Deriving Feeder Cattle Pricing Contracts from Fed Cattle Price Grids:

Simulation Results of Risk-Sharing Contracts

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Abstract:

Post-slaughter quality-based pricing of cattle is increasingly common. This quality, however, is dependent upon unobservable quality characteristics of the feeder cattle used as inputs. Through stochastic simulation we construct incentive compatible quality risk-sharing contracts based upon final grid-quality schedules that facilitate input quality sorting in the feeder cattle market.

Key words: Feeder cattle, quality, incentive compatible contract, premium sharing, simulation, double-sided moral hazard.

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Introduction

More beef carcasses are priced using quality-based pricing grids than ever (GIPSA). Grid pricing improves information linkages between wholesalers and feedlots by rewarding desirable carcass traits and penalizing undesirable traits. However, the grid performance of a carcass is determined by many factors such as genetics, life-long feeding regimen, and health, which are jointly determined by the feedlot and feeder cattle supplier. To the extent that pre-feedlot decisions alter final quality, feeder cattle prices must reflect the quality differences among feeder cattle in order for the refined signals of grid pricing to transmit to those supplying cattle to feedlots. While hedonic analyses of feeder cattle sales data (e.g., Sartwelle *et al.*) has revealed that certain observable characteristics, which are roughly related to final quality (e.g., breed), are rewarded in auction settings, many unobservable traits that are more closely related to carcass qualities (e.g., marbling) are not directly influenced by such market forces. The market may induce production of desirable unobservable traits through reputation formation (Turner *et al.*), but the formation of such reputation-based rents, and hence the speed by which suppliers provide such desirable traits, may be very slow.

An alternative solution might be the issuance of contracts by feedlots or integrators in which the parties jointly responsible for the production of quality (i.e., feedlots and feeder cattle suppliers) share final carcass premiums and discounts. What such a contract might look like is the subject of the present study. We simulate possible grid premium/discount-sharing contracts, which are widely seen on sharecropping (Allen and Lueck), franchising (Lafontaine) and in niche beef markets (Laura's Lean) and gauge if such arrangements provide better incentives with regards to matching feeder cattle with feedlots that can exploit animals' unobservable quality traits. Bhattacharyya and Lafontaine suggest that a linear sharing contract could be optimal in the presence of double-sided moral hazard. We argue that, in the absence of rapid reputation formation by feedlots and feeder cattle sellers, the current set of market arrangements typically used in feeder cattle markets (detailed below) could be plagued by moral hazard. Linear premium sharing contracts may be attractive to feedlots to facilitate the sourcing of animals that will perform well within the context of the feedlot's production program and within the premium/discount schedules used by its usual packing plant, while such contracts could be attractive to feeder cattle suppliers if average price received after premiums and discounts outpaces auction market prices plus a risk premium. The objective of this paper is to construct a feasible and reasonable feeder cattle carcass quality incentive contract through stochastic simulations based upon historical feeder cattle prices, fed cattle prices, input prices and quality premiums and discounts.

We will compare our proposed scheme with two other common business arrangements between feedlots and feeder cattle suppliers. In the first the cow-calf operator sells feeder cattle to the feedlot at the spot market price and there are no interactions thereafter. In other words, the feeder price is independent of the unobservable qualities of feeder cattle in the short run (current period). In the case where the cow-calf operator does not quickly form a reputation, there is a moral hazard problem in that the cow-calf operator has an incentive to reduce effort that would improve unobservable animal quality.

The second arrangement involves the cow-calf operator retaining ownership of cattle and paying a feedlot to feed the cattle until slaughter. The payment to the feedlot is based upon feed cost plus a typical industry markup. The cow-calf operator may face a moral hazard issue as feedlot operators may be tempted to keep animals on the feedlot longer than necessary in order to increase final payment and, in the process, harm final animal quality by overfeeding.

Our proposed feeder cattle carcass quality incentive contract could prevent moral hazard problems from both sides by sharing the premiums/discounts from the output. Such a contract makes both sides benefit from actions that improve cattle quality regardless of the interim transparency of these qualities. Participation incentives are crucial in the set of contracts we devise and may dictate whether such contracts will emerge more broadly in the US cattle sector.

