Contract Pricing and Packer Competition in Fed Cattle Market

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Recently, U.S. the cattle industry has undergone structural changes including increased concentration and a greater degree of quasi-vertical integration coordinated through contract procurement often referred to as captive supplies.[1] An implication of these trends is that packers are rapidly switching from traditional spot procurement in fed cattle markets to contract procurement. Possible motives for the switch to use contract procurement are to reduce price variability and manage risk and also to reduce transaction costs. Both packers and cattle producers can potentially benefit from contract sales as packers insure themselves against quantity short falls and price fluctuations and cattle producers secure reliable sales and smooth price volatility. For packers, a primary benefit from use of captive supply is to secure fed cattle requirements so packing plants can operate at the highest possible level of capacity utilization. In addition, they can potentially gain control over the type and quality of cattle and reduce procurement costs.

However, contract procurement can reduce public market information because contract prices are frequently not reported due to nondisclosure rules. Furthermore, contract procurement may reduce competition in the fed cattle spot market, potentially leading to increased market power for packers (Ward and Schroeder). Contract procurement potentially allows packers to exercise price discrimination in procurement as different prices may be paid for cattle purchased through contracts and cattle procured through traditional spot markets. Hence, concerns about competitiveness among meatpackers arise.

[1] GIPSA defines "captive supply" as cattle owned or fed by a packer, procured through forward contracts and marketing agreements, and cattle that are otherwise committed to a packer more than 14 days prior to slaughter. Captive supplies is a kind of exclusive contracts

While the evidence is not conclusive, most previous empirical studies generally suggest a negative relationship between captive supplies and spot market prices. Elam (1992) found individual states, Nebraska, Kansas, Colorado, and Texas, varied from no price difference to price reductions ranging from \$0.15/cwt to \$0.37/cwt. Hayenga and O'Brien (1992) compare the average weekly fed cattle price in the same four states and found no conclusive evidence that forward contracting decreased fed cattle prices. Schroeter and Azzam (2003) show a small statistically significant negative effect of captive supply volume on cash prices.

While most previous studies do not examine how contracts facilitate or extend market power, MacDonald, et al. argue that contracts can potentially amplify market power through entry deterrence, reduced price competition, and discriminatory pricing.[2] Only a few theoretical studies have investigated how captive supplies use may be used as a strategy to create or extend packer market power.[3] Love and Burton (1999) formalize a strategic rationale whereby packers might use captive supplies to extend market power in cattle procurement. They show that a dominant beef processing firm has an incentive to backwardly integrate to simultaneously escape efficiency loss and exercise market power in spot market procurements. However, their model does not predict an unambiguous effect of backward integration on spot market price. Using a spatial model, Zhang and Sexton (2000) examine how strategic captive supply procurement can affect spot market price. Their model shows that the spot market cattle price can be reduced as transportation cost rises.

Cattle feeders have increasing concerns about the effect of "Top-of-the-Market-Pricing (TOMP)" contracts on prices paid by packers for fed cattle. Contract prices are often established

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[2] They found packers have an incentive to use contract as a strategic variable for the purpose of increasing market power.
[3] Love and Burton (1999); Zhang and Sexton (2000); Xia and Sexton (2004)

based on either nearby spot market price or fed cattle futures market price. For example, under TOMP clauses, contract base price paid to producers is set as the highest spot price at delivery time.[4] With TOMP clauses, packers have an incentive to compete less aggressively in spot markets in order to reduce input cost in contract markets.

Recently, Xia and Sexton examined the effect of coexistence of spot and contract markets in a one-shot game framework where contract price is determined through TOMP clauses. They find that TOMP clauses reduce competition in the spot market and lower producers' profits. Ironically, they find that feeders favor the contract even though TOMP clauses lead to anti-competitive consequences for feeders. Even with lower equilibrium prices Xia and Sexton demonstrate that signing TOMP clauses is a dominant strategy for producers because a producer will suffer more loss without contracts. Their findings, however, are based on the assumption that contract price cannot deviate from spot market price.

