0)</td>
</tr>
<tr>
<td>Hedge Ratio ((\beta))</td>
<td>(\beta = 1)</td>
<td>(\beta = 1)</td>
</tr>
</tbody>
</table>

In this case, the high quality feeder supplies to the forward contract market only in order to make a quality premium, \(\frac{(x^h)^2}{w^h q^h_f}\). Also, more certification training results in a higher forward contract price being paid. In addition, only the expected spot price \(\tilde{p}_s\) and the production cost \(\phi'\) affect the feeder’s production, and neither the risk aversion parameter nor the expected spot price volatility affects the production.

On the other hand, the result indicates that the price paid for cattle procured through forward contracting by the low quality feeder is lower than the expected spot market price. Ward et al. (1998) gave the economic intuition of this result that forward contracting provides risk sharing. It follows that if the packer or processor does not have complete control over production decisions, then feeders or producers may be willing to accept a lower price to have some of the production risk assumed by the processors (Love and Burton 1999). In addition, the low quality feeder also merely supplies his production to forward contract and is willing to pay the quality discount \(\frac{\lambda \tilde{\sigma}^2 q^{i_f}}{2}\). Thus, the results imply that there is no spot market if the optimal contracts shown above are considered.
However, the preceding results merely reflect a particular model setting. For instance, we assume that both type feeders are risk averse. Now we relax this assumption. That is, \( \lambda = 0 \). For the high quality feeder, the forward price remains the same, i.e.

\[
p^h_f = \tilde{p}_s + \frac{(x^h)^2}{w^h q^h_f}.
\]

Since the high quality feeder can receive a higher price than in the spot market, he still chooses to have his production fully hedged. On the other hand, the low quality feeder now receives the forward price \( p^l_f = \tilde{p}_s \). Thus, he is indifferent about whether to supply his production to the forward contract or to the spot market. There are economic incentives to trade cattle on averages (Schroeder et al. 1997). For example, many feedlots sell a large number of their cattle with a quality distribution roughly equal to the distribution of all cattle in the region. At the same time, a packer also buys large numbers of cattle in that area. Both the packer and the feeder gain by pricing on the average.

2.3.4 \( x \) is a productive signal

Now we examine the case of impure signaling and, therefore, interpret the producer’s type \( w^i \) indicating the exogenous ability to produce high quality meat at a lower potential cost. A farm certificate \( x \) is an imperfect signal to reflect meat quality, which means a certificate signal can affect meat quality. The reasoning is as follows: A feeder attends a certification program and receives a certificate when he finishes the training. Thus, a certificate is not only a document to a feeder, but also can increase a feeder’s knowledge or ability to produce high quality cattle. In addition, \( z^i \) represents meat quality and is controlled by feeders. In this model with endogenous quality choice, a one-shot game normally collapses to a unique equilibrium because in one period it is normally less
costly for all types to produce low quality. The moral hazard problem arises, so no one’s certificate can have credibility.

**The moral hazard problem**

The following is an example to show why moral hazard arises and how we conquer this problem in the essay. Suppose there are two states of nature that are anticipated by the insured, $\varepsilon'(low risk)$ and $\varepsilon^*(high risk)$. There are three possibilities:

1. If an agent is without insurance, or, for example, no contract, then he has no intention to pretend he is of high risk if he is of low risk, or vice versa. Both behaviors cost him. Thus, he will choose optimal action to reflect his true type such as $\varepsilon' \rightarrow a'$ and $\varepsilon^* \rightarrow a^*$.

2. If an agent is insured but there is no indemnity to punish his cheating behavior, then the low risk agent will not care about his appropriate action because insurance can protect him. In this case, cheating behavior, or the moral hazard problem, occurs. That is, $\varepsilon' \rightarrow a^*$.

3. If an agent is insured but the clauses include indemnity, then he will choose his optimal action. That is, $\varepsilon' \rightarrow a'$ or $\varepsilon^* \rightarrow a^*$. The indemnity forces either risk agent to act the same as he does without insurance. Thus, the agent pays an indemnity equal to the loss associated with principal’s outcome. That is, $I = \pi^P (\varepsilon^* | x') - \pi^P (\varepsilon^* | x')$.

Here we introduce an ex post action, $a$, after a contract is signed into the model. This is a two-action $(a^h, a^l)$, two-outcome $(z^h, z^l)$ framework. The feeder can choose between high quality input $(a^h)$ and low quality input $(a^l)$ after a contract is signed. The cost of action $a^l$ is embedded to the production function so that the feeder’s profit if
he gets $p'_j$ and chooses action $a^i$ is $\pi^p = p'_j q - c(x,a^i, w') - g(x, w')$ where $\pi^p$ is strictly concave. The only thing the packer can observe before contracting is whether the feeder invests in certification. However, this is an imperfect signal of the feeder’s action $(a)$ taken. Since the forward contracting price is conditioned on the certification signal, the packer is under the risk that the feeder’s choice is not Pareto-optimal after contracting. We assume that the quality of cattle can be verified after delivery.

Suppose that if a feeder follows high quality procedure $(x^h, a^h)$, his probability of succeeding (raising high quality cattle) is 1, whereas if he follows low quality procedure $(x^l, a^l)$, his probability of raising high quality cattle is 0. That is $\text{prob}(z^x | x^h, a^h) = 1$ and $\text{prob}(z^x | x^l, a^l) = 0 \forall i = h, l$. By contrast, $\text{prob}(z | x^l, a^l) = 1$ and $\text{prob}(z | x^h, a^h) = 0$. We exclude the case of $(x^l, a^h)$, because no feeder will invest high quality input after knowing he will receive a low quality price later.

To solve the moral hazard problem, we introduce an indemnity mechanism as a new instrument to deter the deviation from consistent quality. The indemnity mechanism works as a potential penalty, and is triggered when products do not satisfy the signaled quality. The function of indemnity can be explained as follows. A producer negotiates prices with a packer based on his assessment of produced quality. If, upon delivery and inspection (if necessary), the packer believes the producer has overestimated quality, a price deduction relative to the contracted price in the form of an indemnity can be assessed. One example of the indemnity $I(z(x,a,w'), z^*)$ is a function of the actual produced quality, $z(x,a,w')$, the feeder’s signal and the packer’s expected quality, $z^*$, where $x$ is the certification level, $a$ is the represented feeder’s ex post action after
contracting that results in actual quality, and \( w' \) is the producer’s type. The indemnity is assumed to satisfy: \( I(z \geq z^*) = 0 \) and \( I(z < z^*) > 0 \). The equations indicate that indemnity is implemented only if the actual produced quality \( z(x, a, w') \) is lower than the packer’s expected one \( z^* \).

In other words, signaling solves the adverse selection problem, where indemnity solves the moral hazard problem. Table 2.3 summarizes the differences between the imperfect signal model and the perfect signal model of Spence (1973).

Table 2.3: Differences between the perfect signal model of Spence (1973) and the imperfect signal model

| Nature generates the agent’s type (high or low) | Meat quality | The feeder’s ability to produce high quality meat at lower costs |
| Agent selects signal | Certificate → meat quality (hidden information) | Certificate ↠ meat quality (hidden action) |
| Principal’s offer | \( p_f(signal) \) | \( p_f(signal) \) |
| Indemnity mechanism | Based on optimal incentive contracts, signal is credible, and no indemnity is needed. | The indemnity is set up for the signal’s credibility |
| Optimal incentive contract constraints | 1 IR + 1 IC for both high and low quality feeders | 2 IR + 1 IC for high type feeder, 1 IR +1 IC for low type feeder |

**Signaling vs. indemnity**

a) **Signaling without indemnity.**

Indemnity is designed to make the producer’s incentive compatible with the processor’s contracting design. Without indemnity, there exists a possibility of deviation in the model if the high-type feeder invests in a higher-level certificate, but produces low quality meat and still receives a high forward contract price. In this case, the signaling is
incredible, and cannot convince packers to offer forward contract prices depending on the level of certification.

b) Indemnity without signaling.

In the model, signaling is in a form of certification training, which can potentially improve quality. The indemnity mechanism works as a potential penalty to deter the moral hazard problem, so it is triggered when products do not satisfy the claimed quality. Suppose there is no restriction on feeder’s access to certification training. Without signaling feeders still can announce their meat quality to packers. In this case, there is no adverse selection problem. Indemnity sustains the existence of equilibrium. By contrast, if feeders cannot have free access to certification, then signaling is necessary for packers to infer the meat quality.

c) Signaling with indemnity.

Combining signaling and indemnity solves both the adverse selection and the moral hazard problems when access to certification is limited in the market. However, if there is no signaling and no indemnity, then only pooling equilibria exist, i.e. the price is offered on the average quality. In this case, without the quality premium and discount, the producers do not have the incentive to get training for quality improvement. Only the lowest quality meat is supplied to the market.

**A feeder/producer’s behavior**

We introduce the determination of cattle quality: \( z = z(x,a;w^i) \), where \( a \) is the input that results in quality. Since the quality is endogenous and certification is not a pure signal, both will affect the feeder’s production cost: \( c^i = c(q,x,a|w^i) \), where \( c_q > 0, c_s < 0, \text{and } c_a > 0. \) In addition, \( q \) and \( x \) are determined before contracting, and
a is an ex post hidden action from feeder to packer. The possible moral hazard problem results because a is unknown to the packer but controlled by the feeder. Two situations are analyzed below.

Case 1: Without indemnity

\[ \forall i = h, l \quad \pi^i(p_f^h, x^h, a^i) > \pi^i(p_f^h, x^h, a^h). \]  
This means that all types of feeders spend less to produce low quality meat. Thus, once the feeder is offered a high forward contract price from the packer by sending him a high-level certification signal, the feeder has the incentive to deliver low quality meat instead to increase profit. This provides the necessity of indemnity in the packer’s contract design.