Factors that Determine Feeder Cattle Prices

Many feeder cattle are sold at auction markets and their prices are determined during a rapid auction process that allows brief visual inspection.[1] Three general value-determining characteristics of feeder cattle, according to the official United States Standard for Grades of Feeder Cattle, include frame size, thickness and thriftiness. Previous research suggests that a broader set of traits can marginally affect feeder cattle prices, including sex, weight, breed, lot size, visible health (an animal that is visibly healthy today may not be healthy tomorrow, however), uniformity, condition, fill, muscling, frame size, breed and presence of horns (Sartwelle *et al.*, Rawls *et al.*).

All the characteristics mentioned above are observable traits. However, several unobservable traits are involved in the determination of the final carcass quality. For instance, the initial marbling of feeder cattle will affect the final quality grade of a carcass but it is not observable at the time when the sale is made. Observable traits are only indirectly related to the final carcass quality; hence, rewards for feeder cattle based on those characteristics may be biased. A feeder-cattle pricing system that rewards the actual carcass performance could compensate for this sort of bias. Since the final performance of a carcass dictates whether it will receive a premium or a discount, a premium/discount-sharing contract might be the proper arrangement to reveal a true price of feeder cattle.

Incentive Compatible Risk Sharing Contracts

Double-sided moral hazard

Double-sided moral hazard problems exist in many contractual relationships in which the outcomes are jointly determined by the efforts of two actors and in which each actor cannot directly monitor the other's effort level. Examples include franchising, sharecropping, licensing, commercial leasing, author-publisher relationships, and so on.

Sharecropping and franchising are two important examples of the double-sided moral hazard problem. Reid first used this idea to explain the existence of sharecropping contracts; Eswaran and Kotwal later formalized this representation. Agrawal developed a generalized double-sided moral hazard model for contract choice in agricultural production. Bhattacharyya and Lafontaine found that the optimal second-best contract could be implemented via a linear profit sharing contract. They also showed that share parameters are rather constant across the agents (in the multiple agents case) if the technology could be described as Cobb-Douglas production function.

In the cattle feeding business feedlots use feeder cattle as a major, necessary input in their production process and the quality of feeder cattle plays a very important role in determining the final carcass quality and, hence, the grid performance. As a result, we can treat the periods of cow-calf stage and cattle feeding phase as one single operation where both cow-calf operator and feedlot simultaneously contribute their efforts. Although these two stages are sequential, the lack of transparency of effort by both parties is the critical driver of the double-sided moral hazard formulation. A feeder cattle supply contract made between the two parties could formalize this argument by building a principal-agent relationship. In a principal-agent relationship, contracts are often designed so that the agent has an incentive to produce effort that is valued by the principal but unobservable. The agent and principal both have incentives to shirk in order to decrease the cost or disutility of effort given the effort of his counterpart. In spot market transactions between the cow-calf operator and the feedlot it is likely that the cow-calf operator will not provide the level of effort needed to produce the level of quality desired by the feedlot. Alternatively, in a retained ownership contract, in which the cow-calf operator retains ownership of cattle and appoints a feedlot to finish the feeding phase, it is probable that the feedlot will not provide his best effort to feed and manage efficiently. Both situations lead to the result that the final carcass grid performance does not reach its potential. A premium/discount-sharing contract provides incentives for both parties to increase effort level in order to maximize their share of premiums or to minimize their share of discounts. Bhattacharyya and Lafontaine prove that a linear sharing contract could be optimal based on a double-sided moral hazard problem.