In practice, contract prices reflect both observed and unobserved hedonic characteristics of fed cattle and stochastic market related influences. With heterogeneous quality characteristics, contract prices might deviate from spot prices giving packers a degree of latitude in setting contract price. In such a situation, packers have an incentive to transform bidding strategies in spot markets resulting in additional complications with respect to understanding the consequences of TOMP clauses on spot market price. For example, when there is a sufficiently large set of hedonic characteristics it may become hard to find the highest spot market price of the same kind of fed cattle. Widely heterogeneous hedonic characteristics will make it physically infeasible to trace the price on the spot markets for the same quality of cattle.

[4] TOMP clause is discussed first by Davis (2000)

We extend Xia and Sexton's work on TOMP clauses by considering the effects of hedonic characteristics on contract price. This study addresses how contracts affect packer market power using a general pricing scheme which considers hedonic characteristics of cattle quality. We employ a stage game to investigate the effects of the contract procurement on packer competition in the spot market. In particular, we assume a more general relationship between contract price and spot market price, which allows us to capture the impacts of captive supply, hedonic characteristics of fed cattle, and unobserved stochastic components. Previous models are also extended by assuming cattle feeders may be risk averse.

1 The Model

We assume a duopsony case in which there are two packers and N cattle feeders who are engaged in contract and spot markets. Each feeder produces one unit of cattle, and only participates in one market, either the contract market or the spot market. We assume that feeders are risk averse and also price takers (i.e., non-strategic players), and packers are risk neutral who maximize their expected profit from both markets. To facilitate the definition of notations, we use superscripts "*c*" and "*s*" to represent contract and spot markets, subscript i for packer i where $i=a$, b, and subscript k for feeder k where $k=1, 2, \ldots, N$.

1.1 Price Formulation in both Markets

Spot market fed cattle prices are determined by negotiation or bidding.[5] Formula pricing with various types of base price are the most general pricing method for fed cattle transaction in the contract market.[6] The formula base price is usually derived from the various external

[5] Spot market procurement for fed cattle resembles a type of first-price sealed-bid auction, in which, the highest bidder wins the cattle in a feedlot.
[6] Formula pricing in the fed cattle usually refers to the method of finding the base price in grid pricing system but, it also can include non grid pricing method such as live or dressed (carcass) weight pricing.

including the average price paid at a slaughter plant, wholesale prices, futures prices, or reported market average prices (Ward, Schroeder and Feuz). Fed cattle may be valued on live weight basis, carcass (dressed) weight basis, or grid pricing. Live weight or carcass pricing methods apply a uniform average price for the entire lot, while grid pricing is established on a carcass basis. Most spot market sales are priced on a live weight basis while contact sales are based on carcass weight since most formulas are based upon dressed weights.

We assume feeders who accept the contract are paid a higher base price than in the spot market. However, on average, the observed contract price can deviate from the base price to reflect cattle quality attributes or so-called hedonic characteristics. Pricing methods in both spot and contract markets are linked to cattle quality attributes, $\mathbf{z}_k^m$, associated with feeder k and cattle market m. There are various factors differentiate cattle quality attributes, including average live weight of cattle, average dressing percentage of cattle, number of head in the lot, distance from the feedlot to slaughter plant, type of cattle, yield grade and quality grade of feedlots. We emphasize one particular factor which plays a vita role in determining cattle quality, the effort of each feeder. Feeders' efforts, denoted by e_k^m, influence management-based activities which are important quality attributes.

Assumption 1 *The hedonic characteristic function is given by:*

(1) $\mathbf{z}(e_k^m) = \alpha_m e_k^m + \varepsilon_m$ *where* $E(\varepsilon_m) = 0$ *and* $Var(\varepsilon_m) = \sigma^{2,m}$.

This assumption suggests a constant and positive marginal effect of feeders' effort on cattle quality attributes. That is, feeders utilize a higher effort level will delivery a better quality attributes of their cattle. It also shows that the marginal effect may variant with respect to different markets. The possible reason could be feeders in the certain market may be more efficient to convert their effort to quality attributes. The variation of cattle quality attributes in contract and spot markets could also differ. For example, the variance of cattle attributes in contract market can be smaller than spot market variance since dressing percentage is difficult to accurately estimate under live weight pricing but dressed weight pricing eliminate the risk of incorrect estimation. We use $\sigma^{2,s}$ and $\sigma^{2,c}$ to measure the variation of hedonic quality attributes in spot and contract markets.