Case 2: With indemnity

\[ \forall i = l, h, \quad a^* = \arg \max_a \pi(x)q - c(q, x, a) - g(x, w^i) - I(z(x, a, w^i))q, \]

where \( I(z(x, a, w^i)) \) is the indemnity function. With the existence of the possibility of adverse selection and moral hazard problems, when the packer offers the feeder a forward contract \( (p_f^i, x) \), the feeder chooses \( q_f, q_s, x, a \) to maximize his expected utility:

\[
\max_{p_f^i, q_f, q_s, x, a} \mathbb{E}[\pi | w^i] = \\
p_f(x)q_f + \tilde{p}_q q_s - \frac{1}{2} \lambda \text{var}(p_f q_s) - c(q_f + q_s, x, a) - g(x, w^i) - I(z(x, a, w^i), z^*)q_f
\]

where

\[
c(q_f + q_s, x, a) = a(q_f + q_s)^2 - x, \]

\[
g(x, w^i) = \frac{(x)^2}{w^i}, \quad \text{and} \]

\[
I(z(x, a, w^i), z^*) = \gamma(z^* - z(x, a, w^i)) \quad \text{if} \quad z^* < z(x, a, w^i) \]

\[
= 0 \quad \text{if} \quad \text{otherwise} \]

\[
z(x, a, w^i) = xaw^i
\]

Incorporating the above constraints, equation (11) becomes
A processor/packer’s behavior

We have already shown the packer’s demand for the indemnity mechanism. The interesting case is that the packer wants the feeder to invest “correct” inputs, which means inputs consistent with the signal he made previously. Therefore, the packer now needs to design a contract not only to entice the feeder to send the right signal, but also to take the right action afterwards. Therefore, the participation constraints and the incentive constraints in the impure signaling case are different from those we dealt with previously in the pure signaling case. At first, we look at the high type feeder. We still assume that the spot market is an alternative for feeders who supply to forward contracts. From the packer’s perspective, he prefers the high type feeder signing a contract, no matter what quality input is invested, over supplying to the spot market. That is,

\[
(Ih^1) \quad EU(\pi^F (x^h, p_f^h, a^h|w^h)) \geq EU(\pi^F (\tilde{p}_s, a'|w^h)), \text{ and}
\]

\[
(Ih^2) \quad EU(\pi^F (x^h, p_f^h, a', l|w^h)) \geq EU(\pi^F (\tilde{p}_s, a'|w^h)).
\]

In addition, to conquer the adverse selection and moral hazard problems, the packer must offer the high type feeder a forward contract price combined with an indemnity \(I(z \neq z^*)\) such that he pays the feeder under the following incentive constraint:

\[
(Ih^1) : \quad EU(\pi^F (x^h, p_f^h, a^h|w^h)) \geq EU(\pi^F (x^h, p_f^h, a'|w^h))
\]

\[
(Ih^2) : \quad EU(\pi^F (x^h, p_f^h, a^h|w^h)) \geq EU(\pi^F (x', p_f^h, a^h|w^h))
\]

\[
(Ih^3) : \quad EU(\pi^F (x^h, p_f^h, a', l|w^h)) \geq EU(\pi^F (x', p_f^h, a'|w^h))
\]
(IC^h1) means that the high type feeder will choose high quality inputs after sending a high signal instead of choosing low quality inputs, but the packer pays an indemnity.

(ICC^h) means that the high type feeder will not be better off to pretend he is of low quality if he has invested high quality inputs. (IC^h3) means that even if the high type feeder cheated on the ex post action, he still prefers to send the right signal.

As for the incentives for the low type feeder, we exclude the case that the low quality feeder invests high quality inputs for a known low forward contract price. In other words, the low quality feeder does not have the problem of moral hazard. Thus, the participation constraint and incentive constraint are the same as in the case of the pure signaling. That is,

\[(IR^l) \quad EU(\pi^F(x^l, p^l_j, a^l_j \mid w^l_j)) \geq EU(\pi^F(\tilde{p}_s, a^l_j \mid w^l_j))\]

\[(IC^l) \quad EU(\pi^F(x^l, p^l_j, a^l_j \mid w^l_j)) \geq EU(\pi^F(x^h, p^h_j, a^l_j \mid w^l_j))\]

**Packer choice problem**

\[
\max_{p^h_j, p^l_j, a^l_j} E(\pi^F \mid w^h_j)\theta + E(\pi^F \mid w^l_j)(1 - \theta)
= \max_{p^h_j, p^l_j, a^l_j} \theta(p^h_j f(q^h_j) - p^h_j q^h_j) + (1 - \theta)(p^l_j f(q^l_j) - p^l_j q^l_j) + p^l_j f(q^l_j) - \tilde{p}_s q^p_s
\]

subject to

**Capacity constraint:** \(q^h_j + q^l_j + q^p_s \leq \bar{q}^p_s\)

\[(IR^h1) \quad EU(\pi^F(x^h, p^h_j, a^h \mid w^h_j)) \geq EU(\pi^F(\tilde{p}_s, a^l_j \mid w^h_j))\]

\[p^h_j q^h_j + \tilde{p}_s q^p_s - \frac{1}{2} \lambda \sigma_s^2 (q^h_s)^2 - (\varphi^h (q^h_j + q^h_s)^2 - x^h) - \frac{(x^h)^2}{w^h} - \gamma (z^h - x^h a^h w^h) q^h_j \geq \tilde{p}_s (q^h_j + q^h_s) - \frac{1}{2} \lambda \sigma_s^2 (q^h_j + q^h_s)^2 - (\varphi^h (q^h_j + q^h_s)^2)\]
$$\Rightarrow (p_j^h - \bar{T}_i)q_j^h + \frac{1}{2} \lambda \sigma_s^2 (q_j^h)^2 + x^h - \frac{(x^h)^2}{w^h} \geq 0$$

$$(IR^h 2) \quad EU(\pi^F (x^h, p_j^h, a^I|w^h)) \geq EU(\pi^F (\bar{T}_i, a^I|w^h))$$

$$p_j^h q_j^h + \bar{T}_i q_s^h - \frac{1}{2} \lambda \sigma_s^2 (q_j^h)^2 - (\varphi' (q_j^h + q_s^h)^2 - x^h) - \frac{(x^h)^2}{w^h} - \gamma (z^h - x^h a^I w^h)q_j^h$$

$$\geq \bar{T}_i (q_j^h + q_s^h) - \frac{1}{2} \lambda \sigma_s^2 (q_j^h + q_s^h)^2 - (\varphi (q_j^h + q_s^h)^2)$$

$$\Rightarrow (p_j^h - \bar{T}_i)q_j^h + \frac{1}{2} \lambda \sigma_s^2 (q_j^h)^2 + (\varphi^h - \varphi') (q_j^h + q_s^h)^2 + x^h - \frac{(x^h)^2}{w^h} - \gamma (z^h - x^h a^I w^h)q_j^h \geq 0$$

$$(IR^h) \quad EU(\pi^F (x^I, p_j^I, a^I|w^I)) \geq EU(\pi^F (\bar{T}_i, a^I|w^I))$$

$$p_j^I q_j^I + \bar{T}_i q_s^I - \frac{1}{2} \lambda \sigma_s^2 (q_j^I)^2 \geq \bar{T}_i (q_j^I + q_s^I) - \frac{1}{2} \lambda \sigma_s^2 (q_j^I + q_s^I)^2$$

$$\Rightarrow (p_j^I - \bar{T}_i)q_j^I + \frac{1}{2} \lambda \sigma_s^2 (q_j^I)^2 \geq 0$$

$$(IC^h 1): \quad EU(\pi^F (x^h, p_j^h, a^h|w^h)) \geq EU(\pi^F (x^h, p_j^h, a^I|w^h))$$

$$\bar{T}_i q_s^h + p_j^h (x \geq x^h) q_j^h - a^h (q_j^h + q_s^h)^2 + x^h - g(x^h; w^h)$$

$$\geq \bar{T}_i q_s^h + p_j^h q_j^h - a^I (q_j^h + q_s^h)^2 + x^h - g(x^h; w^h) - \gamma (z^h - x^h a^I w^h)q_j^h$$

$$\Rightarrow -(a^h - a^I) (q_j^h + q_s^h)^2 + \gamma (z^h - x^h a^I w^h)q_j^h \geq 0$$

$$(IC^h 2): \quad EU(\pi^F (x^h, p_j^h, a^h|w^h)) \geq EU(\pi^F (x^I, p_j^I, a^h|w^h))$$

$$\bar{T}_i q_s^h + p_j^h (x \geq x^h) q_j^h - a^h (q_j^h + q_s^h)^2 + x^h - g(x^h; w^h)$$

$$\geq \bar{T}_i q_s^h + p_j^I q_j^I - a^I (q_j^h + q_s^h)^2 + x^I - g(x^I; w^h) - \gamma (z^I - x^I a^h w^h)q_j^I$$

$$\Rightarrow (p_j^h - p_j^I)q_j^I - (a^h - a^I) (q_j^h + q_s^h)^2 + (x^h - x^I) - \frac{(x^h)^2 - (x^I)^2}{w^h} \geq 0$$
(IC\(^h\) 3): \(\text{EU}(\pi^F(x^h, p^h_j, a^j, I^h|w^h)) \geq \text{EU}(\pi^F(x^i, p^i_j, a^j|w^h))\)

\[
\bar{p}_j q^h_j + p^h_j q^h_j - a^j (q^h_j + q^i_j)^2 + x^h - g(x^h; w^h) - \gamma(z^h - x^h a^i w^h)q^h_j
\geq \tilde{p}_j q^h_j + p^i_j q^h_j - a^i (q^h_j + q^i_j)^2 + x^i - g(x^i; w^h)
\]

\[
\Rightarrow (p^h_j - p^i_j)q^h_j + (x^h - x^i) - \frac{(x^h)^2 - (x^i)^2}{w^h} - \gamma(z^h - x^h a^i w^h) \geq 0
\]

(\text{IC} \(^i\)) \(\text{EU}(\pi^F(x^i, p^i_j, a^i|w^i)) \geq \text{EU}(\pi^F(x^h, p^h_j, a^j|w^i))\)

\[
\bar{p}_j q^i_j + p^i_j (x < x^h)q^i_j - g(x^i; w^i) \geq \tilde{p}_j q^i_j + p^h_j (x \geq x^h)q^i_j - g(x^h; w^i)
\]

\[
\Rightarrow (p^h_j - p^i_j)q^i_j - \frac{(x^i)^2 - (x^h)^2}{w^i} \geq 0
\]

\textbf{Four properties and forward contract prices}

\textbf{Property 1:} \(IR^j\) is binding. This gives that \(p^i_j = \tilde{p}_j - \frac{\lambda \bar{\sigma}^i_j q^i_j}{2}\).

Proof: The reason and proof are shown in previous pure signaling section.

\textbf{Property 2:} \(IC\(^h\) 2\) is redundant.

Proof: According to (\text{IC}^h 1) and (\text{IC}^h 3),

\[
\text{EU}(\pi^F(x^h, p^h_j, a^h|w^h)) \geq \text{EU}(\pi^F(x^i, p^i_j, a^j|w^h))\].
\]

Besides,

\[
\text{EU}(\pi^F(x^i, p^i_j, a^i|w^h)) \geq \text{EU}(\pi^F(x^i, p^i_j, a^h|w^h))\]

because high quality inputs always cost more than low quality inputs. Thus,

\[
\text{EU}(\pi^F(x^h, p^h_j, a^h|w^h)) \geq \text{EU}(\pi^F(x^i, p^i_j, a^h|w^h))\]

is definite and \(IC\(^h\) 2\) is redundant.

\textbf{Property 3:} \(IC\(^h\) 1\) is not binding.

Proof: Suppose that \(IC\(^h\) 1\) is binding. Then

\[
\text{EU}(\pi^F(x^h, p^h_j, a^h|w^h)) = \text{EU}(\pi^F(x^h, p^h_j, a^j, I|w^h))\].
\]

This implies that for (\text{IC}^h 2),
\[ EU(\pi^F(x^h, p^h_f, a^i, l \mid w^h)) \geq EU(\pi^F(x^i, p^i_f, a^h \mid w^h)) \]. If equality of the last equation holds, then \((IC^h 3)\) must be equality. By doing so, these three incentives do not provide any motivation. Therefore, the argument shown above is not correct.