Risk-sharing

Risk sharing is another possible motivation for contracts (Newbery). Sources of risk in the cattle feeding business include fed cattle price risk, feed price risk, cattle weight-gain performance risk and health risk. For cattle marketed using grid pricing, there is an additional risk because the level of premiums and discounts are subject to change and animals' quality status (marbling and yield grade) are also volatile. The effort levels of both parties affect the carcass quality status. Arrangements in which only one party bears all the quality risk can lead to the moral hazard from his counterpart. Hence, feedlots might be willing to buy feeder cattle from suppliers who accept a risk-sharing contract. Also, cow-calf operators are more likely to provide high quality feeder cattle if they share quality risk because it could decrease the risk of receiving discounts. A risk-sharing contract that shares carcass quality risk can provide both sides with the incentive to exert more effort toward the production of quality than existing arrangements (hence, it appears such contracts would be incentive compatible) and dilute risk between the parties. However, both parties must find the contract to be better than existing arrangements in terms of expected utility; i.e., the participation constraint must be satisfied. Existing arrangements (sales and retained ownership) may not entice total effort to be as high as the risk-sharing contract and typically leave one party to bear all quality risk.

Methodology

As shown in equation (1), a stochastic simulation model is used to simulate the change of attainable profit (π) from beef cattle whose quality performance is randomly drawn from realistic distributions. There are four state variables that determine the profit. The first three are beef carcass characteristics that determine most fed cattle grid prices, i.e., weight (Wt), back fat thickness (BF), and marbling score (MS). The last variable is total feedlot costs (TFC), which include feeder cattle procurement costs, feed costs, management costs and miscellaneous costs. The control variable is a discrete decision to sell the cattle at time *t* or to keep the cattle for an additional time period. We want to maximize the objective function subject to the four constraints functions that determine the value of four state variables.

$$\underset{t}{Max}\ \pi = R(t) - TFC(t) \tag{1}$$

$$s.t \quad R = f(Wt, MS, BF)$$

$$Wt = f(t)$$

$$MS = f(t)$$

$$BF = f(t)$$

$$TFC = f(t)$$

R: total revenue

Live weight and dressing percentage (which is assumed constant and equal to 62.83 percent in our simulation) determine the carcass weight.[2] It is increasing in the number of days on feed (t). Generally cattle are slaughtered such that the hot carcass weight falls between 550 and 950 pounds; carcasses outside this range typically receive a large, discrete price penalty.

The marbling score, which refers to the flecks of fat interspersed among muscle fibers and is considered to represent the quality grade because it is positively related to the palatability, is also increasing in the number of days on feed. The price received per hundredweight of carcass increases as the quality grade passes from standard to select to low choice to high choice to prime.

The yield grade is heavily dependent on the back fat thickness of the animals, which is also increasing in the number of days on feed. However, because more back fat implies a lower percentage of saleable meat, the price per hundredweight of carcass decreases as yield grade increases with the largest price penalty usually occurring when yield grade passes from category three to category four. In most beef grid pricing systems, the value of an individual carcass is determined by adjusting a base value with premiums that depend on weight, quality grade and yield grade of the carcass.[3]

Because the three elements of pricing are all time dependent as is the cost of feeding and maintaining an animal, there exists a four-dimensional dynamic problem in choosing the optimal marketing date. The three beef carcass characteristics are determined by growth function, back fat thickness function and marbling score function, respectively. We make all three functions piecewise linear in our setup. They have different slopes, which represent the growth rate, in the different stages of feeding. We also assign different slopes in each stage for "good animals" and "bad animals". A good animal has higher initial value for marbling score, higher growth rates for total weight and marbling score, lower initial value for back fat thickness and a lower growth rate for back fat thickness (see Table 1).

We create three different kinds of feeder cattle groups: high quality pens, medium quality pens and low quality pens. A high quality pen consists of 90 percent good animals and 10 percent bad animals; a medium quality pen has 50 percent good animals and 50 percent bad animals while a low quality pen consists of 10 percent good animals and 90 percent bad animals. Health conditions are also different among different pens with higher quality cattle having lower morbidity and conditional mortality rates (Table 2). Feedlots are assumed not to know the quality of a pen of feeder cattle until they finish the feeding process because the driving characteristics are unobservable.

