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Doussou Traore
University of Nebraska - Lincoln, Doussou.Traore4@huskers.unl.edu

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By

Doussou Traore

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Doussou Traore, M.S.

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Advisor: Jeffrey S. Royer

In this report, we discuss market relations in the cattle and beef sector of the United States by setting up a sequence of optimization decisions taken by cattle feeders (producers, sellers) and meat packers (processors, buyers) to solve for the equilibrium supply and demand proportions in the contract market in a first stage given the respective degrees of risk aversion for the representative producer and processor. Subsequently we derive the impacts of contracts, namely impacts on the spot market price and the processors' ability to exercise oligopsony power, in a second stage. Using a model for a fixed-price contract, the equilibrium proportions allocated to the contract market by producers and processors correspond to those in Buccola's model of decisions under risk (1981). This model is extended to solve for the equilibrium in the case of unequal bargaining power between the producer and processor. The residual supply function is used to derive the spot market price through a conjectural variation model and we refer to the prominent Lerner Index for the downstream processor's oligopsony power. We find that the use of fixed-priced contracts for risk averse producers and processors can serve to reduce the spot market price offered for cattle given the assumption that the residual supply becomes more inelastic. Hence, the processor enjoys higher oligopsony power in the spot market.

We run simulations in a spreadsheet model to derive further insights about key parameters, including the risk aversion coefficients, the spot market price variance, the

coefficient of expectations, and the bargaining power weights in the contract market. We observe that when the spot market price is expected to be higher than the equilibrium fixed contract price, increases in the producer's coefficient of risk aversion cause their optimal share of cattle marketed through contracts to increase and hence it contributes to a higher spot market price. On the other hand, when the expected market price is lower than the equilibrium contracted price, increases in the producer's coefficient of risk aversion decreases the producers' optimal share of cattle marketed through contracts relative to the processors' and hence contributes to lower spot market prices. These two results are due to the fact that increasing risk aversion decreases the sensitivity with which optimal portfolios react to changes in the price parameters. By simulating increasing (decreasing) spot market price variance, we observe the equilibrium contracted proportions to increase (decrease) accordingly. In turn, this causes a lower (higher) spot market price. The simulations on the degree of the processors' bargaining power in the contract market show that increases in the processors' bargaining power induces higher demand for contracts by processors and lower supply of contracts by producers. This results in a decline in the contract price and an increase in the spot market price.

Finally, a brief exercise in a dynamic decision making reveals that a producer will always choose to contract out a proportion of their cattle as long as they are less than 50% certain that, on average, future market prices will be slightly lower than the offered contract price.

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Glossary of Symbols

Variable	Description
α	Coefficient of expectations; with subscrip "s" for sellers and "b" for buyers
A	Total quantity bought for processing
β	Weighted average conjectural variation for processors
γ	Processor's risk aversion coefficient
δ	Small but significant value
ε	Elasticity of supply
ε_o	Elasticity of residual supply
E_m	Expected market price of cattle
$E_b k$	Equilibrium contract price of cattle
Λ	Producer's risk aversion coefficient
θ	Processor bargaining power in the contract market, $0<\theta<1$
Φ	Elasticity adjustment constant
N	Conjecture of processors
π_s	Seller's profit
π_b	Buyer's profit
C	Per-unit production costs
D	Per-unit processing costs
F	Per-unit fixed costs of production
G	Per-unit fixed costs of processing
kB	Per-unit price in the contract market; as a function of the per-unit variable cost (B) of production and some positive factor (k)
L	Composite Lerner's Index for oligopsony power
m	Marketing input for processing
M	Spot market price
n	Number of processors with n= 1, 2, …, j, i
N	Number of producers
p_t	Probability at time t that $E_m^t > Ebk$
R	Per-unit price of final output
S	Variance term
s	Supply shift constant
t	Number of periods in fixed-price marketing agreement with t=1, 2, …, T
U	Exponential utility function
V	Proportion of cattle sold through contract
W	Proportion of cattle purchased through contract
X	Total quantity produced for sale
Y	Certainty equivalent of risky prospects for the buyer
Z	Certainty equivalent of risky prospects for the seller

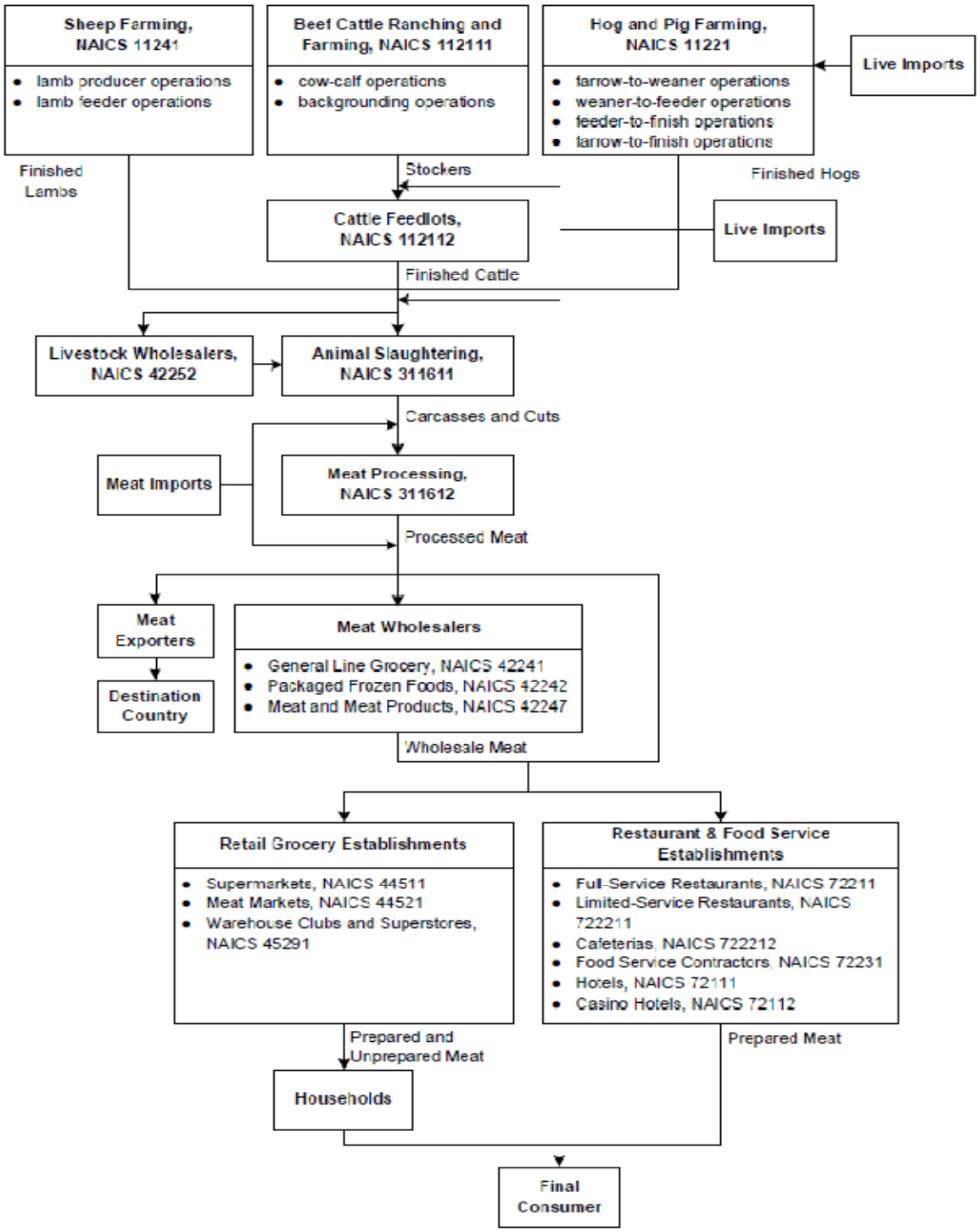
Chapter I. Introduction

Overview of the United States' livestock industry and alternative marketing arrangements (AMAs)

This paper discusses changes in the market relations in the cattle and beef sector of the United States. The elements contributing to these changes are increases in the size of farms, changes in production technologies, increased enterprise specialization, and tighter vertical coordination between stages of production. We specifically address the impacts contractual coordination may have on the markets for cattle feeders and meat packers given their idiosyncratic characteristics. For this purpose, we use a model for contracts to examine the spot market conditions for feeders and packers; notwithstanding, the implications are also relevant for other agricultural raw product markets.