On the other hand, if \((IC^h 2)\) were an inequality, then \((IC^h 3)\) may not sustained because
\[ EU(\pi^F(x^i, p^i_f, a^i \mid w^h)) \geq EU(\pi^F(x^i, p^i_f, a^h \mid w^h)) \).

**Property 4:** \(IC^h 3\) is binding.

Proof: If \(IC^h 3\) is binding, then \((IC^h 1)\) becomes
\[ EU(\pi^F(x^h, p^h_f, a^h \mid w^h)) \geq EU(\pi^F(x^i, p^i_f, a^i \mid w^h)) , \text{ whereas property 2 is still satisfied.} \]

Hence, the equality of \(IC^h 3\) gives
\[ p^h_f = p^i_f + \frac{\gamma x^h w^h (a^h - a^i)}{q^h_f} + \frac{x^h (x^h - w^h)}{q^h_f w^h} \text{ as } x^i = 0 . \]

The forward contract price for high type feeders is the low forward price plus the compensation for indemnity and the quality premium.

**Feeder choice problem**

Substituting the forward contract prices into equation (11), first-order differentiation yields the planned supply for contract and spot markets.

For high quality feeder:

(11) \[ \max_{q^h_f \text{, } q^h_s} EU(x^h, a^h \mid w^h) = (p^i_f + \frac{\gamma x^h w^h (a^h - a^i)}{q^h_f} + \frac{x^h (x^h - w^h)}{q^h_f w^h})q^h_f \]
\[ + \bar{p}_s q^h_s - \lambda \sigma^2_s q^h_s - (a^h (q^h_f + q^h_s)^2 - x^h) - \frac{(x^h)^2}{w^h} - \gamma(z^h - x^h a^h w^h)q^h_f \]

(17) \[ q^h_f : p^i_f - 2a^h (q^h_f + q^h_s) = 0 \]

(18) \[ q^h_s : \bar{p}_s - \lambda \sigma^2_s q^h_s - 2a^h (q^h_f + q^h_s) = 0 \]
From equation (17) and (18),

\[ q_f^h = \frac{(2a^h + \lambda \tilde{\sigma}_s^2) p_f^l}{2a^h \lambda \tilde{\sigma}_s^2} - \frac{\tilde{p}_s}{\lambda \tilde{\sigma}_s^2} \] (19)

\[ q_s^h = \frac{p_f^l - \tilde{p}_s}{\lambda \tilde{\sigma}_s^2} \] (20)

In general, \( p_f^l < \tilde{p}_s \) because the low type feeder pays the quality discount. Thus,

\( q_s^h = 0 \). The high type feeder supplies all of his production to forward contract.

For the low quality feeder:

(11) \[ \Rightarrow \max_{q_f^l, q_s^l} \mathbb{E}U(x_f^l = 0, a_f^l|w') = \]

\[ (\tilde{p}_s - \frac{\lambda \tilde{\sigma}_s^2 q_f^l}{2}) q_f^l + \tilde{p}_s q_s^l - \frac{1}{2} \lambda \tilde{\sigma}_s^2 (q_s^l)^2 - (a_f^l (q_f^l + q_s^l)^2 - x_f^l) - \frac{(x_f^l)^2}{w'} \]

(21) \[ q_f^l : \tilde{p}_s = 2a_f^l (q_f^l + q_s^l) = 0 \]

(22) \[ q_s^l : \tilde{p}_s - \lambda \tilde{\sigma}_s^2 q_s^l - 2a_f^l (q_f^l + q_s^l) = 0 \]

From equation (21) and (22), we derive \( q_f^l = \frac{\tilde{p}_s}{2a_f^l} \) and \( q_s^l = 0 \). This means that a low quality feeder is fully hedged.
Conclusion

Table 2.4 summaries the results.

<table>
<thead>
<tr>
<th></th>
<th>High quality feeder ( (w^h) )</th>
<th>Low quality feeder ( (w^l) )</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Forward contract price</strong> ( (p_f^j) )</td>
<td>( p_f^h = p_f^j + \frac{\gamma^h w^h (a^h - a^l)}{q_f^h} + \frac{x^h (x^h - w^h)}{q_f^h w^h} )</td>
<td>( p_f^l = \tilde{p}_s - \frac{\lambda \tilde{\sigma}^2 q_f^l}{2} )</td>
</tr>
<tr>
<td><strong>Forward contract supply</strong> ( (q_f^j) )</td>
<td>( q_f^h = \frac{(2a^h + \lambda \tilde{\sigma}^2) p_f^j}{2a^h \lambda \tilde{\sigma}^2} - \frac{\tilde{p}_s}{\lambda \tilde{\sigma}^2} )</td>
<td>( q_f^l = \frac{\tilde{p}_s}{2a^l} )</td>
</tr>
<tr>
<td><strong>Spot market supply</strong> ( (q_s^j) )</td>
<td>( q_s^h = 0 )</td>
<td>( q_s^l = 0 )</td>
</tr>
<tr>
<td><strong>Hedge Ratio</strong> ( (\beta) )</td>
<td>( \beta = 1 )</td>
<td>( \beta = 1 )</td>
</tr>
</tbody>
</table>

Then we suppose that both types of feeders are risk neutral. That is, \( \lambda = 0 \). For the high quality feeder, the forward price is

\[
p_f^h = \tilde{p}_s + \frac{\gamma^h w^h (a^h - a^l)}{q_f^h} + \frac{x^h (x^h - w^h)}{q_f^h w^h}.
\]

Since the high quality feeder now receives a price that is higher than the price he receives when he is risk averse, he still chooses to have his production fully hedged. On the other hand, the low quality feeder now receives the forward price \( p_f^l = \tilde{p}_s \). Thus, he is indifferent about whether to supply his production to the forward contract or to the spot market.

2.4 Conclusions and Discussion

In practice, the need for diversity, quality control, and supply control in the food system has reduced the ability of spot markets to coordinate production and processing effectively. In other words, spot markets increasingly encounter difficulty in conveying the full information concerning the attributes (quantity, quality, etc.) of a product. Where spot markets fail to achieve the needed coordination, other options, such as contracts, can be used. However, coordination in an economic system incurs costs in completing...
transactions. These costs depend in part on the incentives and relationships between the trading parties. For example, the agent may exhibit adverse selection behavior (i.e., not performing the expected work) or moral hazard behavior (i.e., the results are inconsistent with the principal to the transaction).

In this essay, we consider the second-best situation where there is asymmetric information and the principal can only observe a variable correlated with the agent’s action. We show what the optimal incentive contracts require as adverse selection and/or moral hazard occur. Our results show that the high quality feeder receives quality premiums on forward contracts, whereas the low quality feeder receives forward contract prices that are lower than the expected spot price due to quality discounts. In addition, under the optimal incentive contracts offered by the packer, the high and low quality feeders supply their total production to the forward contract market. This result occurs because we assume that both type feeders are risk averse. That is, the risk associated with selling to the spot market (the magnitude of which is defined by the variance) gives feeders negative utility. Thus, this enhances the low quality feeders’ incentive to supply to forward contracts, even though they will receive a quality discount. In this case, the spot market does not exist if all feeders in market are offered optimal contracts.

However, when the feeders are risk-neutral, the low quality feeders can bear all the risks. They are indifferent between supplying to forward contracts or spot markets. Spot supply may appear, along with spot demand. Since the high quality cattle are still fully hedged because of quality pricing in forward contracts, only low quality meat is traded in the spot market. This result explains the fact that some feeders still prefer selling to spot

---

8 The best situation occurs when the principal can observe the agent’s type or action. In that case, he can order the agent to choose the efficient action. Or, equivalently, the principal can fine the agent if he does not choose the efficient action.
markets, even though most forward contracts provide value-based marketing of live cattle, while the spot market does not (Schroeder et al. 1997).

We also clarify the concern that less market information can inhibit efficient price discovery and determination because fewer prices are publicly reported. We show in this essay that the effective use of contracting, by offering optimal incentive contracts to manage quality, implies that spot prices can adequately reflect cattle quality in the spot market. In sum, we conclude that the study of forward contracting in a signaling setting leads to several predictable results. However, we can have a more realistic depiction of the way the actual marketing systems works. One avenue of future research lies in relaxing the assumption of interaction between producers (or processors); another lies in moving the analysis towards a dynamic environment. Different producers (or processors) along the supply (or processing) chain act in a manner contingent upon the actions of other producers (or processors) along the chain. The interaction of value based pricing and the structure of the marketing channel for production decisions needs further study. In addition, by casting the problem into a dynamic framework, there is moral hazard problem but no adverse selection problem. This occurs because the agent’s type is unchangeable after it has been revealed in the first period, but the agent’s action remains unobservable.

As for policy implications, the mission of the USDA is to provide the effective means of establishing a trading base for producers and packers and to provide them with accurate, timely, and unbiased market information. Through quality signaling (market information), certification (quality assurance), and indemnity (inspection), the gaming results of this essay provide a clear picture to help us understand the roles of the USDA’s
grading, certification, and inspection programs. On the other hand, we also recognize that it is in both the USDA’s and the beef industry’s best interest to enhance the marketing of U.S. beef products.

Captive Supply of Cattle and GIPSA’s Reporting of Captive Supply, USDA Grain Inspection, Packers and Stockyards Administration, 2002.


Figure 2.1 One of separating equilibria

\[ \bar{p}_s - \frac{\lambda \hat{\sigma}^2_q}{2} \frac{x^b}{w^h q_j} \]

\[ \bar{p}_s - \frac{\lambda \hat{\sigma}^2_q}{2} \frac{x^b}{w^h q_j} \]

\[ x = x^*(w^j) \]

\[ x = x^*(w^h) = x^h \]
Appendix 1: An overview of captive supply and motivations

Formally, the USDA Grain Inspection, Packers and Stockyards Administration (GIPSA) identifies captive supply cattle by the following procurement categories: Contract, Marketing Agreement, Packer Fed, and Other. GIPSA annually reports contract, market agreement and other cattle as forward contract and marketing agreement cattle in its Packer and Stockyards Statistical Report. In addition, forward contracts are defined as contracts entered into two or more weeks prior to slaughter, which specify a given price, quantity, delivery location and time, and quality (GIPSA Report 2002).