Packers directly pay for quality attribute rather than feeders' effort level. Thus, the potential moral hazard problem is greatly avoided since quality attributes can be observed or obtained in spot and contract markets, while feeders' effort is privately hold information.

Assumption 2 *The transaction price paid to feeder k in the spot market price is written as*

$$(2) \qquad W_k^s = w^s + \delta_s \mathbf{z}(e_k^s),$$

where $\mathbf{z}(e_k^s)$ is defined by equation (1). w^s is a price component not relating to hedonic quality attributes and δ_s is the unit prices of hedonic quality attribute $\mathbf{z}(e_k^s)$.

Assumption 2 suggests that actual transaction price in the spot market can be decomposed into market price component and non-market hedonic price components.

Assumption 3 *Contract price W_k^c is based on the spot market price and certain hedonic quality attributes:*[7]

$$(3) \qquad W_k^c = \beta E\left(W_k^s\right) + \delta_c \mathbf{z}(e_k^c) = \beta\left(w^s + \delta_s \overline{\mathbf{z}}(e_k^s)\right) + \delta_c \mathbf{z}(e_k^c)$$

Assumption 3 suggests that the contract price consists of two parts: formula-based spot market price and price paid for certain hedonic quality attributes. Spot and contract markets may be

[7] Xia and Sexton's model assume the deviation of contract price from spot market price is not allowed. In their model, contract price for each feeder is always same with the spot price: $W_i^c = W_j^c = h(W^s) = w^s$

interested in different quality attributes, and they may put different weights on the same quality attributes as well. We use δ_c as the unit prices paid for the quality attributes that of interest to the contract market.

Assumption 3 is consistent with the contract procurement in cattle industry. Packers normally procure the cattle in feedlot base instead of buying individual cattle. Thus, reported prices are based on the average cattle characteristic of the feedlots sold in specified periods and geographic areas. Therefore, we assume average spot market price as a base price of contract market. Also, hedonic characteristics of cattle produced in contract market is included in contract market pricing scheme to reflect the quality difference between each feedlot in contract market. The key component in contracts is to define β. We expect β is greater than 1, which ensures that feeders who accept contract will have a higher price than those in the spot market. We will examine our expectation later to confirm.

1.2 Stage Game

Figure 1 illustrates the stage game by specifying the actions undertaken by packers and feeders and the corresponding choice variables in each stage. We assume this game evolves in three stages, and both contract and spot markets sequentially evolve.

In first stage, two packers A and B choose a number of feeders, n_A^c and n_B^c, to offer the contracts, respectively. They also decide weights that they apply to the average spot market price as the price base and the price premium paid to certain quantity attributes. Feeders who are offered the contract decide to accept or reject the offer. Feeders will accept the contract if they obtain a high profit by participating in the contract market. We assume that feeders who are offered the contract always accept the contract to sell on the contract market when solving the stage game.[8] We revisit this issue by compare the profit without contract and with contract later to confirm our assumption. In second stage, all feeders no matter whether they accept the contract or not choose their effort level to optimally produce quality attributes. In the last stage, packers A and B competes in spot market to purchase cattle that are not committed in the contract market to maximize his expected profit, respectively. That is, packers A and B purchase cattle from n_A^s and n_B^s feeders in the spot market.