The production and marketing of meat include multiple stages, as per Figure 1 below. At the farm level, cattle are produced on single species farms and usually at multiple locations including breeding operations, feeder operations, and finishing operations (USDA, 2005; MacDonald and McBride, 2009). These farms have become much larger and specialized recently. Finished livestock are delivered for slaughter to specialized establishments with single species and in some cases multiple species. Once livestock are slaughtered, carcasses and cuts from animals may be further processed at processing establishments before being delivered to consumers, either through retailers or at restaurants and food service establishments.

Figure 1: Overview of the Meat Production Industries from Farm to Final Consumer



Note: NAICS = North American Industry Classification System.

Source: USDA, 2005.

The linkages between each of the illustrated stages are achieved through schemes that have evolved throughout the history of the industry. These schemes generally agree with the belief that an economic organization is designed to minimize the transaction costs of doing business between parties. Economizing on transaction costs is seen as the primary motivation for adopting different structures governing the relationship between parties of a transaction (Williamson, 1979; Wu, 1992; Ward, 1997; USDA, 2005; Kvaloy and Tveteras, 2008). As the transactions between two parties become recurrent and involve high uncertainties and high levels of specific investment, as is the case for livestock, the two will have strong incentives to integrate or to coordinate to some degree. Beldon (1992) explains that the ineffectiveness of traditional markets in communicating signals to producers and the inconsistency of producer response have contributed to the increasing use of other institutional models to coordinate production, marketing, and processing in many industries.

Alternative marketing arrangements (AMAs) are increasingly applied in the livestock industry. AMAs refer to all possible alternatives to the "cash" or "spot" market. They are methods through which livestock and meat are transferred through successive stages of production; the AMA specifies the pricing method and the terms of delivery. AMAs can also refer to captive supplies, which by definition are slaughter livestock that are committed to a specific buyer two weeks or more in advance of slaughter. These practices are undertaken in the industry for efficiency purposes including financial risk management, diffusion of innovations, quantity and quality assurance, information, and traceback capabilities. Documented benefits to cattle feeders include price risk management, access to markets and to financing, opportunities for carcass quality premiums, and reduced marketing costs (Shroeder et al, 1993; USDA, 2005; Taylor et al, 2007). Packers' benefits

include secured cattle slaughter volume to match capacity, more control over the type and quality of cattle, and reduced procurement and information costs. Cash or spot market transactions refer to transactions that occur immediately. They serve an important purpose in the industry, particularly for small producers and small packers. They also provide benefits to market users because the transaction terms such as prices, location, and observable quality characteristics are readily available and easy to record.

From October 2002 through March 2005, the use of AMAs, including packer ownership, was estimated at 38% of the fed cattle volume destined to beef production, 89% of the finish hog volume, and 44% of the fed lamb volume sold to packers (USDA, 2005). However, there is a high weekly variability in procurement method both in percentage terms and in absolute volume as per Ward (2005). Between 2001 and 2003, for any given week, the percentage allocation for cattle to cash market was as low as 24.5% and as high as 76.9%. In the same period, the combination of supply contracts and marketing agreements ranged between 22.1-64.8%, forward contracts were between 0.2-9.4%, and packer ownership was between 2.6-13.6%.

Beef producers have increased the level of vertical coordination through marketing agreements, alliances, retained ownership, part-ownership, and partnerships with downstream processors. Likewise, downstream processors have achieved coordination through part-ownership, partnerships, and profit sharing with other downstream processors, upstream producers, and cow-calf operations. There are also alliances with some retailers and food service companies. Unlike the case with other meats such as poultry, due to the combination of large investment requirements (land) and complex genetic specificities (wide base and long cycle), vertical coordination in the beef production system is typically not done by fully combining stages (vertical integration). When full

integration occurs in the sector, the enterprises tend to operate as separate profit centers. For instance, the largest investors in National Beef Packing also have cow-calf operations, but the business entities are not combined (USDA, 2005).

AMAs include arrangements such as forward contracts, marketing agreements, procurement or marketing contracts, production contracts, packer ownership, custom feeding, and custom slaughter. Marketing agreements are the most commonly used AMA in cattle procurement and marketing. A typical marketing agreement contract runs from four to seven years and stipulates the producer compensation scheme, risk sharing provisions, minimum number of fed cattle to be supplied in each period, and minimum standards for cattle quality (Hayenga *et al.* 1996). Spot market examples include auction barn sales; video or electronic auction sales; sales through order buyers, dealers, and brokers; and direct trades (or private treaty sales).

The increased use of AMAs raises a number of questions about their motivations and their effects on economic efficiency and on the distribution of the benefits and costs between the different actors of the supply chain. The main actors along the beef supply chain are cattle feeders (farm level), meat packers (wholesale), retailers and consumers.

Purpose of the study

Welfare impacts of the practice of AMAs are of concern. As Rogers and Sexton (1994) observe, many agricultural markets have oligopsonistic characteristics, in which a small number of downstream processors exercise market power over a much larger number upstream producers. Some industry observers (USDA, 1996a and 1996b) fear that increased vertical integration, in any degree, in the livestock industry has the potential to increase the oligopsony power of the already highly concentrated downstream meat packers. Contractual agreements are feared to be able to

allow for strategic behavior, interfere with price discovery, result in unequal access to markets and market information, and can be used by large packers to deter entry. For instance, large processors are able to encourage producers to enter into a production contract by offering attractive terms at first. Processors could then exploit the subsequently gained market power to impose less favorable contracts in the next period in an unequal bargaining process.

Moreover, in 2002 Taylor observed a long-term downward trend of the monthly real retail value of beef since 1980 along with a declining trend in the real price of fed cattle; all while between 1993 and 2002, the farm-to-wholesale price spread has amplified by 50%. Taylor, in his testimony to the U.S. Senate on the hearing on a proposed ban on packer ownership of livestock and USDA's enforcement of the Packers and Stockyards Act, defends that the exertion of monopsony or oligopsony power is the only plausible explanation for the strong upward trend in the farm-to-wholesale spread for beef; and holds the following position on the issue:

> The implication of preferential treatment of some of the contractors (cattle feeders) by packers is that the aggregate supply curve for slaughter is shifted outward, lowering cash market price and thereby harming independent producers. The preferential treatment of some producers may allow them to maintain profitability even with lower cash prices. However, independents will be eventually forced out of the business due to sustained losses. If the beef and pork sectors evolve like the poultry industry, we can expect that once the independents are gone, the premia for the remaining cattle feeders will evaporate, leaving them at the mercy of the monopsonistic or oligopsonistic contractors (pp.8).

The issue of vertical integration in agricultural markets is an exceptionally important one; a structured study is hence necessary to better understand different practices and to explain the implications for all parties involved. We intend to evaluate the process where risk averse feeders and packers enter into contracts for the sale and purchase of cattle within an oligopsonistic setting. Many attributes for heterogeneity can characterize such decision making.

In this study, we evaluate feeders and packers in terms of their respective degrees of risk aversion. The degree of risk aversion is a key attribute as it can explain why the parties to a transaction are more or less willing to lock in a predetermined price and quantity now as opposed to waiting to see if the market would or would not turn out in their favor later after all other required investments have been made. It is believed that output is likely to be more restricted under contracts than under other means of exchange; and hence, it is misleading to use a vertical integration model as a proxy for a contract model in assessing any impacts (Wu, 1992). Hence, we use a model for contracts.