Cattle grid prices based on historic data from 1990 to 2000 is then used to estimate the profit of high, medium and low quality pens of cattle. Specifically, we assume 150 pens of 100 500-pound feeder steers (50 high quality pens; 50 medium quality pens and 50 low quality pens) are placed on feed at the beginning of November each year from 1990 to 2000. The base price and Choice-Select spread for each simulated pen is assumed to exactly follow the prevailing national weekly prices for each year while all other grid values, which showed significantly less variation over the past decade, are assumed to take the average values expressed in Table 3. We choose a November placement data because this is a common marketing time for many cow-calf producers. Our simulated feedlot producer chooses the marketing date based on his expectations on base price and quality premium. The feedlot operator in our simulation does not base marketing decisions upon perfect foresight of prices and the premium/discount schedule. Rather, for each year of data used, we estimate simple regressions of the base price and the choice-select spread as functions of time and assume the feedlot operator uses these regression coefficients to predict prices upon which marketing decisions are made. That is, we assume the feedlot operator has a general idea about the direction of market prices but will be unable to predict prices perfectly. We felt this was an appropriate middle ground between perfect market foresight and naïve expectations.

The differences of profit among pens of varying quality levels indicate the strength of the incentive that feedlots have to procure high quality feeder cattle. The premiums and discounts from the three traits are used to construct a premium/discount-sharing contract. The specific contract we explore is one in which the cow-calf operator obtains 75 percent of the quality grade premium/discount and in which the feedlot absorbs death loss. We also assume that the feedlot makes one sorting of cattle into more uniform groups during the feeding process in order to increase profit by marketing these subgroups of cattle at different times.

Simulation Results

Tables 4-10 show the simulation results for 1650 pens over 11 years (150 pens each year) under the three forms of feeder cattle transactions: (1) fall cash spot market sales by cow-calf operators, (2) premium sharing contracts between cow-calf operators and feedlots and (3) retained ownership by the cow-calf operator through slaughter. In scenario 1 the cow-calf operator sells feeder cattle to the feedlot during the fall at the spot market price and there are no cash transfers thereafter. We consider two cases under this scenario. (1a) The feedlot executes one sorting of the pen of cattle (i.e., markets two separate groups of finished cattle) and chooses the profit-maximizing marketing date for each group given the expectation process outlined in the previous section; these additional sorting and marketing efforts are assumed to cost the feedlot $3 per head for each animal in the pen. (1b) The feedlot executes one sorting of the pen but its choice for marketing dates are the profit-maximizing date plus an independently and identically distributed error term chosen from a normal distribution with a standard deviation of 5 days; the error term captures imperfections in the sorting technology currently available to feedlot operators. Under scenario (1a) the feedlot's profit would be $75.98 per head if it purchases a group of high quality cattle and $27.30 if it purchased a group of medium quality cattle. A low quality group of feeder cattle loses $22.13 per head. If the feedlot was unable to sort the cattle, per head profits would be $34.43, -$16.64 and -$69.28 per head for high, medium and low quality cattle, respectively. The margin of profits between the high quality and the medium quality pen ($48.68/head) shows a strong incentive for the feedlot to procure high quality feeder cattle. It is even stronger for the feedlot that cannot sort cattle before slaughter because they could lose money from a medium quality pen.

In scenario 1b, where the feedlot cannot precisely pick the optimal marketing date, the feedlot's profits for the three quality levels are all very close to those in the optimal case. Unless reputation can be formed, the cow-calf operator has little profit-based incentive to exert quality related effort under this type of transaction because the payment does not depend on unobserved feeder cattle quality traits. As a result, the feedlot must sort cattle before harvest in order to gain a profit from a group of medium quality cattle. To the extent that cattle procured from the spot market fall below the medium quality level used in this study, i.e., to the extent that the spot market transacts only low quality cattle, feedlots may find it difficult to be profitable from spot market transactions due to the moral hazard.