Forward contracts and market agreements often specify numbers of head to be delivered at a future date or per unit of time. Pricing often is by formula, based on average prices for other cattle slaughtered at the plant or on publicly reported prices, with premiums and discounts applied for differences in cattle quality. Market agreements generally permit the seller to have substantial influence over the week of delivery, while the buyer may make a visual estimate of the cattle quality and determine the exact day of delivery. In a forward contract, feeders and packers agree on a delivery month, quality standard, and price basis. As the delivery month approaches, the seller notifies the packer of the date he wants to lock in the price. The locked price is determined by applying the basis to the futures market price for that date. As for packer feeding, when packer-owned cattle are ready for slaughter, the feedlot manager will notify the packer, and the packer then schedules the delivery date. Table 2.1 summarizes incentives for cattle feeders and packers to enter into a particular type of captive supply (Schroeder et al. 1997, Ward 1998, and USDA 2002).
Table 2.1 Incentives for cattle feeders and packers to use captive supply

<table>
<thead>
<tr>
<th>Type of Captive Supply</th>
<th>Cattle Feeder Benefits</th>
<th>Packer Benefits</th>
</tr>
</thead>
<tbody>
<tr>
<td>Marketing Agreements</td>
<td>Premiums for cattle quality</td>
<td>Increase cattle quality control</td>
</tr>
<tr>
<td></td>
<td>Ensure a buyer for cattle</td>
<td>Secure slaughter needs</td>
</tr>
<tr>
<td></td>
<td>Reduce marketing costs</td>
<td>Reduce procurement costs</td>
</tr>
<tr>
<td></td>
<td>Obtain carcass information</td>
<td></td>
</tr>
<tr>
<td>Forward Contracts</td>
<td>Reduce price risk</td>
<td>Increase price risk</td>
</tr>
<tr>
<td></td>
<td>Ensure a buyer for cattle</td>
<td>Increase cattle quality control</td>
</tr>
<tr>
<td></td>
<td>Reduce marketing cost</td>
<td>Secure slaughter needs</td>
</tr>
<tr>
<td></td>
<td>Obtain favorable financing</td>
<td>Reduce procurement costs</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Packer Feeding</td>
<td>Increase feedlot utilization</td>
<td>Increase cattle quality control</td>
</tr>
<tr>
<td></td>
<td>Improve packer and feedlot relationship</td>
<td>Secure slaughter needs</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

9 Price risk, or say the risk of price volatility, results from the underlying distribution of prices.
Appendix 2 Grading, certification, and inspection systems in current U.S. agricultural markets

Grading: Quality grades are used to categorize product quality. Grading is based on measurable attributes that describe the value and utility of the product. Beef quality standards, for instance, are based on attributes such as marbling (the amount of fat interspersed within lean meat), color, firmness, texture, and age of the animal. USDA quality grade marks are widely used as a “language” among traders and are usually seen on beef, chicken, butter, and eggs. For many products, such as fresh and processed fruits and vegetables, the grade mark is not always visible on the retail product. In these commodities, the grading service is used only by wholesalers.

Evidence (Schroeder et al. 1997) has shown that USDA quality grades will gradually begin to be replaced by branded beef products targeted to specific markets in the future. This is because vertical coordination allows for better control of the production chain and ensures product quality and consistency; therefore, vertical coordination can easily be substituted for federal quality grades. Schroeder’s conclusion further suggested that if long-term contracts between producers and packers are desired, it might be necessary to develop vertical coordination together with improved quality monitoring. In other words, contractual agreements may be necessary to better ensure the producers’ and packers’ incentives, such as quality of product.

Certification: The USDA provides certification services, for a fee, that facilitate ordering and purchase of products used by large-volume buyers. Certification assures buyers that the products they purchase will meet the terms of their contracts, with respect to quality, processing, size, packing, and delivery. AMS’s (USDA’s Agriculture Marketing Service)

---

Details see Agriculture Fact book 1999.
dairy programs conduct comprehensive evaluations of manufacturing plant facilities and equipment for dairy and related products to assure their eligibility to receive grading services and to display the grade shield on their products.

There are some other examples to show that certification may encourage producers to breed certain types of quality, e.g. U.S. Premium Beef (USPB) and Beef Quality Assurance (BQA) programs. These programs usually present certificates to those producers/feeders who participate in their organizations. Certification could be a training process, which includes good feed management practices, proper health procedures, and correct ways to castrate and give injections, implants, etc. Thus, these certification-training programs suggest that a farm certificate may not be a pure signal, as in Spence’s model. A certificate for the producer is not only used as a way to avoid inaccurate assessment of quality in the market, but also serves as an investment for the producer. The higher the level of certification a producer obtains, the higher is the producer’s ability to operate efficiently, e.g. reduce production costs.

**Inspection**: The existence of inspection assures payment protection, fair competition, and detects improper and fraudulent practices. Take two examples in practice. First, the Federal Grain Inspection Program serves American agriculture by providing descriptions and testing methodologies for measuring the quality and quantity of grain, rice, edible beans, and related commodities. Second, the Office of Food Safety oversees the Food Safety and Inspection Service (FSIS), the agency within the USDA responsible for ensuring the safety, wholesomeness, and correct labeling and packaging of meat, poultry, and egg products. FSIS inspectors check animals before and after slaughter, preventing
diseased animals from entering the food supply and examining carcasses for visible
defects that can affect safety and quality.
Essay 3: Forward Contracting Specification through Bargaining

Abstract

The focus of this essay is on pricing mechanisms that involve collective bargaining. Collective bargaining by farmers constitutes an institutional response to an imbalance in farmer-processor bargaining power. The economic analysis in this essay will help farmers to understand what they can realistically accomplish when they organize bargaining cooperatives. We clarify the economic conditions, such as equilibrium price, equilibrium quantity, and welfare effect, which may favor the success of collective bargaining.

The results in this essay show that bargaining does not simply increase prices paid to farmers when compared with the situations in monopsony and in the competitive market; the total surplus associated with bargaining is also positive. We conclude that collective bargaining can increase producer profits in marketplaces where they face individual processors that might exercise monopsony power in the absence of collective bargaining. In the absence of collective bargaining, we find it likely that individual producers receive the lowest price and zero profit.
3.1 Introduction

Agricultural producers have long been concerned with low and unstable farm prices and income. These conditions have been interpreted as threatening to the feasibility of sustainable agricultural systems. Two approaches are pursued. One approach is central control or management through various forms of government intervention, such as government payments to farmers and price supports for farm products. Over the past decade, this approach has been found to be financially unsustainable for the private sector (Levins, 2001). The other approach is that the government grants farmers the right to collectively bargain with the handlers and processors of their products. Most of the growth in agricultural bargaining took place after World War II in response to the dramatic changes, such as economic integration and mergers, which occurred in the food distribution system (Bunje, 1980).

In relation to their buyers, farmers are small in size and large in number. This is certainly true in most fed cattle, fruit and vegetable, and dairy markets, where feeders/growers/farmers are numerous, and where packers/processors are relatively concentrated.

Pricing alternatives, such as quality-based pricing designed by optimal incentive contracts, have already been discussed in Essay 2. Two main issues are highlighted. First, pricing methods that reflect quality differences were shown to dominate those
that generate uniform prices, which do not reflect quality. Second, the success of some certification marketing programs depends critically upon the certification program integrity and whether the certified product is perceived to be differentiated from other products.

The focus of this essay is on pricing mechanisms that involve collective bargaining. Collective bargaining by farmers constitutes an institutional response to an imbalance in farmer-processor bargaining power. Prices and terms of trade are negotiated by cooperatives with processors. In this case, farmers can enhance prices and their income (Sexton 1990). However, agricultural economists have paid surprisingly little attention to the economic and market implications of such bargaining (Young and Hobbs, 2002). The purpose of this essay is to try to fill this gap. In addition, a farm bargaining cooperative has some of the same weaknesses of other organizations that attempt to arrive at the collective judgment of their members. This usually results from a lack of knowledge and experience about the principle of bargaining among members (Bunje, 1980). Even though farmers have long recognized that cooperatives enable them to do collectively what they cannot do individually, not all farmers have the same knowledge of business practices and procedures, as well as the market. Therefore, educating producers about negotiating
and evaluating contracts will become an increasingly important extension of the public sector education and training (Young and Hobbs, 2002).

The economic analysis in this essay will help farmers to understand what they can realistically accomplish when they organize bargaining cooperatives. Also, we clarify the economic conditions, such as equilibrium price, equilibrium quantity, and welfare effect, which may favor the success of collective bargaining. Once these conditions are identified, the probability of success for the farmers who participate in collective bargaining increases.

Two objectives are pursued in this essay:

1). Clarify the role cooperatives might play in providing collective bargaining for farmers.

2). Evaluate the implications of associated changes in producers that result from collective bargaining. Specifically, a) evaluate how the extent of collective bargaining may affect price, quantity and profit, and b) compare price level, quantity, and profit under collective bargaining versus the cases where farmers remain independent and face a single buyer (monopsony).

The remainder of the essay proceeds as follows. In the second section, the approach in this essay is presented and placed into context with recent literature. Some salient features of current agricultural markets where bargaining occurs are
presented to motivate model specification. Next, two variants of the model are examined to compare with two extreme cases: competitive equilibrium and monopsony market. In the final section, we discuss some implications of our model and conclude.

3.2 Approach

In this essay, we develop two simple bargaining games for analyzing the implications of collective bargaining. Typically, formal negotiations involve rounds where the processor and the cooperative alternate offers or where the cooperative presents offers that are either accepted or rejected by the processor until an agreement is reached (Bunje, 1980). These characteristics motivate our choice of the Rubinstein bargaining model of alternating offers (see Rubinstein (1982)\(^1\)), instead of the Nash bargaining model, which has been adopted to describe other settings by von Ungern-Sternberg (1996) and Venturini (1998). Indeed, at the optimum, the solution of the (noncooperative) Rubinstein model converges to the solution of the (cooperative) Nash bargaining model\(^2\). In addition, the model with a market setting characterized by the presence of cooperative bargaining is examined, as well as its consequences on bargaining outcomes and on equilibrium prices, quantities, and profits.

---

\(^1\) A brief overview of Rubinstein (1982) bargaining is presented in Appendix 2.

\(^2\) For details, see Muthoo (1999), chapter 3.
3.2.1 Salient features of collective bargaining in current agricultural markets

In general, cooperatives negotiate with processors after a good estimate of product quantity and quality can be obtained, typically just prior to harvest. This implies bargaining pursued with total supply being fixed. Thus, resulting prices are a function of a predetermined volume. In most cases, processors always purchase all member production. An alternative condition is one where quantity decisions are based on processor need, and are determined prior to price negotiations. However, this again results in price being a function quantity. The information that is included in negotiations includes projections of production, consumption, costs of production and harvesting, and related prices if they are public. An overview of collective bargaining in the current U.S. agricultural setting is presented in Appendix 1.

There are four salient features of the current markets where bargaining occurs³:

1). Bargaining activities exist primarily in markets where contract production is the dominant form of coordination.

2). Bargaining activities are observed to have functioned successfully in markets for processed fruit and vegetables, sugar beets, and fluid milk, where few processors service particular local markets.

³ See details in Hueth and Marcoul, 2000b.
3). Most of the commodities for which bargaining occurs exhibit a high degree of geographic concentration.

4). Producers have limited “outside options” because there is a relatively small number of buyers in their respective markets, transportation costs are high, and product life is short.