The present analysis should provide useful information to cattle feeders, meat packers, consumers, and public policy makers. A demonstration of what can be expected in the market with increased contracting and decreasing open market transactions, as well as an assessment of the underlying reasons, is informative for both producers and processors who are considering whether to enter into contracts or to transact in the spot market. Generally, information about the effects of contract coordination on the market structure and thereby on social welfare is valuable to public policy makers in determining whether to adopt policies that support or discourage the use of contracts in the procurement of beef-cattle. Additionally, before taking a stand to promote or to oppose the use of contractual agreements in the beef sector, it is important to understand the different economic incentives and/or disincentives for both producers and processors to use different marketing forms and the consequences of limiting such options in the market. Hence, the purpose here is to provide a structured framework and to take a deeper look into the economics of contractual agreements such as *ex ante* risk mitigation purposes and to highlight the possible consequences *ex post* on the spot market and market power.

Chapter II. Literature Review

The literature review is in two parts. The first part discusses evidence of oligopsonistic behavior in the livestock industry. An oligopsonistic market is a market in which there are only a few large buyers for a product or service. This allows the buyers to exert a great deal of control over the sellers and can effectively drive down prices. Chen and Lent (1994) looked at the effects of an agricultural product supply shift on the equilibrium prices and quantities of farm products purchased by food processors, and on profits of food processors. In this paper, a similar framework is used for deriving the Lerner Index of oligopsony power.

Rogers and Sexton (1994) identified several characteristics of first-handler agricultural markets that leave them susceptible to buyer power when buyer concentration increases. These characteristics are the bulky and perishable nature of the product that is costly to transport, the processors' demand for specialized farm products, and the inelastic supply at the farm level due to high sunk assets. They limit spatial competition among buyers, and higher industry concentration together with inelastic farm supply present compelling structural evidence of buyer market power.

Azzam and Schroeter (1995) analyzed the tradeoff between regional oligopsony power and cost efficiency resulting from consolidation in a food processing industry. The model was used to calculate the cost reductions necessary to offset the anti-competitive effects of market power and to compare them to actual cost savings achieved through plant scale or multi-plant operating economies. They found the estimated cost savings necessary to neutralize the anti-competitive effects of consolidation in beef packing were about half the actual cost savings of scale economies.

Furthermore, in 1997, Azzam separated the market power effect of concentration from its cost-efficiency effect. Using an example of the U.S. beef-packing industry, an empirical analysis was conducted on the model. The findings support the existence of both oligopsonistic market power and slaughter-cost efficiency in the industry. However, the cost efficiency effect outweighs the market-power effect.

Subsequently, Azzam and Rosenbaum (2001) looked at the link between market concentration and price. In the paper, they developed a theoretical model to address how much of the link can be attributed to market power and how much to efficiency. Applied to the U.S. Portland cement industry, the model indicated that both impacts matter. In relative terms, however, the market power effect was twice as large as the efficiency effect. The differences in results mainly came from differences in the industries in question and the timing of the studies. In the case of livestock, the period leading up to late 1990s was characterized by increasing consolidations downstream. However, of concern is that more recently, the exertion of monopoly and monopsony power has negated the efficiency gains in meatpacking and retailing that occurred in the 1980s (Taylor, 2002).

This second part of literature review discusses work conducted on vertical integration and contractual coordination in livestock marketing and the revealed open market impacts. The use of different marketing methods has a seasonal component and can vary widely from plant to plant and week to week (Ward, 2000). The market power incentives for processors and packers to integrate backward and the effect of such integration on prices, output, and economic welfare have been analyzed using a model developed by Martin Perry in 1978. Perry provided a workable concept of backward integration. The traditional measure of backward integration by a

firm has been the ratio of its own production of an intermediate input to its total employment of the input. Such a measure defines vertical integration as the resolution of the firm's production decisions and is empirically useful. Instead, Perry proposed a measure of backward integration which is independent of the production decisions made by an imperfectly competitive buyer. This measure allowed the evaluation of the impact of backward integration on a monopsonist's choices of input production and employment. In the model, a monopsony firm purchases an input it uses in producing a final product, which it sells to consumers in a competitive market. In addition to purchasing input, the firm can produce the input by integrating backward and acquiring the production capacity of some of the input producers. The optimal degree of integration, as defined by the proportion of the input production capacity acquired by the monopsonist, depends on its acquisition costs.

Perry demonstrated that for several reasonable specifications of the acquisition costs, the monopsonist will have an incentive to integrate backward, at least partially. He also demonstrated that increased backward integration by the monopsonist will generally produce an increase in input employment, resulting in increased output and a lower final product price for consumers. Total economic welfare would be improved, but the price received by the remaining independent input producers would decrease. According to Perry, vertical integration, and presumably vertical coordination, in response to transactional economies can be expected to increase economic welfare. On the other hand, vertical integration in reaction to market imperfections may either increase or decrease economic welfare, thereby raising public policy questions regarding the desirability of integration.

Azzam and Wellman (1992) applied Perry's model to examine the expected effects of increased backward integration by packers in the slaughter hog industry. Assuming constant elasticity forms for the derived demand for hogs and the hog supply function, they simulated the effects of increasing the degree of vertical integration by a monopsonistic packer on hog slaughter and variables related to independent producers for a range of elasticities of demand and supply. Their results demonstrated that increased integration can be expected to increase overall pork production and lower consumer prices while decreasing hog production by independent producers and lowering both the price they receive for hogs and their net earnings.

A limitation of monopsony models is that they cannot be used to analyze the market power incentives to integrate backward under oligopsonistic conditions that characterize many agricultural markets (Rogers and Sexton, 1994). Azzam (1998) extends a one-product two-input model to consider a profit maximizing and partially integrated oligopsonistic industry. The result shows that although the empirical relationship between captive supplies and the price received by independent producers is negative, it may or may not be attributed to noncompetitive conduct.

Azzam's paper did not offer an explicit motivation for exclusive contracts. Rather, an equilibrium displacement model of an industry was used to derive an expression for the elasticity of the open market price with respect to the degree of integration of the processors. The elasticity of the open-market price with respect to the degree of vertical integration was evaluated by considering shocks in the output demand, in the respective supplies of the open-market farm input, captive supplies, or the market input. The resulting expression conveyed that the response of the open market price to changes in the degree of vertical integration is

determined in a complex way by the respective fractions of expenditures on the farm input accounted for by open-market and captive supplies; by the respective fractions of total expenditures on all inputs accounted for by non-captive supplies, captive supplies, and marketing input; by the elasticity of substitution between the farm input and the marketing inputs; by the supply elasticity of the farm input from external sources; by the open-market power; and by the extent to which that market power is affected by increasing levels of captive supplies relative to total slaughter. The sign of the elasticity was unambiguously negative under circumstances described in the paper. The sign remained negative whether vertical integration did or did not worsen conduct, or whether conduct was competitive or noncompetitive.

Azzam's results suggest that noncompetitive conduct is not a necessary condition for the inverse relationship between the open-market price and the degree of vertical integration. Azzam concludes by stating that further research, such as studying the market comparative statics under alternative motives for backward integration and alternative market structures and distinguishing between their idiosyncratic predictions, could be an improvement over his model. Another improvement would come through considering a contract price that is not equivalent to the marginal cost of captive supply, as assumed in the present paper.

The objective in Schroeter and Azzam's 1999 econometric analysis of 1995/96 fed cattle procurement in the Texas panhandle was to get a clear understanding of the nature of the short-run relationship between packers and feeders to determine whether the capability exists for one party to use short-run strategies as a means of manipulating spot market prices to the detriment of another party. They looked at the week-to-week relationship between the delivery volumes of cattle procured by non-cash methods and the spot market price of fed cattle. The regression

results, at the plant level and at the regional level, uncover a stable and robust empirical regularity that the use of non-cash procurement methods is negatively correlated with the spot market prices. They add further insights stating that for both packers and feeders are able to inter-temporally shift non-cash cattle deliveries in response to economic incentives dictated by changing market conditions. For instance, other things equal, deliveries of marketing agreement and forward contract cattle will tend to be "high" when the ex ante forecast of the spot market price is "low."