In some situations a feedlot could earn more profit in the case where he cannot precisely pick the optimal marketing date than the one where he can (e.g., compare the profits for low quality cattle under scenario 1(a) in Table 4 with low quality cattle under scenario 1(b) in Table 5). The reason for these unusual outcomes is that the so-call "optimal marketing date" is based on the expected base prices and grids. However, given the expectations regime we choose, the resulting price predictions can be wrong for a given week. If the feedlot makes an error in picking the optimal date but the price prediction was incorrect in a favorable direction, the feedlot could end up earning more profit than the case where the 'right date' based on an incorrect prediction was used.

Scenario 2 also features two special cases that parallel those for scenario 1 in which sub-scenario (2a) features perfect selection of the marketing date and sub-scenario (2b) features this the perfect solution plus an error. In scenario 2a a feedlot that draws high quality cattle and makes one sort before marketing would pay the cow-calf $12.94 per head of premium under the premium/discount sharing contract and keep a profit of $63.04 per head (Table 6). A sorting feedlot that draws medium quality cattle would make $23.48 per head and pay the cow-calf operator $3.82 per head while, if low quality animals were transacted, the cow-calf supplier loses $5.14 per head and the feedlot loses $16.99 per head. Without sorting, only high quality cattle groups allow the feedlot to earn positive profits. The feedlot could make $23.76 per head and pay the cow-calf operator $10.58 per head. Otherwise he could end up losing $18.69 to $60.83

per head if he draws lower-than-average quality cattle. Note that the cow-calf operator who provides higher than average quality feeder cattle earns similar profits whether or not the feedlot performs a pre-harvest sort ($10.58 vs. $12.94 per head), suggesting the lack of effort by the feedlot would largely be internalized.

To analyze potential participation in such contracts, we transfer Table 6 into a normal-form game (Figure 1). The row player is the cow-calf operator and the column player is the feedlot. We differentiate the effort level of the cow-calf operator by the quality of the feeder cattle he provides. The effort level of the feedlot is simply distinguished into high and low by whether the feedlot conducts a pre-harvest sort.[4] In other words, sorting indicates a high effort level by the feedlot while the lack of a sort indicates low effort level. The Nash equilibrium in this game is obviously the bundle in the right upper corner where the cow-calf provides high quality cattle to the feedlot and the feedlot conducts a pre-harvest sort. The outcome is (13, 63).

Table 7 shows the results for the case where the feedlot has prediction error added to the optimal marketing date. The profits for the feedlot and the cow-calf operator are very close to those in the optimal case. As a result, we keep the same arguments as in the case in which the feedlot picks the optimal date without error.

Tables 8-10 show the simulation results of scenario 3 where the cow-calf operator retains the ownership of cattle and pays feedlots to feed the cattle until slaughter. We assume the owner requires (and pays) the feedlot to conduct pre-harvest sorting. If the feedlot can pick the optimal marketing date based on the expected grids, he could receive $33.30 per head as a payment by raising a group of high quality animals while the cow-calf operator earns $42.68 per head. A feedlot would receive $32.34 per head and $31.88 per head by raising medium and low quality cattle, respectively. However, the cow-calf operator would lose money by providing a group of cattle whose quality are lower than average (see Table 8). In this case, a lower effort level by the cow-calf operator is nearly completely internalized because the feedlot's payment is largely independent of feeder cattle quality. The case where the feedlot cannot pick optimal marketing date obtains similar results as those of scenario 3a.

Given that the payment to the feedlot is based upon feed cost plus a typical industry markup, a longer cattle finishing period will yield a larger payment for the feedlot. Therefore, the feedlot has an incentive to keep cattle longer than what would be optimal in the eyes of the cow-calf operator. Scenario 3c simulates the situation of feedlot moral hazard by assuming there is an error in marketing similar to that in scenario 3b, however the sign of the error is always positive (i.e., the error is always that cattle are kept too long). From Table 10 one can see that the profit for a cow-calf operator who provides high quality cattle is $26.34 per head, about $16 lower than the case without moral hazard while the feedlot operator would net $0.80 per head by randomly extending the marketing date beyond that which is optimal. While $0.80 is not a large figure, the average profits of custom feedlots over time are quite small; hence even small increments to profits over time could be relatively lucrative. Consequently, even though the cow-calf operator will always provide a high effort level (due to the magnitude of the profit margin between different quality levels), the moral hazard by the feedlot could yield sub-optimal profits.