3.2.2 Models of bargaining

Many practical issues about cooperatives, such as their method of bargaining and decision making, their objectives and benefits, the actual process of negotiation, and the major problems they face, have already been addressed in many previous studies, see Bunje (1980), Iskow and Sexton (1992), Jermolowicz (1999), Gray and Kraenzle (2002), Hueth and Marcould (2002ab), and numerous USDA reports. The issue of farm bargaining as a way to countervail the processors’ bargaining power has been investigated formally within the theoretical frameworks of game bargaining. We review briefly some past studies that have examined the issue as follows.

von Ungern-Stenberg (1996) developed a model where a small number of retailers bargain as undifferentiated buyers to establish intermediate prices with a single producer. The retailers are assumed to compete in a Cournot fashion in the retail market. In a first stage, the bargaining process between the producer and the retailers is modeled. In a second stage, the competition among the retailers is
analyzed. His results indicate that the producer’s selling price, or say the price the retailers pay for the input, is a decreasing function of the retailers’ bargaining power and an increasing function of the number of retailers. This result captures the idea that concentration in retailing is a source of bargaining power for retailers.

Another paper that has examined the issue of countervailing power is the work of Dobson and Waterson (1997). By using the same approach as von Ungern-Stenberg (1996), they assume a Bertrand Nash setting of imperfectly competitive retailers. Their results suggest that retailers obtain a stronger bargaining position as a consequence of greater concentration, and that, if there were intense competition among them, then greater concentration in retailers may be socially beneficial, following a fall in consumer prices.

McDonald and Solow (1981) used a partial-equilibrium bargaining model to elaborate a macroeconomic question between real wage rate and employment. They considered a case that a labor union as a monopolist and a firm as a monopsonist bargain over wages and employment and reach an efficient outcome. Along the contract curve, the efficient bargaining defined in their model will push the firm to hire more workers than it would prefer at the negotiated wage. Therefore, if there were fluctuations in aggregate demand in the product market, they claimed that the major change in employment and real wages might be sticky.
Venturini (1998) further developed a Nash bargaining game to examine the negotiation process between one manufacturer and N retailers. He suggested that vertical competition between manufacturer and retailer, as well as the number of retailers, may affect independent bargaining power. This occurs because vertical competition in his model was assumed to decrease the manufacturer’s disagreement payoff, but to increase the retailers’ disagreement payoff. Therefore, the result illustrates that vertical competition increases retailers’ bargaining power and reduces equilibrium transfer prices.

Early work about the economic effects of agricultural price bargaining can be traced to Helmberger and Hoo (1965). Their model treats buyers of agricultural products as a colluding monopsony and concludes that the monopsony may overstate the market power and exploit the surplus (see Kinnucan (1995) cited therein). Sexton (1994) further used noncooperative game theory to discuss how a bargaining mechanism works between processors and producers, but assumes that the trade quantity is independent of the bargaining outcome. Some principles, such as first-mover advantage, the importance of patience, and outside options, were identified in his paper. Furthermore, Kinnucan (1995) applied an equilibrium
displacement model\(^4\) to examine the price and quantity impacts of price bargaining, where a farm cooperative cannot control its members’ supply. His results show that under the assumption that a cooperative has no control over the quantity produced, the cooperative’s bargaining power is enhanced and a significant transfer from processors to producers results when demand is inelastic.

### 3.3 The model

Consider a market for a homogeneous agricultural good such as milk or fruit. Suppose there are two kinds of traders: a processor and some homogenous individual farmers. A processor who is a spatial monopsonist uses the raw product as an input to produce the final products and then sells to consumers in a competitive market. Suppose that individual farmers can aggregate to become a cooperative. The cooperative markets their production to maximize the aggregate profit. Each member is paid the average price received for all product of like quality delivered during the duration of the transaction. The reason we consider the processor as a spatial monopsonist is as follows: Packer/processor concentration in the beef industry has received considerable attention from cattle producers. One of the recent GIPSA packer concentration studies (Hayenga, et al. 1996) revealed that 95 percent of cattle are purchased within a 270-miles radius of the plant. In addition, their results

---

\(^4\) A displacement model is combined with econometric estimates of key model parameters to identify the impacts on prices and quantity.
indicate that in the Upper Midwest region packers were estimated to be paying an average of $0.09/cwt less for cattle purchased within 100 miles and $0.29/cwt less for cattle purchased between 100 to 300 miles of the plant. The possibility of monopsony power leading to a lower price of cattle was found.

The contract is set up after the cooperative and the processor bargain over the contract price and/or quantity of delivery. This bargaining is accomplished by an alternating-offers procedure. Successful bargaining identifies mutual benefits and resolves conflicting interests in a way that results in both joint and individual gains from cooperation. (Muthoo, 1999, Ch.1). In the model, we assume that there is no opportunity for either player to find opportunities to bargain with other agents, i.e., no outside options are allowed.

During a bargaining session, an offer is represented by a pair \((p, q)\) where \(p \geq 0\) is the offered price and \(q \geq 0\) is the contract quantity. If the cooperative and the processor reach agreement on a pair \((p, q)\), then player \(i\)’s \((i = C \text{ (cooperative)} \text{ and } P \text{ (processor)})\) payoff is specified as the form of \(\pi'(p, q) \exp(-r_i \tau)\), where \(\exp(-r_i \tau)\) is player \(i\)’s discount factor, \(r_i > 0\) is time preference, and \(\tau\) is the time length of the bargaining period. On the other hand, if the players perpetually disagree, then each

---

5 The alternating-offers procedure is a process of making offers and counteroffers, which continues until a player accepts an offer.

6 According to the alternating-offers procedure, an outside option exists when a player rejects an offer and opts out, in which case negotiations terminate in disagreement.
player’s payoff is zero. The game equilibrium determines a resulting price and quantity pair that is assumed to have been transacted instantaneously.

To proceed, we introduce each trader’s behavior first.

**The processor’s choice problem**

If the processor buys a quantity \( q \) at a price \( p \), then the processor’s profit is:

\[
\pi^p(p,q) = R(q) - pq = p_bF(q) - pq,
\]

where \( p_b \) is the wholesale price of the processed product and \( F(q) \) is the production function of the wholesale product and its byproducts. \( R(q) = p_bF(q) \) is the revenue obtained by the processor by transforming the quantity \( q \) of the input into some output and then selling the output on some competitive final market at the price \( p_b \). Define \( F(q) = aq^2 + bq \). Assume that \( F'(q) > 0 \) and \( F''(q) < 0 \), and more specifically, \( b > 0 > 2aq \) and \( a < 0 \).

Incorporating the production function into equation (1), the processor’s profit is written as:

\[
(1) \Rightarrow \pi^p(p,q) = p_b(aq^2 + bq) - pq
\]

The processor’s demand function is derived from the corresponding first-order condition:

\[
FOC: \quad \frac{\partial \pi^p}{\partial q} = p_b(2aq + b) - p = 0
\]

\[
(2) \quad q^p = \frac{p - bp_b}{2ap_b}
\]
The cooperative’s choice problem

The cooperative serves as a seller, and its profit can be represented as follows:

\( \pi^C(p, q) = pq - C(q), \)

where \( C(q) \) is the cost to the cooperative of producing the quantity \( q \) of the input.

Define \( C(q) = dq^2 \) and assume that \( C'(q) > 0 \) and \( C''(q) > 0 \), so \( d > 0 \).

Incorporating the cost function into equation (3), the profit for the cooperative can be represented as:

\( \Rightarrow \pi^C(p, q) = pq - dq^2, \)

The corresponding first-order condition gives the cooperative’s supply function:

\[ FOC : \quad \frac{\partial \pi^C}{\partial q} = p - 2dq = 0 \]

\( q^C = \frac{p}{2d} \)

Next, we consider alternative bilateral equilibria. The first case is that two players bargain over both price and quantity. The second case is that two players bargain over the price, given that quantity is predetermined.

3.3.1 Case 1: Rubinstein Model

The processor and the cooperative are assumed to bargain over the price and quantity of trade according to an alternating-offers protocol. Bargaining, as defined by Muthoo, occurs when two players have a common interest to cooperate, but have conflicting interests over exactly how to cooperate. In the model presented here, the
common interest is the gain from trade (transactions resulting from agreement). This gain is the sum of both the processor’s and the cooperative’s surplus. An offer is a pair \((p,q)\), where \(p \geq 0\) and \(q \geq 0\). For convenience, denote \(\theta_i \equiv \exp(-r_i\tau)\).

Notice that \(0 < \theta_i < 1\). The cost implied by introduction of the discount rate \((r_i)\) results due to the time required for bargaining and, given that this cost will reflect time value, it can be interpreted as a measure of patience. If players differ in patience, it follows that the more patient (small discount rate) agent will hold greater bargaining power. As will be clear, a player’s bargaining power can be interpreted as conditioned on patience, or the discount rate.

Using Rubinstein’s results (1982), the equilibrium share \((w^i, i = P, C)\) of gains from trade \((S)\) for the processor and the co-op is, \(w^P = (\frac{1 - \theta_c}{1 - \theta_p \theta_c})S\) and \(w^C = (\frac{1 - \theta_p}{1 - \theta_p \theta_c})S\), respectively. These are exactly the proportions of total gains from trade weighted by the opponent’s preference. Also, within the limit, as the time interval between two consecutive offers tends to zero \((\tau \to 0)\), the equilibrium partition converges to shares \(w^P = (\frac{r_c}{r_p + r_c})S\) and \(w^C = (\frac{r_p}{r_p + r_c})S\). This depends on the players’ relative magnitude of bargaining power (as captured by the ratio \(\frac{r_p}{r_c}\)).

To consider bargaining, however, we interpret equilibrium share as an indicator. It is clear that as \(\frac{r_p}{r_c}\) increases, the processor’s (cooperative’s) relative patience decreases (increases), \(\frac{r_c}{r_p + r_c}\) decreases and \(\frac{r_p}{r_p + r_c}\) increases, so \(w^P\) decreases.
and $w^C$ increases. That is, the equilibrium sharing shows that a player’s bargaining power is decreasing with his own discount rate, and increasing with his opponent’s discount rate.