Love and Burton (1999) developed a strategic rationale for spatial backward integration of a dominant firm and a competitive fringe. A partially backward integrated dominant firm can increase profit through efficiency gains in production and through a lower price for externally purchased input. The optimal degree of backward integration results when the dominant firm's profit from exerting monopsony market power in the external spot market equals its profits from producing raw input internally, less the incremental cost of acquiring internal raw input production capacity. The open market price may rise or fall depending upon how integration affects the residual elasticity of raw product supply.

Zhang and Sexton (2000) studied an interesting empirical regularity occurring in markets featuring contract and spot exchanges: the spot price is inversely related to the incidence of contract use in the market. They used a spatial model and a non-cooperative game approach to develop a duopsony (two buyers) within spatial markets to show that exclusive contracts can be used in some market settings to diminish competition between buyers. The motivation for the use of captive supply contracts in this case was to influence the cash market price; the implications for competition are therefore much different from prior analyses. The

most general model involved processors deciding first on the geographic areas in which to offer captive supply contracts and then in the spot market to procure supply not committed through captive contracts. As the model was not tractable in its full generality, the authors focused on two simplified versions of the more general model. The first version was an asymmetric model in which firm A offers captive supply contracts but firm B does not. In the second version, both firms may offer captive supply contracts, and therefore compete in both the contract and spot markets.

They concluded that captive supplies, in settings where the spatial dimension is important (costly transportation), represent geographic buffers that reduce competition among processors. The model predicted that, all things equal, if captive supply contracts are being used to influence the cash price, those feedlots with captive supply contracts would be located at greater distances from the packer than their cash market suppliers. This is due to the potential of boundary jumping that could occur. The model also predicted that the producer price in the captive supply contracts must be at least as high as the cash market price, holding other factors such as quality constant.

Furthermore, they concluded that captive supply contracts will be more prevalent in the more concentrated procurement areas because they are rendered ineffective by boundary jumping in markets when competition (as measured by the transportation cost) is sufficiently intense. Their conclusions are important because prior studies have tended to emphasize explanations that do not involve market manipulations. Contracts may be motivated by any of several efficiency considerations, addressing problems of adverse selection and/or moral hazard

among producers, as mentioned in the introduction of this paper. Nonetheless, the analysis shows captive supplies may influence the cash market price to producers' detriment.

As Taylor (2002) mentioned, there is substantive theoretical literature that established conditions under which either contracting or vertical integration may be privately preferred yet socially inefficient, even in the absence of externalities. It is important to evaluate the expanding use of contracts in agricultural markets. This review of the literature emphasizes that concerns are greatest in markets that feature high buyer concentration and high transportation costs (especially when relative to the net value of the finished product). With the exception of Zhang and Sexton (2000), the papers reviewed model vertical integration as a proxy for all forms of vertical coordination through contracts even though output is likely to be more restricted under contracts. A formal model for supply contracts specific to the cattle and beef sector is indeed an important contribution to the literature.

Chapter III. Model

In this section, the purpose is to set up a sequence of optimization decisions taken by both cattle feeders (producers or sellers) and meat packers (processors or buyers) to solve for the equilibrium supply and demand in the contract market and to derive the subsequent spot market outcomes given the producers and processors' respective degrees of risk aversion.

The set up the model depicts cattle marketing consists of periodic transactions. In each period, there are two sequential stages. In the first stage, the producers, having already made their production decisions, decide on the proportion of their planned production they want to sell under contract. Likewise, the processors, also having already made their production decisions, decide on the proportion of the raw product they want to purchase under contract. The first stage is a static optimization problem set up using Buccola's decisions-under-risk model for a fixed-price contract case (Buccola, 1981). They do this by maximizing the values of their respective certainty equivalents for profits given their utility functions. Subsequently, in a second stage, we use the residual supply to derive the spot market price using a conjectural variations model.

Producers and processors marketing decision

Producers' problem

Producers are many and each has attributes that determine their choice to sell in one form of market as opposed to the other. Following Buccola's (1981) decisions under risk model, consider a producer who plans to produce X units of a good and has the choice of selling some of these units under a marketing contract and some on the open market. Fixed-price contracts are typical because cattle feeders have the choice of contracting a portion of their cattle for a

fixed and known price over the period of the contract; the remainder can be sold afterwards at the prevailing market price, which at the decision time is a random and unknown variable. The per-unit contract price received is *kB* which is a function of the per-unit variable cost *B* (a random variable) of production and some positive factor (*k*). Both *B* and *k* are constant in a fixed-price contract; and therefore have a variance of zero. Defining *M* as the spot market price and *V* as the proportion of *X* sold under contract given $0 \le V \le 1$, C as the per unit variable cost, and *F* as per-unit fixed costs, seller profit π_s is:

$$(1) \qquad \pi_s = X\left[VkB + (1-V)M - C - F\right]$$

Following Buccola, the negative exponential utility function $U = -e^{\lambda\pi}$, $\lambda > 0$, with constant risk aversion coefficient λ is used in this analysis. Assuming that the returns are normally distributed, the negative exponential utility may be maximized explicitly by maximizing the producer's certainty equivalent of risky prospects *Z*:

$$(2) \qquad Z = E_s(\pi) - (\pi/2)\,\mathrm{var}(\pi) \text{ if } \lambda > 0 .$$

The certainty equivalent of risky prospects is the guaranteed payoff at which the producer is "indifferent" between accepting the guaranteed payoff and a higher but uncertain payoff. Below, expected values are denoted by *E*, variances and covariances by *S*. Assuming the variance of fixed costs *F* is zero, the general certainty equivalent *Z* of risky prospect is:

$$Z = X\left[\left(E_{sm} - E_{sc} - F\right) + \left(-E_{sm} + E_b k\right)V\right] - \left(\lambda / 2\right)X^2 \left[\left(S_m^2 + S_c^2 - 2S_{mc}\right) + \left(2\left(-S_m^2 + S_{mc}\right) + 2k\left(S_{bm} - S_{bc}\right)\right)V + \left(S_m{}^2 - 2S_{bm}k + S_b{}^2 k^2\right)V^2\right] \quad (3)$$

E_{sm} is the expected spot market price, E_{sc} is the expected variable cost of production, $E_b k$ is the fixed-price of contract, $S_m{}^2$ is the spot market price variance, $S_c{}^2$ is the variance of the variable production cost, S_{mc} is the covariance between the spot market price and the variable cost of production, S_{bm} is the covariance between constant b and the spot market price, S_{bc} is the covariance between the constant b and the variable cost of production. All else is previously defined.

As per Buccola, the optimal contract proportion V^* at which certainty equivalent Z reaches an extreme value for a fixed-price contract is:

$$V^* = \frac{E_{sm} + E_b k - \lambda X\left(-S_m{}^2 + S_{mc}\right)}{\lambda X S_m{}^2} = 1 + \frac{-E_{sm} + E_b k}{\lambda X S_m{}^2} - \frac{S_{mc}}{S_m{}^2}. \quad (4)$$

where $0 < V^* < 1$.

The producer maximizes her expected utility by selling V^*X under the contract and $(1-V^*)X$ in the open market. The responsiveness of V^* to different values of λ and $E_b k$ provides

interesting insights into the behavior of the contract supply curve. The impact of a marginal increase in the fixed-price on the optimally contracted proportion is $\frac{\partial V^*}{\partial(E_b k)} = \frac{1}{\lambda X S_m^2}$, positive and invariant with respect to the fixed-price level. Similarly, the impact of increased risk aversion on the optimally contracted proportion is $\frac{\partial V^*}{\partial \lambda} = \frac{E_{sm} - E_b k}{\lambda^2 X S_m^2}$. This term has an ambiguous sign: where $k<E_{sm}/E_b$, V^* rises with increasing λ; where $k>E_{sm}/E_b$, V^* falls with increasing λ. The term is equal to zero where $k=E_{sm}/E_b$. Also, note that V^* increases with the spot market price variance S_m^2 and decreases with the covariance between the spot market price and the per-unit variable cost of production S_{mc}.