Discussion

From the above analysis, one can see that the premium/discount-sharing contract provides both the feedlot and the cow-calf provider incentives to make high levels of effort to improve final cattle quality. Under the assumptions used in the analysis this type of contract also yields the highest level of average profits for the suppliers of high quality feeder cattle and similar average profits for the suppliers of medium quality feeder cattle. Feedlots would find the contract advantageous because high quality feeder cattle suppliers self-select into the contract, and these cattle provide a higher average profit. The suppliers of low quality cattle would never want to enter such a contract, which helps feedlots avoid unprofitable pens of cattle.

The format of the sharing contract could also include features that ease cash flow constraints for cow-calf operators who are used to receiving cash from fall sales of feeder cattle. For instance, the feedlot could pay the cow-calf operator 90 percent of the spot market price for feeder cattle at the time of purchase and then, after the cattle are slaughtered, the feedlot could pay the cow-calf the remainder of the base price plus premium or minus the appropriate discount.

Summary and Conclusions

Our analysis suggests that there is the potential for moral hazard in typical forms of feeder cattle transactions. The potential exists for moral hazard on the cow-calf operator side of a simple spot market transaction because the cow-calf operator has little incentive to exert effort to improve unobservable quality traits. The potential exists for moral hazard on the feedlot side of retained ownership contracts because feedlot operators may not profit from effort spent on sorting or may increase profits by delaying slaughter dates. A linear premium/discount sharing contract can circumvent the double-sided moral hazard problem because it provides both parties incentives to make high levels of efforts.

Other mechanisms have also emerged in the marketplace to address the lack of incentives for all parties to exert effort to improve quality. Certified feeder cattle sales are becoming increasingly popular. These sales feature feeder cattle for which certain characteristics that are usually unobservable (preventative health treatments and more subtle genetic traits) have been verified by an independent third party before the sale of the feeder cattle. Future research should compare the relative efficacy of premium sharing contracts and certified feeder cattle sales in circumventing the incentive issues in this market.

Further analysis is also warranted to consider the aggregate institutional implications that might arise if linear premium sharing contracts or certified feeder cattle sales prove popular. Current auctions may become an outlet for only lower quality of animals as contracts or certified sales draw higher quality cattle away from general markets.

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Table 1. Initial Value and Slope (Growth Rate) for Three Cattle Quality Functions

Time Period (days on feed)	Weight (lb/day)		Marbling Score		Back Fat (mm/day)	
	Good	Bad	Good	Bad	Good	Bad
Initial	500	500	3.5	2.5	4	6
0-100	3.5	2.8	0.01	0.01	0.09	0.09
101-145	3.5	2.8	0.04	0.02	0.12	0.12
145+	3.5	2.8	0.02	0.01	0.15	0.15

Units for weight are in pounds, for marbling score are expressed in an industry standard scoring system and for back fat are in millimeters.

Table 2. The Combination of Pens of Varying Quality Level

Quality Level	% Good Animal	% Bad Animal	Morbidity Rate	Mortality Rate*
High	90%	10%	35.7%	2%
Medium	50%	50%	56.5%	2.5%
Low	10%	90%	77.3%	3%

* Mortality rate is conditional upon becoming sick.

Table 3. Dollars Per Carcass Weight (cwt) Premium and Discounts Used in This Paper [A]

Quality Grade	Prem/Disc ($)	Yield Grade	Prem/Disc ($)	Carcass Weight	Prem/Disc ($)
Prime	5.57	YG 1	2.24	<500 lbs	-22.18
CAB	3.00	YG 2	1.00	500-550 lbs	-17.79
Choice	0.00	YG 3	-0.21	550-600 lbs	-0.57
Select	*	YG 4	-15.27	600-900 lbs	0.00
Standard	-17.81	YG 5	-20.87	900-950 lbs	-0.24
				950-1000 lbs	-14.63
				>1000 lbs	-21.63

A- Data source: USDA weekly summary of beef grids premiums and discounts, 1999-2001.