To proceed, we assume that both processor and cooperative have the same discount rates, i.e., $r_p = r_c$. This assumption holds for the situation when two players have the same accessibility of capital market. It follows that the two players (processor and cooperative) equally share the total surplus (or, gains from trade). In the unique subgame perfect equilibria (SPE), the equilibrium quantity trade $q^e$ maximizes the total surplus. In the model, the total surplus is:

$$S(p, q) = \pi^P(p, q) + \pi^C(p, q) = p_q(aq^2 + bq) - dq^2$$

Thus, $q^e$ is the unique solution to $S'(q) = 0$. That is,

$$q^e = \frac{bp_q}{2d - 2ap_q}$$

In the Rubinstein model, the equilibrium price is a weighted combination of the equilibrium average revenue and equilibrium average cost, and the weights depend on the relative bargaining power. That is,

$$p^e = \frac{r_p}{r_p + r_c} \left( \frac{R(q^e)}{q^e} \right) + \frac{r_c}{r_p + r_c} \left( \frac{C(q^e)}{q^e} \right)$$

Since the processor and the cooperative have the same discount factor, the equilibrium trade price $p^e$ equally divides the generated surplus $\pi^P(q^e) + \pi^C(q^e)$. Hence,
(7) \[ p^* = \frac{1}{2} \left( \frac{R(q^*) + C(q^*)}{q^*} \right) = \frac{bp_b(3d - ap_b)}{4(d - ap_b)}. \]

### 3.3.2 Case 2: Quantity is predetermined

Here, we consider a three-stage game. In the first stage, the cooperative rationally chooses its supply \( q^C \) that is also the trade quantity. The processor and the cooperative bargain over the price \( p \) in the second stage, given that quantity is predetermined in the first stage. In the third stage, the processor sells the final product to a competitive market. The subgame perfect equilibrium (SPE) concept is also used to characterize the outcome of this game. We adopt a backward induction method to solve the model.

In the third stage, the processor sells the final product, \( F(q^C) \), to some competitive market and receives a competitive price \( p_b \). Equation (8) is the processor’s profit.

\[
\pi^p(p, q^C) = p_b(a(q^C)^2 + bq^C) - pq^C
\]

Plugging this into the cooperative’s supply function, that is equation (4) in (8), gives:

\[
\pi^p(p, q^C) = p_b \left( a \left( \frac{p}{2d} \right)^2 + \frac{bp}{2d} \right) - \frac{p^2}{2d}
\]

In the second stage, the processor and the cooperative bargain over the price \( p \) and the quantity \( \frac{p}{2d} \). While two players bargain, the relative bargaining power plays a role in the equilibrium partition. Denote \( \beta_i \), where \( i = P,C \) as the processor’s and the cooperative’s bargaining power, respectively. Assume \( \beta_i \) is
exogenously determined by some behavior parameters, such as risk aversion, or by some market conditions, such as supply or demand elasticity. To ensure a stable equilibrium, the sharing rule, which allocates total surplus, requires that the equilibrium price $p^*$ equally satisfies the conditions of both players’ payoffs. That is, $\beta_p \pi^p(p^*, q^*) = \beta_c \pi^c(p^*, q^*)$. Note, a higher value of $\beta_i$ means a lower bargaining power for player $i$.

In the model, we assume that two players have the same bargaining power, i.e., $\beta_p = \beta_c$. Thus, the sharing rule derives the equilibrium price such that two players’ profits are equal. That is,

$$\pi^p(p, q = \frac{p}{2d}) = \pi^c(p, q = \frac{p}{2d}).$$

Setting the value of the profit of the processor equal to the profit of the cooperative,

$$p_b(a(p^2) + \frac{bp}{2d}) - \frac{p^2}{2d} = \frac{p^2}{2d} - d(p)$$

yields the quadratic equation:

$$\frac{(ap_b - 3d)}{4d^2} p^2 + \frac{bp_b}{2d} p = 0,$$

with the roots $p = 0$ and $p = \frac{-2bp_b}{(3d - ap_b)}$.

The equilibrium price is:

$$p^* = \frac{2bp_b}{(3d - ap_b)}$$

To solve the first stage, plug (10) into the cooperative’s profit function (3).

$$\pi^c(p^*, q^c) = \frac{2bp_b q^c}{(3d - ap_b)} - d(q^c)^2$$

The first-order condition gives the optimal supply by the cooperative at the first stage:
For comparison, monopsony and competitive markets are introduced below.

**3.3.3 Case 3: Monopsony**

The monopsonistic market in the model occurs when the individual producers do not aggregate as a whole and leave the market as one buyer and many competitive sellers. The processor now is the monopsonist who cannot purchase an unlimited amount of an input at a fixed price. The price that she must pay for each quantity purchased is given by the market supply curve for the input. The revenue function and cost function are as before: \( R = pF(q) \) and \( C = pq \), respectively. However, the price of inputs is an increasing function of the amount purchased. We use the inverse supply function from equation (4). That is \( p = 2dq \). Hence, the processor’s profit function now becomes:

\[
\pi^M(p = 2dq, q) = p_b(aq^2 + bq) - 2dq^2
\]

Setting the marginal revenue equal to its marginal cost yields the equilibrium demand \( q^M \) and the equilibrium price \( p^M \).

\[
\begin{align*}
\text{FOC} & : \frac{\partial \pi^M}{\partial q} = p_b(2aq + b) - 4dq = 0 \\
(12) & \quad q^M = \frac{bp_b}{4d - 2ap_b} \\
(13) & \quad p^M = \frac{bdp_b}{2d - ap_b}
\end{align*}
\]
3.3.4 Case 4: A competitive market

As a benchmark, the competitive market equilibrium is derived. The quantity demanded $q^P$ from equation (2) must equal the quantity supplied $q^C$ from equation (4) at the equilibrium price $p^*$. Setting $q^P = q^C$, $\frac{p - bp_b}{2ap_b} = \frac{p}{2d}$ and, therefore,

$$p^* = \frac{bdp_b}{d - ap_b}$$  \hspace{1cm} (14)

$$q^* = \frac{bp_b}{2d - 2ap_b}$$  \hspace{1cm} (15)

3.4 The Results

Table 3.1 summarizes the equilibrium quantities and the equilibrium prices for the four cases detailed above.

<table>
<thead>
<tr>
<th>EQUILIBRIUM OUTCOME CASES</th>
<th>CASE1: RUBINSTEIN MODEL</th>
<th>CASE2: BARGAIN OVER PRICE ONLY</th>
<th>CASE3: MONOPSONY</th>
<th>CASE4: COMPETITIVE EQUILIBRIUM</th>
</tr>
</thead>
<tbody>
<tr>
<td>Equilibrium quantity $q_1$</td>
<td>$\frac{bp_b}{2d - 2ap_b}$</td>
<td>$\frac{bp_b}{3d - ap_b}$</td>
<td>$\frac{bp_b}{4d - 2ap_b}$</td>
<td>$\frac{bp_b}{2d - 2ap_b}$</td>
</tr>
<tr>
<td>Equilibrium price $p_1$</td>
<td>$\frac{bp_b(3d - ap_b)}{4(d - ap_b)}$</td>
<td>$\frac{2bdp_b}{3d - ap_b}$</td>
<td>$\frac{bdp_b}{2d - ap_b}$</td>
<td>$\frac{bdp_b}{d - ap_b}$</td>
</tr>
</tbody>
</table>

First, we compare the equilibrium quantities. The monopsony (case 3) equilibrium demand for the input is clearly lower than market competition. The monopsonist is the only buyer having more market power than those individual sellers. Also, the quantity traded by the Rubinstein model is the same in competitive equilibrium. This result is straightforward: in the Rubinstein model, the processor
and the cooperative set quantity to the level that maximizes the total surplus. This is exactly how a competitive equilibrium works. As for the relationships among other cases, the following calculations provide some information.

\[
q_2 - q_4 = \frac{-bp(p + ap)}{2(3d - ap)(d - ap)}
\]

In the model, \(q_2\) is derived from a bargaining equilibrium, where the cooperative rationally chooses the trade quantity and the price equals two player’s profits. Intuitively, the bargaining outcome is between the monopsony and competitive equilibrium. That is, \((16)\) is less than zero and \(d + ap < 0\). Therefore, \(q_1 = q_4 > q_2 > q_3\).

Next, we check the equilibrium price.

\[
p_1 - p_3 = \frac{bp(p + ap)^2}{4(3d - ap)(d - ap)} > 0
\]

\[
p_1 - p_4 = \frac{-bp(p + ap)}{4(d - ap)} > 0
\]

\[
p_2 - p_4 = \frac{-bp(p + ap)}{3(d - ap)(d - ap)} > 0
\]

Equations \((18)\) and \((19)\) show that the two bargaining equilibrium prices are higher than the competitive price. Besides, the price solved from the Rubinstein model is higher than the price from case 2, where the quantity is predetermined. In the Rubinstein model, the price is a weighted average of the processor’s revenue and the cooperative’s cost. The sign of \((18)\) depends on parameterizations of the processor’s final product market, his production function, and the cooperative’s cost function.
Thus, a positive sign might not be a general result, but provides information about what elements may affect the bargaining price.

The reason why the price in the Rubinstein model is higher than that of case 2, where quantity is predetermined, is not straightforward. In case 2, the price is derived from equaling two player’s profits, given that trade quantity is predetermined, whereas the equilibrium price of the Rubinstein model is weighted by some of two players’ profits. Therefore, if the trade quantity in case 2 is large, then this large supply drives the price down, and vice versa. Further, the result shows that the cooperative’s payoff may not increase as a result of being able to set the trade quantity. In other words, the buyer dominates the seller in this model. Overall, 

\[ p_1 > p_2 > p_4 > p_3. \]

Next, consider the profits of the processor and the cooperative in each case.

| TABLE 3.2 THE PROFITS OF THE PROCESSOR AND THE COOPERATIVE FROM 4 CASES |
|----------------|----------------|----------------|----------------|
| PLAYER \ CASES | CASE1: RUBINSTEIN MODEL | CASE2: BARGAIN OVER PRICE ONLY | CASE3: MONOPSONY | CASE4: COMPETITIVE EQUILIBRIUM |
| Processor (buyer) | \( \pi_p^1 = \frac{b^2 p_b^2}{8(d - a p_b)} \) | \( \pi_p^2 = \frac{b^2 dp_b^2}{(3d - a p_b)^2} \) | \( \pi_p^3 = \frac{b^2 p_b^2}{4(2d - a p_b)} \) | \( \pi_p^4 = \frac{-ab^2 p_b^3}{4(d - a p_b)^2} \) |
| Co-op (seller) | \( \pi_C^1 = \frac{b^2 p_b^2}{8(d - a p_b)} \) | \( \pi_C^2 = \frac{b^2 dp_b^2}{(3d - a p_b)^2} \) | \( \pi_C^3 = 0 \) | \( \pi_C^4 = \frac{b^2 dp_b^2}{4(d - a p_b)^2} \) |
| Total surplus | \( \pi_{p+C}^1 = \frac{b^2 p_b^2}{4(d - a p_b)} \) | \( \pi_{p+C}^2 = \frac{2b^2 dp_b^2}{(3d - a p_b)^2} \) | \( \pi_{p+C}^3 = \frac{b^2 p_b^2}{4(2d - a p_b)} \) | \( \pi_{p+C}^4 = \frac{b^2 p_b^2}{4(d - a p_b)^2} \) |
Case 3 is a monopsony market. The processor appropriates all profit and leaves zero profit to the cooperative. Case 4 considers a competitive market. The profit earned by each player depends on his technology. The differential profits for each player across cases can be written. For the processor,

\[
\begin{align*}
\pi_3^p - \pi_4^p &= \frac{b^2 d^2 p_b^2}{4(2d - a p_b)(d - a p_b)^2} > 0 \\
\pi_3^p - \pi_1^p &= \frac{-a b^2 p_1^1}{8(2d - a p_b)(d - a p_b)} > 0 \\
\pi_3^p - \pi_2^p &= \frac{b^2 p_b^2(d - a p_b)^2}{4(2d - a p_b)(3d - a p_b)^2} > 0 \\
\pi_2^p - \pi_1^p &= \frac{b^2 p_b^2(d + a p_b)^2}{8(d - a p_b)(3d - a p_b)^2} > 0 \\
\pi_4^p - \pi_2^p &= \frac{b^2 p_b^2(4d^3 + d p_b(d - a p_b)^3)}{4(d - a p_b)^2(3d - a p_b)^2} > 0
\end{align*}
\]

From equations (20)-(24), \(\pi_3^p > \pi_4^p > \pi_2^p > \pi_1^p\). The processor receives the highest profit from the monopsony market, and the lowest profit from case 1. This clarifies the potential of collective bargaining to establish a balance for a single processor.