Processors' problem

Now, following Buccola's buyer situation, the processor wishes to buy A units of cattle slaughter and pack for re-sale. The contract and open markets are both available to the buyer as well. Buyers are assumed to be perfectly competitive in the output market and receive a per-unit resale price R, D and G are respectively the per-unit processing and fixed costs , W as the proportion of cattle purchased through contract, and all other variables as previously defined. The buyer's profit function is as follows:

$$\pi_b = A[R - WkB - (1-W)M - D - G] \tag{5}$$

where $0 \le W \le 1$.

In a fixed-price contract, if prices and returns are normally distributed and the buyer has an exponential profit utility with absolute risk-aversion coefficient γ, the certainty equivalent Y is maximized:

$$
\begin{aligned}
Y = {} & A\left[\left(E_r - E_{bm} - E_d - G\right) + \left(E_{bm} - E_b k\right)W\right] \\
& - \left(\gamma / 2\right)A^2[(S_r^2 + S_m^2 + S_d^2 - 2(S_{mr} + S_{rd} - S_{md})) \\
& + (2(-S_m^2 + S_{mr} - S_{md}) + 2k(-S_{br} + S_{bm} + S_{bd}))W \\
& + (S_m^2 - 2S_{bm}k + S_b^2 k^2)W^2]
\end{aligned}
\tag{6}
$$

S_{md} is the covariance between the open market price of the raw product and the processing cost, and S_{mr} is the covariance between the raw product price and the finished market price. The portfolio proportion W^* at which the processor's certainty equivalent Y, and thus expected utility, reach an extreme value is:

$$
\begin{aligned}
W^* &= \frac{E_{bm} - E_b k - \gamma A\left(-S_m{}^2 + S_{mr} - S_{md}\right)}{\gamma A S_m^2} \\
&= 1 + \frac{E_{bm} - E_b k}{\gamma A S_m{}^2} - \frac{(S_{mr} - S_{md})}{S_m{}^2}
\end{aligned}
\tag{7}
$$

The impact on the optimal contracted proportion W^* with respect to the contract price $E_b k$ is $\frac{\partial W^*}{\partial E_b k} = \frac{-1}{\gamma A S_m{}^2}$. This shows that the buyer's demand for fixed-price purchases tends toward becoming perfectly inelastic with respect to changes in the fixed-price as the absolute risk-aversion

coefficient, the total quantity sought for purchase, or the perceived variance of spot market prices becomes large. Note that when the risk aversion coefficients and the total quantities of buyer and seller are identical, slopes of the supply and demand curves are equal and opposite in sign.

Equilibrium in the contract market

As per Buccola, if producers and processors have equal bargaining power and identical subjective probability distributions of revenues and costs, equilibrium is reached in the fixed-price contract market when V^* from Equation (4) equals W^* from Equation (7):

$$(8) \qquad E_b k_e = E_m - \gamma X \frac{(S_{mr} - S_{md} - S_{mc})}{\left(1 + \frac{\gamma}{\lambda}\right)}$$

The equilibrium fixed contract price $E_b k_e$ is less than the expected market price E_m if the covariance between raw product and finished product market prices S_{mr} is algebraically greater than the sum (S_{md}+S_{mc}) of covariances between raw product market price and production costs. The equilibrium fixed price depends on the magnitudes of S_{mr} and (S_{md}+S_{mc}) as well as on the ratio γ/λ.

Now we extend the Buccola model by considering the case where processors and producers do not have equal bargaining power in the contract market. To model imperfect competition in the contract market, we first solve for the monopsonistic solution, under which the processor sets the terms, and that represents one extreme. We use the equal bargaining solution

for the other extreme; this corresponds to the intersection of the V^* and W^* derived above as $E_b k_e$. Alternatively, we could derive the contract price in the situation that the producer sets the terms making the monopolistic solution the other extreme, but this option is not very likely for the case of the cattle industry[1]. Thus, we define the various linear combinations between the contract price in the perfectly competitive solution and the price in the monopsonistic solution as representing various degrees of market power.

In the monopsonistic solution, the proportion demanded W^* is determined by the intersection of the marginal factor cost (MFC) function and the demand (W^*) function. The expected contract price $E_b k_m$ is determined from the supply (V^*) function in the same manner as the input price is determined in the standard monopsony model.

Given $MFC = E_b k(V^*) + V^* \frac{dE_b k(V^*)}{dV^*}$; from equation (4) we know $\frac{dE_b k}{dV^*} = \lambda X S_m^2$ and solving for $E_b k$ in V^* we obtain $E_b k(V^*) = E_m - \lambda A S_m^2 \left[(1 - V^*) - \frac{S_{mc}}{S_m^2} \right]$. The resulting MFC function is as follows:

$$MFC = E_m - \lambda A S_m^2 \left[(1 - 2V^*) - \frac{S_{mc}}{S_m^2} \right] \tag{9}$$

[1] Another problem with using the situation in which the producer possesses all the market power is that both the producer-dominant and processor-dominant solutions result in a reduction in the quantity, or proportion, contracted. In either a monopsony or a monopoly case, the firm with all the bargaining power restricts output to increase its profits, but they dictate the price from different curves (either the marginal revenue curve or the marginal factor cost curve). Therefore, if we were to define those two solutions as the extreme solutions, it would be difficult to create a range of prices or quantities that would indicate an increase or decrease in bargaining power because the movement would be non-linear.

We solve for $E_b k(W^*)$ from equation (7) and get

$E_b k(W^*) = E_m + \gamma A S_m^2 \left[(1 - W^*) - \frac{S_{mr} - S_{md}}{S_m^2} \right]$. Setting $E_b k(W^*)$ equal to the *MFC*, we solve for the corresponding proportion contracted in a monopsony case, W_m^*.

$$(10) \qquad W_m^* = \frac{1}{\gamma + 2\lambda} \left[\gamma + \lambda - \gamma \frac{S_{mr} - S_{md}}{S_m^2} - \lambda \frac{S_{mc}}{S_m^2} \right]$$

The actual contract price is read from the supply function as in the standard monopsony model. We substitute W_m^* into the $Ebk(V^*)$ to determine the monopsony contract price $E_b k_m$.

$$(11) \qquad E_b k_m = E_m + \lambda A S_m^2 \left[(1 - W_m^*) - \frac{S_{mc}}{S_m^2} \right]$$

Ultimately, the expected contract price $E_b k$ is the weighted average of the price under the assumption that there is equal bargaining power ($E_b k_e$) and the price under the assumption that processor is able to set the price ($E_b k_m$), where $E_b k = \theta E_b k_m + (1 - \theta) E_b k_e$ and $0 \le \theta \le 1$. Hence, θ represents the degree of bargaining power held by the processor. If the processor does not have superior bargaining power, θ=0 and the Buccola solution prevails. However, if θ>0, the processor possesses some degree of bargaining power and as θ increases the solution tends toward the monopsony solution, which holds if θ=1.

Deriving equilibrium in the spot market: the oligopsony case

The oligopsony power enjoyed by the buyers in the open market is revealed in a second stage. At this point, processors have fixed amount of cattle contracted and an upward sloping residual supply of cattle available to them as was determined in a first stage. In this second stage, the processor determines how much of the raw product to purchase in the spot market to reach the optimal quantity for processing. This will depend on the price she expects to receive in the processed product market, *R*. The price for the raw product in the open market is determined by the behavior of the processors in the cash market during the second stage. The processing industry has *n* firms producing a homogenous product, beef. We assume a fixed-proportions production technology such that $A_i = \tau X_i$ where we normalize by setting $\tau = 1$, so $A_i = X_i$. Using a conjectural variation model, we derive an expression for the representative processor *i*'s market power who maximizes profit π_{bi}

$$(12) \quad \pi_{bi} = RA_i - M(1-W^*)x_i - kBW^* - Dm_i - G$$

As $W^*=V^*$ in equilibrium, we rewrite the expression as follows:

$$(13) \quad \pi_{bi} = RA_i - M(1-V^*)x_i - kBV^* - Dm_i - G$$

given

$$A_i = f(x_i, m_i)$$

$$M = g(X, V^*)$$

$$X = \left[\sum_{i=1}^{n} x_i \right]$$

The quantity of beef produced by processor i, A_i, is a function of the cattle supplied to her (x_i) and the marketing input (m_i). The marketing input is any input other than the raw cattle that goes into the processing stage (i.e. labor, capital, and others). Function $f(x_i,m_i)$ is assumed to be smooth, concave, and twice and continuously differentiable in x. The production technology is assumed to be separable in the farm and marketing input m, in the sense that the marginal rate of technical substitution between contracted and spot market purchases of x is independent of m. The spot market price M is a function g of the total quantity supplied X and the proportion contracted V^*. The terms x_1, x_2,..., x_n are raw inputs bought by processor *1*, processor *2*, …, and processor n.