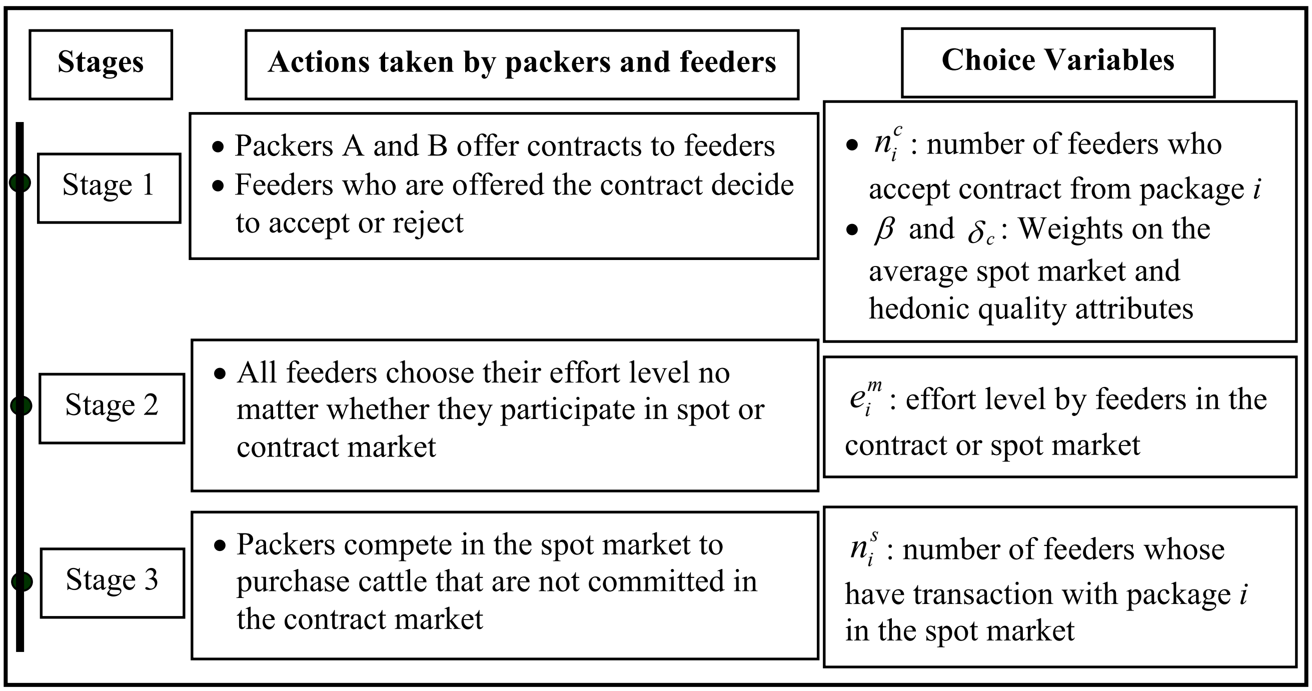

Figure 1: Actions and Choices Variable in the Stage Game

1.3 Solving the Stage Game Using Backward Deduction

Given the game structure illustrated in Figure 1, we use backward deduction to analytically solve the rest of stage game.

[8] In real market contract price is, on average, higher than spot price. Xia and Sexton (2004) show why rational producers accept the contract

(1) Stage III: Spot Market

Suppose that $(n_A^c + n_B^c)$ feeders already signed the contract with a processing firm. There are $N - (n_A^c + n_B^c)$ feeders left in the spot market to sell their fed cattle. Assume that aggregate spot market supply function of feeders takes the following functional form:[9]

$$(4) \qquad X_s^s = (N - n_A^c - n_B^c)\Phi(W_k^s)\,.$$

To simplify the model, following Xia and Sexton (2004) we assume that $\Phi(W_k^s) = W_k^s$. The demand in the spot market coming from two packers is $X_d^s = n_A^s + n_B^s$ since we assume each feeder produces one unit of cattle. The market equilibrium is achieved in the spot market when $X_s^s = X_d^s$. That is,

$$(5) \qquad (N - n_A^c - n_B^c)W_k^s = n_A^s + n_B^s\,.$$

Hence, the equilibrium spot price in the spot market is

$$(6) \qquad W_k^s = \frac{n_A^s + n_B^s}{N - n_A^c - n_B^c} = \frac{n_A^s + n_B^s}{N - n^c}\,.$$