Table 4. Feedlot Profit in Scenario 1A.

(Feedlot Picks Optimal Marketing Date given Price Expectations)

Quality Level	Feedlot Profit ($/Head)		Average Optimal Marketing Date (Days on Feed)	
	Unsorted	One Sorting	Unsorted	One Sorting
High	34.34	75.98	174	167, 203[A]
Medium	-16.64	27.30	175	165, 196
Low	-69.28	-22.13	176	164, 193

A – The first (second) number is the marketing date for the first (second) group emerging from the feedlot's pre-harvest sorting efforts.

Table 5. Feedlots Profit in Scenario 1B.

(Feedlot's Marketing Date is Optimal Marketing Date + Error)

Quality Level	Feedlot Profit ($/Head)		Average Optimal Marketing Date (Days on Feed)	
	Unsorted	One Sorting	Unsorted	One Sorting [A]
High	33.49	74.97	174	167, 203
Medium	-17.68	31.97	175	165, 196
Low	-66.56	-18.99	177	164, 193

A – The first (second) number is the marketing date for the first (second) group emerging from the feedlot's pre-harvest sorting efforts.

Table 6. Feedlots and Cow-calf Operators' Profit in Scenario 2A.

(Feedlot Picks Optimal Marketing Date given Price Expectations)

Quality Level	Feedlot Profit ($/Head)		Cow-Calf Profit ($/Head)	
	Unsorted	One Sorting	Unsorted	One Sorting
High	23.76	63.04	10.58	12.94
Medium	-18.69	23.48	2.05	3.82
Low	-60.83	-16.99	-8.44	-5.14

Table 7. Feedlots and Cow-calf Operators' Profit in Scenario 2B.

(Feedlot's Marketing Date is Optimal Marketing Date + Error)

Quality Level	Feedlot Profit ($/Head)		Cow-Calf Profit ($/Head)	
	Unsorted	One Sorting	Unsorted	One Sorting
High	23.00	62.33	10.49	12.64
Medium	-19.54	28.67	1.87	3.30
Low	-57.98	-12.94	-8.58	-6.05

Table 8. Feedlots and Cow-calf Operators' Profit in Scenario 3A.

(Feedlot Picks Optimal Marketing Date given Price Expectations)

Quality Level	Feedlot Profit ($/Head)	Cow-Calf Profit ($/Head)
High	33.30	42.68
Medium	32.34	-5.05
Low	31.88	-54.01

Table 9. Feedlots and Cow-calf Operators' Profit in Scenario 3B.
(Feedlot's Marketing Date is Optimal Marketing Date + Error)

Quality Level	Feedlot Profit ($/Head)	Cow-Calf Profit ($/Head)
High	33.25	41.73
Medium	32.34	-1.36
Low	31.88	-50.87

Table 10. Feedlots and Cow-calf Operators' Profit in Scenario 3C.
(Feedlot Always Keep Cattle Too Long)

Quality Level	Feedlot Profit ($/Head)	Cow-Calf Profit ($/Head)
High	34.23	26.34
Medium	33.28	0.50
Low	32.77	-52.46

Figure 1. A Game Between the Feedlot and the Cow-calf Operator in a Premium Sharing Contract (Unit: $/Head)

		Feedlot: No Sorting	Feedlot: Sorting
Cow-calf Operator	**High**	(11, 24)	(13, 63)
	Medium	(2, -19)	(4, 23)
	Low	(-8, -60)	(-5, -17)

Endnotes

[1] Auction sales featuring feeder cattle that are third-party certified to meet key unobservable traits (e.g., health) are becoming more popular, however.

[2] The carcass weight is the weight of slaughtered animal after the viscera, hide, head, feet and tail are removed.

[3] Note that penalties are commonly assessed for several other binary quality issues (e.g., dark cutters) that are not addressed in this analysis.

[4] The effort level of the feedlot could be indicated by many other factors such as management and feed efficiency, et cetera. We simplified it by only using pre-harvest sorting.