The weighted average conjectural variation, or the degree of collusion, β is represented below in Equation (14). The weighted average conjectural variation is the sum of the conjectures of all n firms with respect to firm i.

$$(14) \quad \beta = \frac{d(1 - V^*)X}{dx} = \left(1 + \sum_{\substack{i=1 \\ i \neq j}}^{n} \left(\frac{dx_j}{dx_i} \right) \right).$$

The conjecture $v = \frac{dx_j}{dx_i}$ indicates the representative processor's expected change in the purchases of inputs by rival processor *j* given a change in the representative processor's own purchases. We propose that *v* is identical for all *i* and *j*, then β and *v* simply equal as follows:

$$(15) \quad \beta = v$$

We take the definition of the Composite Lerner Index, *L*, for the processors as the expression for their market power (Chen and Lent, 1992).

$$(16) \quad L = \frac{H}{\varepsilon_o}(1+\beta)$$

where $H = \sum_{i=1}^{n} x_i^2 / X^2$ is the Herfindahl Index. The Lerner Index presented in equation (16) states that oligopsony power in the spot market is a function of the residual supply elasticity of the cattle input (ε_o), the weighted average conjectural variation (β) and the size of processing firms with relation to the industry which is an indicator of the amount of competition among them (*H*). We eliminate the negative sign that precedes the equation with the purpose of evaluating the absolute values of the term. *L* is equal to zero under perfect competition as *n* increases up to a critical mass. The impact of contracting on the spot market oligopsony power depends on the relative changes ε. In the next lines we shall reveal the impacts on the supply elasticity.

We now determine the equilibrium price and quantity in the spot market. The constant elasticity raw product supply is a function of some supply shifting constant *s*, the sport market price *M*, and the supply elasticity ε. The expression for the supply function prior to contracting is:

$$(17) \quad X = sM^{\varepsilon}$$

The expression for the residual supply function in the second stage spot market is therefore:

$$(18) \quad (1-V^*)X = sM^{\varepsilon_o}$$

As the supply shifts in the second stage, this study considers the case where the elasticity decreases as sellers face less marketing options at this stage. The residual spot market supply elasticity ε_o is assumed to be a linear decreasing function of ε as V^* increases as follows:

$$(19) \qquad \varepsilon_o = (1-\phi V^*)\varepsilon$$

where ϕ is some value such that $0 \le \phi \le 1$. This simple formula ensures that as long as $V^*>0$, $\varepsilon_o \le \varepsilon$ even though the values that ϕ can take are arbitrary. This means that contracting causes the spot market supply to exhibit a more inelastic response to price changes. In this case, lower supply elasticity in turn contributes to amplifying the degree of oligopsony power in the spot market.

The expression for the spot market price is as follows:

$$(20) \quad M = \left(\frac{(1-V^*)X}{s}\right)^{\frac{1}{\varepsilon_o}} = ((1-V^*)X)^{\frac{1}{\varepsilon_o}}(s)^{-\frac{1}{\varepsilon_o}}$$

We observe the spot market price M is negatively related to the proportion contracted V^*. The slope of the supply curve is derived as follows:

$$(21) \quad \frac{d(1-V^*)X}{dM} = \varepsilon s M^{\varepsilon_o - 1} = \varepsilon_o (s)^{\frac{1}{\varepsilon_o}} \left((1-V^*)X\right)^{\frac{\varepsilon_o - 1}{\varepsilon_o}}$$

Adaptive expectations in spot market price

In this section, we determine the producer and processor respective expectations of the market price which conform to the adaptive expectations model frequently used in econometric analyses (Pindyck and Rubinfeld, 1998). In this model, the producers and processors form their expectations of the future market price based on the past prices. In our application, the difference between the expected value of the per-unit market price (E_m^t) and the expected value in the previous period (E_m^{t-1}) is assumed to be a proportion (α) of the difference between the actual value in the previous period (M_{t-1}) and the expected value in the previous period:

$$(22) \quad E_m^t - E_m^{t-1} = \alpha(M_{t-1} - E_m^{t-1}) \text{ where } 0 < \alpha \leq 1$$

Terms α_s and α_b are the coefficients of expectations for producers and processors, respectively. We rewrite the relationship with subscripts s and b added for sellers and buyers respectively as follows:

$$(23) \quad E_{sm}^{t} = \alpha_s M_{t-1} + (1-\alpha_s) E_{sm}^{t-1}$$

$$(24) \quad E_{bm}^{t} = \alpha_b M_{t-1} + (1-\alpha_b) E_{bm}^{t-1}$$

This states that the expected values of the market price for producers and processors, respectively, in the current period are weighted averages of the actual value in the previous period and the expected value in the previous period. Term E_m differs between producers and processors as they do not necessarily place the same weights on past prices and past expectations.

In the next chapter, we build a spreadsheet model with the adaptive expectations and the optimization results to further evaluate and produce insights on the general model by simulating the impacts of changes in key parameters on the variables under study. The parameters simulated are: (1) the coefficients of risk aversion for the processors (γ) and producers (λ); (2) the spot market price variance (S_m^2); (3) the coefficients of expectations for the processors (α_b) and producers (α_s); (4) and the bargaining power weight (θ).

Chapter IV. Spreadsheet Model and Simulation Analyses

The equilibrium that resulted from the producers' and processors' problems under the equal bargaining power case (θ=0), and the adaptive expectations framework in a spreadsheet to conduct simulations and sensitivity analyses on the key parameters just specified. We set the number of producers N at 100 and the number of processors n at 10. We set the processed beef price by adjusting to the 2008 retail value of choice beef of USD 438. Quantities supplied and demanded are normalized to 100 and proportions are easily viewed in percentage terms. Historical market prices for cattle are taken from actual gross farm values between 2003 and 2009 provided in the USDA Beef Price Database. And the current market price, M_t, is generated by the model through equation (22). We assume a constant-elasticity cattle supply curve which means that the elasticity does not vary along the supply curve. The supply elasticity changes as the curve shifts after the contractual transactions.

We set variable costs at 50 and fixed costs at 100. We also used the historical prices to determine the spot market price variance (S_m^2). The coefficients of expectations, α_b and α_s, are fixed at 0.5 for 4 of the simulations; this places equal weights on the historical prices and historical expectations. The coefficient of risk aversion for producers (λ) and processors (γ) are set to 1 but are allowed to vary for the purpose of the first simulation analysis. Finally, we arbitrarily set covariances S_{mr}, S_{mc} and S_{md} at 400, 200 and 200, respectively. All the variables are determined in the model as presented by equations (1), (4), (5), (7), (8), (10), (11), (14), (17), (18), (19), (20), (23), and (24).

Simulations with the coefficient of risk aversion

The first simulation consists in evaluating the coefficient of risk aversion (λ) to see what could occur to our model results when we consider different risk aversion for our sellers and buyers. The risk effects are evaluated by varying the coefficient of risk aversion for producers and then for processors between the ranges of measurement of 0.001 (low risk aversion) and 2.0 (high risk aversion). For the purposes of these first sets of simulations, first we deviate from the equilibrium restriction so V^* is no longer equal to W^* and so we do not associate any implications with open market equilibrium; second we fix v=0 assuming a Cournot conjecture and the number of processors and producers n=10 and N=100, respectively; third we fix the coefficients of expectations α_s=α_b=0.5, the elasticity adjustment constant ϕ = 0.06 and the supply shifting factor s=0.000001. We evaluate the coefficients of risk aversion for the cases where the equilibrium contract price is lower than the expected spot market price $E_b k<E_m$ as well as for the cases where the equilibrium contract price is higher than the expected spot market price $E_b k>E_m$. The results for the producers and the processors are summarized in Tables 1 and 2, respectively.