The total profit for packer *i* from both the contract and spot markets is written as

$$(7) \qquad \pi_i = \left\{[p - W_k^c]n_i^c + [p - W_k^s]n_i^s - TC(n_i^c, n_i^s; \mathbf{v})\right\} \quad \text{for } i = \text{A, B}$$

where p is the output price, $TC(\cdot)$ is total processing cost function for packer *i*, which is assumed to be constant. is a number of feeder (also the total quantity of cattle purchased) in the contract (m=c) or spot (m=s) market. In stage III packers choose the quantity of cattle to purchase in the sport market $\left(n_i^s\right)$given that he/she already has a contract quantity n_i^c. That is,

[9] We assume the linear supply function. The supply function only represents non-hedonic components settled at spot market.

packer i maximize the expected profit specified in equation (11) by choosing n_i^s. Taking derivate of equation (11) with respect to n_i^s yields the first order condition,

$$(8) \qquad \frac{\partial \pi_i}{\partial n_i^s} = -\frac{\beta n_i^c}{N - n_A^c - n_B^c} + \left(p - \frac{n_A^s + n_B^s}{N - n_A^c - n_B^c} \right) - \frac{n_i^s}{N - n_A^c - n_B^c} = 0 .$$

Based on equation (8) we are able to derive the response function of each packer:

$$(9\text{-a}) \qquad n_A^s = \frac{p(N - n_A^c - n_B^c)}{2} - \frac{n_B^s}{2} - \frac{\beta n_A^c}{2} \text{ for packer A, and}$$

$$(9\text{-b}) \qquad n_B^s = \frac{p(N - n_A^c - n_B^c)}{2} - \frac{n_A^s}{2} - \frac{\beta n_B^c}{2} \text{ for packer B.}$$

Solving equations (9-a) and (9-b) simultaneously we obtain the Cournot-Nash equilibrium quantities in the spot market conditional on the contract market equilibrium:

$$(10\text{-a}) \quad n_A^s = \frac{(N - n_A^c - n_B^c)p}{3} - \frac{\beta\left(2n_A^c - n_B^c\right)}{3},$$

$$(10\text{-b}) \quad n_B^s = \frac{(N - n_A^c - n_B^c)p}{3} - \frac{\beta\left(2n_B^c - n_A^c\right)}{3}.$$

Substituting equations (10-a) and (10-b) into equation (6) yields the equilibrium price in the spot market,

$$(15) \qquad W_k^s = \frac{n_A^s + n_B^s}{N - n_A^c - n_B^c} = \frac{2p}{3} - \frac{\beta\left(n_A^c + n_B^c\right)}{3(N - n_A^c - n_B^c)}.$$

(2) Stage II: Feeders' choice of their effort level in both markets

We assume feeders' cost function per unit of cattle is

$$(16) \qquad c(e_k^s) = c_0 + \frac{1}{2}\left(e_k^s\right)^2,$$

where c_0 is the cost of other inputs besides the effort. We assume that feeders' unit profit function is

(17) $$\pi_k^{F,m} = W_k^m - \left(c_0 + \frac{1}{2}\left(e_k^s\right)^2 \right),$$

where W_k^m is defined either by equation (2) for the spot market price or equation (3) for the contract market price. Furthermore, we assume that feeder k maximizes the expected utility which follows the mean-variance functional form by choosing the effort level,

(18) $$\max_{e_k^m} \left\{ EU(\pi_k^{F,m}) \right\} = \max_{e_k^m} \left\{ E(\pi_k^{F,m}) - \frac{\gamma_k}{2} Var(\pi_k^{F,m}) \right\},$$

where $\gamma_k > 0$ is a constant absolute risk aversion.