For the cooperative,

\[
\begin{align*}
\pi_1^c - \pi_4^c &= \frac{-b^2 p_b^2(d + a p_b)}{8(d - a p_b)} > 0, \text{ since } d + a p_b < 0. \\
\pi_2^c - \pi_4^c &= \frac{-b^2 d p_b^2(5d - 3a p_b)(d + a p_b)}{4(d - a p_b)^2(3d - a p_b)^2} > 0, \text{ since } d + a p_b < 0.
\end{align*}
\]

The result shows that \(\pi_1^c > \pi_2^c > \pi_4^c > \pi_3^c\). The cooperative receives the lowest profit (zero) in the monopsony market, but receives the highest profit under collective bargaining, considered by the Rubinstein model. The bargaining activity transfers the processor’s profit to the cooperative.
For total surplus, we have the differential between Case 2, where quantity is predetermined, and Case 3, the monopsony market.

\[
(27) \quad \pi_2^{p+c} - \pi_3^{p+c} = \frac{b^2 p_b^3 (7d^2 - 2adp_b - a^2 p_b^3)}{4(2d - ap_b)(3d - ap_b)^2}
\]

The third row of Table 3.2 shows that the competitive equilibrium supports the highest total surplus. Collective bargaining following the Rubinstein model provides the same highest total surplus. Although the trade quantity is the same with the Rubinstein model and the competitive market, the higher equilibrium price associated with collective bargaining in the Rubinstein model reduces the processor’s profit at a level equal to the increases in the cooperative’s profit. The sign of equation (27) depends on the sign of \(7d^2 - 2adp_b - a^2 p_b^3\). Without comparison with case 2, where quantity is predetermined, the monopsony market has the smallest total surplus. On the other hand, even though the cooperative has the right to rationally decide the trade quantity, the total surplus might be lower than it can receive in the monopsony market.

Overall, \(\pi_1^{p+c} = \pi_4^{p+c} > \pi_2^{p+c} \) (and \(\pi_3^{p+c}\)).

In sum, four cases are examined in this essay: the Rubinstein alternating-offers procedure, bargaining over price only, monopsony, and competitive equilibrium. The players trade the same quantity in the Rubinstein model as in the competitive market. In monopsony, the smallest quantity is traded. In addition, bargaining models result in a higher price, than do the competitive case. By comparison, the
monopsony results in the lowest price. Moreover, we evaluated four cases from the perspective of each player. For the processor, there is no doubt that he collects all of the surplus in the monopsony market. Further, bargaining also provides greater profit than does the competitive market. Similarly, bargaining results in greater profits for the cooperative than are available from a competitive market or from the monopsony case. Thus, the function and importance of cooperative bargaining is realized.

3.4.1 Discussions on bargaining power

The above results for Case 1 and 2 rely on the assumption that two players have the same bargaining power, recall $r_p = r_c$ for Case 1 and $\beta_p = \beta_c$ for Case 2. We now relax this assumption and consider a situation where the processor has greater bargaining power than the cooperative, i.e., $r_p < r_c$ for Case 1 and $\beta_p < \beta_c$ for Case 2. In Case 1, this assumption does not affect the equilibrium quantity, because, under all bargaining power scenarios, it results in a Pareto optimal total surplus. In the Rubinstein model, the equilibrium price is a weighted combination of the equilibrium average revenue and equilibrium average cost, and these weights depend on the relative bargaining power. Recall equation (7).

Plugging the equilibrium quantity (6) into (28), the equilibrium price (7) becomes:

$$(7) \Rightarrow p^r = \frac{bdp_br_c + bp_b(2d_ap_b)r_p}{2(d_ap_b)(r_p + r_c)}$$
The comparative statistics of (7) show that $\frac{\partial p^c}{\partial r_p} > 0$ and $\frac{\partial p^c}{\partial r_c} < 0$. The equilibrium price increases (decreases) as the processor (cooperative) has higher bargaining power (the small value of $r_p$ ($r_c$)).

As for Case 2, where quantity is predetermined, if we relax the assumption of two players with the same bargaining power, according to the sharing rule (recall $\beta_p \pi^p(p^c,q^c) = \beta_c \pi^c(p^c,q^c)$), the equilibrium price is:

$$p^e = \frac{2bdp_b\beta_p}{(2d - ap_b)\beta_p + d\beta_c}$$

(10) shows that $\frac{\partial p^e}{\partial \beta_p} > 0$ and $\frac{\partial p^e}{\partial \beta_c} < 0$. That is, the greater the processor’s relative bargaining power (the lower value of $\beta_p$), the lower is the equilibrium price.

On the other hand, increased cooperative bargaining power will result in a greater equilibrium price. As for the equilibrium quantity, (11) becomes:

$$q^c = \frac{bp_b\beta_p}{(2d - ap_b)\beta_p + d\beta_c}$$

(11) shows $\frac{\partial q^c}{\partial \beta_p} > 0$ and $\frac{\partial q^c}{\partial \beta_c} < 0$, so the equilibrium quantity will change as the bargaining power changes. The cooperative will rationally supply more as its bargaining power increases, and vice versa.

Also considering the other two cases, monopsony and competitive market, the results for the four cases with respect to equilibrium prices and quantities may change. Assume that the bargaining power of the processor is greater than that of the cooperative. The equilibrium quantity in Case 2 decreases as the processor gains
greater bargaining power, until the quantity of the monopsony is reached, and thus, $q_1 = q_4 > q_2 \rightarrow q_3$. In addition, the equilibrium prices of both Case 1 and 2 decrease as the processor gains greater bargaining power, and may converge to the monopsony price if the processor has the absolute market power. The magnitudes of these decreases depend on the values of $r_i$ and $\beta_j$. In other words, there is a possibility that the order of $p_1 > p_2 > p_4 > p_3$ may not hold.

The above discussions consider the case where there is one processor versus some homogenous farmers. If we consider a case with more than one processor, say two processors, then the type of competition between two processors has to been considered. For example, we assume that two processors compete in a Cournot fashion in a wholesale market, as in von Ungern-Stenberg (1996). That is, one can make more profit as he can supply more in the wholesale market; in other words, he has to get more supply from the raw product market. Thus, in order to get sufficient input supply, processors may bid aggressively in the raw product market. This, in turn, decreases the relative bargaining power of processors, and increases the price of raw product. Such oligopsony situations deserve further study.

3.5 Membership Decision and Outside Option

It is generally agreed that a key factor in a bargaining cooperative’s effectiveness is its ability to control a substantial supply of the product (Helmberger and Hoo (1965)
and Bunje (1980)). Member farmers who form cooperatives provide the supply of the product. Thus, supply-control by a cooperative can be enhanced by increasing the number of member-farmers. To design effective membership structures, it is critical that cooperatives have accurate information about their membership.

While most group marketing efforts by farmers are organized as cooperatives, individual farmers must decide whether or not to participate in the cooperative. The crucial problem is to define the farmers’ outside options, i.e. determine what advantages can be expected from joining the cooperative as compared to not joining. In theory, if each player’s outside option is less than or equal to the share he receives from the bargaining model, then the outside options have no influence on the equilibrium sharing.

von Ungern-Sternberg (1996) simply defines the producer’s outside option as trading with other buyers. He considers a monopoly situation with one producer facing homogenous buyers where those buyers are in a Cournot type competition. If the producer does not reach an agreement with one of the buyers, then an outside option must be available from other buyers. Within the Cournot, competition a decrease in the number of buyers leads to an increase in equilibrium final product prices.

\[7 \text{ See details in Muthoo (1999), chapter 5.}\]
In reality, several commodities, such as potatoes and apples, do have good spot market alternatives (Iskow and Sexton, 1992). According to the USDA report in 1997, the most common marketing techniques used by cooperatives are long-term contracts, short-term contracts, electronic marketing, and open market sales. Long-term contracts are a year or more in length, short-term contracts are less than a year, and open market sales are made at prices and terms available at the time of sale.

Electronic marketing is a transaction completed over computer auctions or satellite video.

In this section, we assume that the only marketing alternative for those individual farmers who do not join a cooperative is to trade in the spot market, a competitive market. The outside option for an individual farmer can be modeled as follows. A farmer, if he supplies to the spot market, will maximize his expected profit based on the expected spot price, \( p^* \). A farmer’s expected profit, \( \pi^*_i \), can be written as:

\[
\pi^*_i = p^*_i q^i - d(q^i)^2,
\]

where \( d(q^i)^2 \) is the quadratic production cost to the farmer, and \( d \) is a positive parameter. The first-order condition derives the optimal supply to the spot market.

\[
FOC: \frac{\partial \pi^*_i}{\partial q^i} = p^*_i - 2dq^i = 0
\]

---

8 Considering different cooperatives with different marketing techniques, see White, Jr. (1993) and Wissman (1997).
(29) \[ q^i = \frac{p_x^c}{2d} \]

Plugging (29) into (28), the farmer’s expected profit in the spot market can be written as:

(28) \[ \pi_i = \frac{(p_x^c)^2}{4d} \]

This establishes a reservation profit, which profits from selling to a cooperative must exceed.