Table 1: Summary of Risk Aversion Simulations for Producers

	Ebk<Em			*Ebk > Em*		
λ	***V****	***W****	***M***	***V****	***W****	***M***
0.001	0.3209	0.4938	198.11	0.5994	0.4936	185.50
0.003	0.4361	0.4938	194.70	0.5289	0.4936	190.26
0.005	0.4591	0.4938	193.76	0.5148	0.4936	191.05
0.007	0.4690	0.4938	193.33	0.5088	0.4936	191.38
0.009	0.4745	0.4938	193.08	0.5054	0.4936	191.56
1.000	0.4935	0.4938	192.17	0.4938	0.4936	192.15
2.000	0.4936	0.4938	192.16	0.4937	0.4936	192.16

Table 2: Summary of Risk Aversion Simulations for Processors

	Ebk < Em			*Ebk > Em*		
γ	***V****	***W****	***M***	***V****	***W****	***M***
0.001	0.4935	0.6664	192.17	0.4938	0.3880	192.15
0.003	0.4935	0.5513	192.17	0.4938	0.4584	192.15
0.005	0.4935	0.5282	192.17	0.4938	0.4725	192.15
0.007	0.4935	0.5183	192.17	0.4938	0.4786	192.15
0.009	0.4935	0.5129	192.17	0.4938	0.4819	192.15
1.000	0.4935	0.4938	192.17	0.4938	0.4936	192.15
2.000	0.4935	0.4937	192.17	0.4938	0.4936	192.15

In Table 1, having fixed γ=1, we observe that when $E_b k < E_m$, increases in the feeders' coefficient of risk aversion, λ, causes their their optimal share of cattle marketed through contracts to increase and hence contributes to increasing the spot market supply elasticity and hence the Lerner Index. The spot market price, M, decreases accordingly. On the other hand, when $E_b k > E_m$, increases in λ, decreases the feeders' optimal share of cattle marketed through contracts and hence contributes to increasing the spot market price.

Thus, we observe that the influence of feeders' relative degree of risk aversion on packers conduct depends on their expectations of the future market price. In the case of the packers, in Table 2, holding λ=1, we observe that although packers' market power is affected by feeders' relative degree of risk aversion, this is not true with respect to their own risk aversion. From our model, the explanation for this is evident in the derivation of oligopsony power as the optimization problem is set up subject to the quantity supplied $(1-V^*)X$; so changes in W^* have no effect on ε_o.

In the rest of the simulations, we keep the same values that were previously assigned for the different parameters and constants; we only make changes in the parameter in question.

Simulations with the spot market price variance

The purpose here is to assess how the spot market price is affected by the spot market price variance. Our simulation confirms a downward linear association between S_m^2 and M as increases in the variance induces an increase in the equilibrium contracted proportions due to higher perceived risk in the spot market. This implies the possibilities of a future increasing

trend in the use of contracts in cattle procurement as the prices of these commodities become more volatile as well as a decreasing trend in the price offered in the spot market.

Sensitivity analysis with the coefficient of expectations

To verify how the model behaves according to our assumption of the coefficients of expectations, we conduct a sensitivity analysis by varying the value we give to α_s and α_b in the spreadsheet. The results are summarized below in Table 3 for producers and processors, respectively. We note that the coefficient only affects our estimations for the expected open market price (E_m) and hence the equilibrium contracted price ($E_b k$). These in turn have implications for the profits that producers and processors receive. However, we observe these coefficients do not have any significant effect on the shares contracted as $E_b k_e$ closely follows E_m. Therefore, the spot market supply elasticity and market power are not very responsive.

Table 3: Sensitivity analysis of the Coefficients of Expectations

α_s	E_{sm}	*Ebk*	*M*	α_b	E_{bm}	*Ebk*	*M*
0.10	200.43	203.63	192.15	**0.10**	200.43	203.63	192.16
0.30	210.67	208.75	192.16	**0.30**	210.67	208.75	192.16
0.50	206.82	206.82	192.16	**0.50**	206.82	206.82	192.16
0.70	202.72	204.77	192.16	**0.70**	202.72	204.77	192.16
0.90	200.42	203.62	192.15	**0.90**	200.42	203.62	192.16

Simulations with contract market bargaining weights

In this last simulation, we evaluate the outcomes of different bargaining for processors. By examining changes in the different degrees of bargaining power θ, we observe that increases in the processors' bargaining power induces increases the processors' demand for contracts but decreases the producers' supply of contracts. This affects the two markets through declining contract prices and increasing spot market prices.

Table 4: Summary of Simulations on Contract Market Bargaining Weights

ϕ	V^*	W^*	$E_b k$	M
0	0.4937	0.4937	206.82	192.16
0.10	0.4772	0.5101	206.17	192.95
0.30	0.4443	0.5430	204.87	194.38
0.50	0.4114	0.5759	203.57	195.61
0.70	0.3785	0.6088	202.28	196.66
0.90	0.3456	0.6418	200.98	197.55
1	0.3291	0.6582	200.33	197.93

Chapter V. A Dynamic Case with a Marketing Agreement

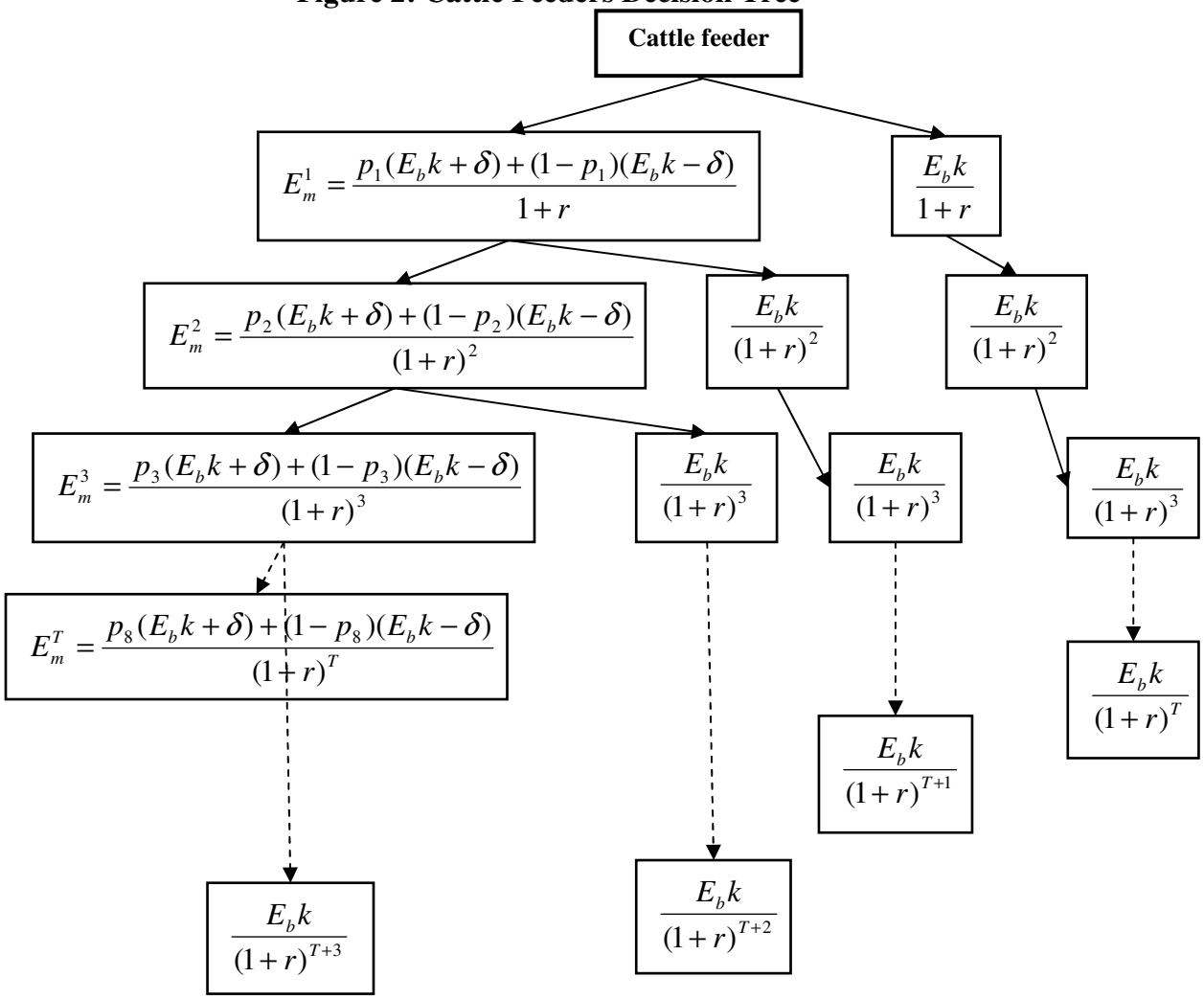
We have accomplished our first objective of setting up a case where expectations derived from past experiences can contribute to the decisions of profit maximizing producers and processors under risk. In this section, we discuss the dynamic aspects of contracts as we know that the most prominent type of contract used in the procurement of livestock is a marketing agreement in which a packer and a feeder agree to purchase/sell livestock through a long-term ongoing oral or written arrangement with specific terms (Taylor et al., 2007). A typical marketing agreement for cattle runs for four to seven years and consists of multiple transactions in each. In the longer run, X, A, $E_b k$ can all change and create additional uncertainties in the producers and processors' problems and in achieving equilibrium. Now, we briefly evaluate the feeder's decision making process in entering a marketing agreement.

Consider a marketing agreement with one transaction in each period. Given the long biological cycle of beef and high capital needs, it is safe to keep X and A fixed for the duration of the agreement. If we assume a fixed contract pricing strategy that only changes to include quality premium/discounts in the same manner as in the open market, we are also safe to keep $E_b k$ locked for the life of the contract. Given the previously derived variances, we know V^* and W^*; now we wish to establish the process in which our upstream agents, the cattle feeders, make their decisions to enter in a long term agreement given the spot market and its opportunities and uncertainties.

Deciding whether or not to enter into a contract are based on the total present value of expected returns during the course of the periods. We define a few parameters and variables. The term t determines the periods of each transaction up to the last period T so that t=1, 2, ..., T.

The term p_t is the probability at time t that $E_m^t > E_b k$; δ is a very small but significant value so that $E_m^t > E_b k$ is transformed into $E_m^t = E_b k + \delta$ and $E_m^t < E_b k$ is transformed into $E_m^t = E_b k - \delta$. Finally r is a time discount factor. As per the decision tree mechanism in Figure 2, we assume a binding contract so that although there is the possibility to choose to contract in any period, once the decision to contract is made, it will bind for at least T more periods.

Figure 2: Cattle Feeders Decision Tree



As the motivation here is for hedging purposes, the optimization problems for one unit take the following form, in which we solve for an average p_t at which the feeder is indifferent between the two marketing options such that discounted contracted values of one unit of cattle are equal to the discounted expected market values of one unit of cattle:

$$(25) \quad \sum_{t=1}^{T} \frac{E_b k}{(1+r)^t} = \sum_{t=1}^{T} \frac{p_t (E_b k + \delta) + (1 - p_t)(E_b k - \delta)}{(1+r)^t}$$

From Equation (25), we deduce that the indifference point between the two markets is where the average probability p_t^a of receiving an expected market price higher than the equilibrium contract price equals to 0.5. This brief exercise has enabled us to understand that a cattle feeder will decide to contract if she *ex ante* places a less than 50% chance that, on average, future market prices will be slightly lower than the offered contract price.

Chapter VI. Conclusions

In this paper, we show a case where the choice of marketing for buyers and sellers is regarded as part of the optimization problem. Through a model of decisions under risk, producers (cattle feeders) and processors (beef packers) reach equilibrium contracted proportions and a fixed contract price. We extend this model to also consider cases of unequal bargaining power between producers and processors. In a second stage, these proportions as well as market expectations have real implications for the spot market. In addition to risk mitigation purposes, cattle feeders and meat packers engage in marketing agreements for several other reasons such as quantity and quality assurance, information and market access, and efficiency.

We find that the practice of fixed-price contracts can serve to reduce the spot market price. Hence, the processor enjoys higher oligopsony power in the spot market. Although, noncompetitive conduct is not a necessary condition for the inverse relationship between the spot market price and the degree of vertical coordination, contracts may have the ability to reduce the subsequent spot market price if the residual supply elasticity is reduced by the shift.

We run simulations in a spreadsheet model to derive further insights about key parameters, including the risk aversion coefficients, the spot market price variance, the coefficient of expectations, and the bargaining power weights in the contract market. We observe that when the spot market price is expected to be higher than the equilibrium fixed contract price, increases in the producer's coefficient of risk aversion cause their optimal share of cattle marketed through contracts to increase and hence it contributes to a higher spot market price. On the other hand, when the expected market price is lower than the equilibrium

contracted price, increases in the producer's coefficient of risk aversion decreases the producers' optimal share of cattle marketed through contracts and hence contributes to higher spot market prices. These two results are due to the fact that increasing risk aversion decreases the sensitivity with which optimal portfolios react to changes in the price parameters. By simulating increasing (decreasing) spot market price variance, we observe the equilibrium contracted proportions to increase (decrease) accordingly. In turn, this causes a lower (higher) spot market price. The simulations on the degree of the processors' bargaining power in the contract market show that increases in the processors' bargaining power induces higher demand for contracts by processors and lower supply of contracts by producers. This results in a decline in the contract price and an increase in the spot market price.

Finally, a brief exercise in dynamic decision making reveals that a producer will always choose to contract out a proportion of their cattle as long as they are less than 50% certain that, on average, future market prices will be slightly lower than the offered contract price.

We recognize that other attributes ought to be considered in evaluating the impacts of contractual agreements. We propose an empirical extension to determine the main motives that drive contractual agreements in cattle marketing and their respective significance on the spot market structure. We have established that both upstream and downstream agents are motivated to diversify their transactions between a more certain present and an uncertain future in the view of maximizing their profits and utilities given their respective degrees of risk aversion. In our theoretical model, the equilibrium share of contracts (V^* and W^*) is close to 50%. In practice, this share is about 38%. There are factors other than risk that contribute to the decision making of cattle feeders and meat packers. The empirical study would no longer have a representative

producer and a representative packer but instead have different ones each with a unique portfolio in each period. Some are totally independent and transact only in the cash market; some transact only in the contract market; and some allocate their cattle between the two markets. In this, we could explain and measure the extent to which risk aversion and other factors such as size, quality, location, capital and conduct impact the proportions contracted and the spot market price. Additionally, the empirical analysis could involve estimating the residual supply elasticity and separate the market power effects.

A factor that is frequently cited as a motivation to contract on the processors side is the case of noncompetitive conduct. A popular example is that of obscure pricing. Obscure pricing occurs when one party manipulates the market such that the price that is offered to one is hidden to the others. This practice can be effectively controlled by enforcing legislation such as the Mandatory Price Reporting Act passed by Congress in 1999 and implemented in 2001 which mandates reporting of transaction data only by beef packers who slaughter an average of 125,000 cattle (Azzam, 2003). The Captive Supply Reform Act proposes to amend the Packers and Stockyards Act of 1921, to prohibit the use of certain anti-competitive forward contracts. This measure would require that supply contracts and agreements between packers and livestock producers include fixed-price formulas and that these arrangements be conducted in the open.

In this paper, the same fixed-price contract is available to both parties. This implies that the same pricing information and competitive conditions are available to all parties. However, in practice, many contracts are established in a case-by-case basis; from one-sided deals offered by large packers to negotiated deals in which terms are reached in an extensive bargaining process. We propose an extension to this paper that takes into account different producer and processor

types (different degrees of bargaining power) engaging in a bargaining process over the price of the contract. This should result in multiple equilibriums of proportions contracted and of contract prices with different implications on the spot market.

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