By contrast, if a farmer chooses to join a cooperative where \( N \) homogenous member-farmers are assumed in the cooperative, then recall from Section 3.3.1 that the farmer’s production and price received from the cooperative according to the Rubinstein (1982) model are:

(6) \[ q^i = \frac{bp_b}{2N(d - ap_b)} \]

(7) \[ p^c = \frac{bp_b(3d - ap_b)}{4(d - ap_b)} \]

Hence, the farmer’s profit function for joining a cooperative is:

(30) \[ \pi^i = \frac{b^2 p_b^2}{8N(d - ap_b)} \]

Intuitively, the outside option (the expected profit in the spot market) matters only if it is above the bargaining outcome payoff. That is, an individual farmer is willing to join a cooperative as long as he can get at least the same profit as what he would earn if he chooses to stay outside. That is, \( \pi^i \geq \pi_i \). However, free entry and arbitrage between sales to the spot market and cooperatives will imply \( \pi^i = \pi_i \).
That is, the profit received from the cooperative due to bargaining will be equal to the profit received from the spot market under the assumption of homogenous farmers and open membership\(^9\). According to this argument, the most efficient number of members for the cooperative can be derived by equating (28) and (30). That is,

\[
N = \frac{d b^2 p_b^2}{2(p^*_e)^2(d - a p_b)}
\]

From (31), it is obvious that the optimal number of members decreases as the expected spot price increases. The greater the expected spot price, the more attractive it is for a farmer to stay outside the cooperative. In addition, an increase in the processed price results in an increase in the optimal number of members. Note that the sharing rule of the Rubinstein model in case 1 is assumed to equally divide the total surplus. Increases in the processed price are expected to cause the total surplus to increase, which means that both processor’s and cooperative’s profits increase as well. Hence, given \(N\) members in the cooperative, every member’s profit increases when the total surplus increases.

Furthermore, just as individual farmers have an outside option, processors have an alternative to obtain supply from the spot market. The most obvious alternative

---

\(^9\) Open membership is one of the first cooperative principles, which distinguishes cooperative from non-cooperative businesses. The others include one member has one vote, political and religious neutrality, no unusual risk assumption, etc. See details in Co-op 101: An Introduction to Cooperatives, USDA, 1997.
supply source for processors is nonmember production. In other words, processors can purchase from the spot market. Since the spot market is competitive, the price is a decreasing function of quantity. If more farmers joined the cooperative, then less production is supplied to the spot market, and, in turn, the spot price may increase. In sum, the implications of an outside option for individual farmer’s decisions, and individual farmer’s decisions for an outside option, are interrelated. The trade-off exists between joining a cooperative and staying outside. This is because, while a farmer decides to join the cooperative to share the collective bargaining profit, his entry will reduce the sharing profit, and the expected profit to stay outside of the cooperative increases because of increases in the expected spot price. Thus, this endogeneity of the outside option is an important issue to be kept in the model, when explicitly modeling such a situation.

3.6 Discussion of Possible Extensions

Farmers organize a bargaining cooperative when it helps them to accomplish their goals better than they could if they traded in the market as individuals. However, members typically have diverse economic interests (Reynolds, 1997). To evaluate the collective bargaining that involves heterogeneous farmers, the approach by the Rubinstein model may not be appropriate. The heterogeneous farmers can be characterized by introducing differential production costs. Suppose that there are
two types of production costs: one is high and the other is low. Given that a uniform price is paid to each member-farmer and that each type of farmer is distributed equally, low cost farmers will be driven out of the cooperative. In equilibrium, the high cost farmers choose to join the cooperative, whereas the low cost farmers stay outside. This hypothesis is confirmed by an argument stated by Reynolds (1997). He claimed that cooperatives have historically been competitive in managing marketing and farm service tasks that are relatively uniform for the membership. In addition, cooperatives may want to avoid increasing membership when it leads to increased diversity across member interests. Rather in this case, observation indicates cooperatives should set up new organizations to meet specialized needs.

One method to model collective bargaining with heterogeneous farmers is to design collective bargaining as a cost-sharing device. Given some cost distribution, one may show that there exists a critical value of cost, at which farmers join a cooperative if their costs are below this value, and stay outside if their costs are above this value. The details warrant further study.

3.7 Conclusions

Economic reality is forcing farmers to manage their industry and earn more profits from the marketplace (Levins, 2001). The weakness for an individual farmer in marketing can be addressed as follows. First, few farmers who market their
production to a processor can match the buyer’s power and size. Despite the growth in the size of individual farmers, few can match the power of the buyer except when joining with others to achieve a measure of equity (Bunje, 1980). Second, while bargaining, the Rubinstein model has shown the need to play games with timing in order to gain an advantage. Few individual farmers have the flexibility to deny the advantages that have been theirs by default. Third, few individual farmers have the time to analyze the market for their production. Without a skillful representative and basic information, rational and accurate marketing decisions may not be made. Therefore, by working together in collective bargaining through cooperatives, farmers gain better control of their own economic destiny.

This essay identifies the problem of whether bargaining is appropriate for a given market environment. We set up a bargaining model between buyers and sellers for their contracts in which they bargain over price and/or quantity. Comparing two varieties of bargaining models with two extreme cases, competitive equilibrium and the monopsony market, we can gain more insights into collective bargaining’s value and importance. Table 3.3 summarizes the rank of effects on price, quantity, and profit across the four cases.
The results in this essay show that bargaining doesn’t just increase prices paid to farmers when compared with monopsony and competitive markets; the total surplus associated with bargaining is also positive. We conclude that collective bargaining can increase producer profits in marketplaces, where they face individual processors that might exercise monopsony power in the absence of collective bargaining. In the absence of collective bargaining, we find it likely that individual producers will receive the lowest price and zero profit.

In addition, bargaining’s success or effectiveness should be evaluated based on its total impact, thereby considering total surplus. As the competitive market improves total surplus, the formation of the bargaining unit serves to transfer some of the surplus from the processor to the farmer cooperative. In other words, collective bargaining through cooperatives enables farmers to capture margins from the marketplace, which otherwise would go to processors. Hence, bargaining reduces

<table>
<thead>
<tr>
<th>TABLE 3.3 RANK OF EFFECTS ACROSS CASES</th>
</tr>
</thead>
<tbody>
<tr>
<td>CASE1: RUBINSTEIN MODEL</td>
</tr>
<tr>
<td>-------------------------</td>
</tr>
<tr>
<td>Equilibrium price</td>
</tr>
<tr>
<td>Equilibrium quantity</td>
</tr>
<tr>
<td>Processor profit</td>
</tr>
<tr>
<td>Cooperative/farmers</td>
</tr>
<tr>
<td>profit</td>
</tr>
</tbody>
</table>

...
asymmetric bargaining power between two groups, while also maximizing total surplus. Also, collective bargaining through cooperatives can be an effective vehicle for farmers integrating down the market channel.
References:


Appendix 1: An overview of collective bargaining in current U.S. agricultural markets

Today, there are more than 4,000 agricultural cooperatives in the U.S., and they handle 30 percent of farm output (Hayenga et al. 2000). In general, cooperatives are coalitions of farmers/producers offering their members a number of services, such as production and marketing advice. In addition, cooperatives tend to equalize bargaining power by negotiating prices and terms of trade with processors. The operation of cooperatives is like a producer cartel, which maximizes producers’ joint profit, thereby circumventing the monopsony power of the processor (Sexton 1986). Cooperatives represent their members’ collective views and accomplish their collective aims concerning prices and terms of trade (Bunje 1980).

Some cooperatives limit their activity to negotiating prices and terms of sale with buyers. These cooperatives are also called bargaining associations (USDA 1999). We provide a brief review of cooperative bargaining in recent U.S. agricultural markets. For example, a cattle-feeding cooperative can be a group bargaining organizations for fed cattle marketing (Schroeder, et al. 1997). It is a management team, which collects fed cattle for sale, negotiates sales on behalf of cattle owners, and coordinates delivery to packers. The goal of a cooperative (group bargaining) is to improve coordination between cattle feeders and packers by reducing buyer costs of procuring desired cattle qualities and quantities.
Another example of cooperatives is the fruit and vegetable cooperatives. Fruit and vegetables crops are very weather-sensitive commodities and are prone to wide swings in supplies and prices (Jermolowicz 1999). The cooperatives represent their members to negotiate not only raw product price, but also some non-price terms of trade, such as time and method of payment and quality standards. Their primary objective is to increase grower returns by countervailing the market power of buyers.
Appendix 2: A brief overview of the Rubinstein (1982) alternating-offers bargaining game

In the model of Rubinstein (1982), two players must agree on how to share a pie of size 1. The first move of the game is player 1 making an offer, which player 2 then either accepts or rejects, with acceptance ending the game. If a rejection occurs, player 2 makes an alternating offer. The game continues so long as no offer has been accepted. The subgame perfect equilibria (SPE)\(^\text{10}\) has some equilibrium properties as follows\(^\text{11}\). The first is efficiency. All SPE agreements are reached immediately. The second is that players play stationary strategies\(^\text{12}\). Under the assumption of “stationarity”, for any history after which it is play i’s turn to make an offer, he makes the same offer, and for any history after which it is his turn to respond to an offer, he uses the same criterion to choose his response. The third is first mover advantage. The first mover obtains more than half of the pie. This result indicates that there is an advantage to being the first to make an offer. However, in the finite horizon game, when the discount factor goes to one of the players, the first mover advantage disappears. The last property is the comparative-statics of impatience. Since bargaining imposes costs, which are represented by time discount factors on both players, a player’s bargaining power is assumed to be dependant on

\(^{10}\) The notion of SPE requires that the action prescribed by each player’s strategy be optimal, given the other players’ strategies, after every history (Osborne and Rubinstein 1994, p.97).

\(^{11}\) See details in Muthoo (1999), chapter 3.

\(^{12}\) In equilibrium, a player makes the same offer whenever she has to make an offer.
his relative discount rate. That is, a player’s bargaining power is smaller when his
discount rate increases. Hence, it is intuitive that the equilibrium partition depends
on the players’ relative bargaining powers.

In the unique SPE, the equilibrium quantity traded maximizes the total surplus.
To maximize total surplus, the buyer’s marginal revenue must equal the seller’s
marginal cost. The total surplus can be increased by increasing (or decreasing) the
seller’s output, as long as the addition to the revenue exceeds (or is less than) the
addition to the cost. This suggests that the bilateral monopoly equilibrium (the
resulting equilibrium between the monopsonist processor and the co-op behaving as a
monopolist) is Pareto efficient. It is straightforward that an outcome is Pareto
efficient if and only if agreement is reached immediately as bargaining begins. The
equilibrium trade price is a convex combination of the buyer’s equilibrium average
revenue and the seller’s equilibrium average cost. In other words, the seller and the
buyer set quantity to the level, which maximizes the total surplus, and use the price as
an instrument to divide the generated surplus.
Vita

Ming-Chin Chin

Education: Ph.D., Agricultural Economics, The Pennsylvania State University.

M.A., Economics, June 1995, National Cheng Chi University, Taiwan.

B.A., Economics, June 1993, National Cheng Chi University, Taiwan.

Area of Concentration:

Primary: Pricing and Marketing Economics

Secondary: Production Economics

Relevant Professional Experience:

Research Assistant:

Robert D. Weaver, Penn State (Fall 2000-Spring 2003).

John C. Becker, Penn State (Summer 2000-Spring 2001).

Ching-Cheng Chang, Academia Sinica, Taiwan (Summer 1996-Spring 1998).

Hsin-Ping Chen, National Cheng Chi University, Taiwan (Fall 1993-Spring 1995).

Instructor:

International Trade, Chi Lee College of Business, Taiwan (Fall 1995-Spring 1998).

Statistics, Chi Lee College of Business, Taiwan (Fall 1995- Spring 1998).