Proposition 1*: Feeders' optimal effort level in the spot and contract markets are*

(19) $e_k^m = \delta_m \alpha_m$ *for m=s or c.*

Proof*:* The variance of feeder k's profit is $Var(\pi_k^{F,m}) = \delta_s^2 E\left(\mathbf{z}(e_k^m) - \overline{\mathbf{z}}(e_k^m)\right)^2 = \delta_s^2 \sigma_{\mathbf{z}}^{2,s}$. Substituting equation (16) and variance into the expected utility yields

$$EU(\pi_k^{F,m}) = \left(\delta_s \alpha_s e_k^s\right) - \left(\frac{1}{2}\left(e_k^s\right)^2\right) - \frac{\gamma_k}{2}\delta_s^2 \cdot \sigma_{\mathbf{z}}^{2,s}.$$

The necessary first order condition for the optimal effort level is

$$\frac{\partial EU(\pi_k^{F,s})}{\partial e_k^s} = \delta_s x_k^s \frac{\partial \overline{\mathbf{z}}(e_k^s)}{\partial e_k^s} - e_k^s = \delta_s \alpha_s - e_k^s = 0,$$

which explicitly define the optimal effort level, i.e., $e_k^m = \delta_m \alpha_m$. ■

Proposition 1 shows that feeders who accept contract exert the effort level of $e_k^c = \delta_c \alpha_c$ and those who participate in the spot market utilize their effort level of $e_k^s = \delta_s \alpha_s$. That is, all feeders engaged in the same market have an identical effort level. The difference of the effort level between two markets depends on the weights of hedonic quality attributes and the conversion efficiency from the effort to quality.

(3) Stage I: Contract market

Substituting equation (15) and equation (19) for $m=c$ into equation (3) yield the contract price:

$$(20)\qquad W_k^c = EW_k^c = \beta EW_k^s + \delta_c \alpha_c e_k^c = \frac{2\beta p}{3} - \frac{\beta^2 \left(n_A^c + n_B^c\right)}{3(N - n_A^c - n_B^c)} + \delta_c^2 \alpha_c^2 .$$

The total expected profit for packer i is the same as in equation

$$(21)\qquad E\pi_i = E\left\{[p - W_k^c]n_i^c + [p - W_k^s]n_i^s - TC(n_i^c, n_i^s; \mathbf{v})\right\} \quad \text{for } i = A, B.$$

The only difference between equations (7) and (21) is that packers expect their profit in the first stage since the spot market activities have not been realized yet. Thus, feeders maximize the expected profit in the first stage by choosing the optimal quantity or number of feeders to contract with in this case. Furthermore, feeders know the best response function of the spot market quantity written in equations (12-a) and (12-b) conditional on the contract market quantity. Therefore, feeder i's maximization problem is given below:

$$(22)\qquad \max_{n_i^c} \{E\pi_i\} = \max_{n_i^c} E\left\{[p - W_k^c]n_i^c + [p - W_k^s]n_i^s - TC(n_i^c, n_i^s; \mathbf{v})\right\},$$

Where n_i^s is written in equation (12-a) for i=A or (12-b) for i=B. The necessary first order condition is

$$(27)\qquad \frac{\partial E\pi_i}{\partial n_i^c} = \left(3V - \beta(\beta - p)\right)(N - n_A^c - n_B^c)^2 + \beta N(1 - p)(N - n_A^c - n_B^c) + \beta^2 N^2 = 0 .$$

where $V = 3p - 2\beta p - 3\delta_c^2 \alpha_c^2 - \dfrac{p(p + 2\beta)}{3}$.

Because of the symmetric condition in the spot or contract market, simultaneously solving equation (27) for *i=A* and *i=B* yields the optimal contract market quantity for two packers:

$$(28) \qquad n_A^c = n_B^c = n^c = \frac{N}{2} - \frac{\beta N\left(\sqrt{(1-p)^2 - 4\Delta} + (1-p)\right)}{4\Delta},$$

where $\Delta = 9p - 9\delta_c^2\alpha_c^2 - p(p+8\beta) - 3\beta^2$.

Once we obtain the optimal contract quantity, we are able to derive all the other relevant information in the contract and spot markets. Substituting equation (28) into equations (12-a) and (12-b) yields the spot market equilibrium quantity:

$$(29) \qquad n_A^s = n_B^s = n^s = \frac{\beta N}{6}\left(\frac{\left(\sqrt{(1-p)^2 - 4\Delta} + (1-p)\right)(2p+\beta)}{2\Delta} - 1\right).$$

Similarly, we obtain the expected contract and spot market price below:

$$(30\text{-a}) \quad EW_k^s = \frac{\left(\sqrt{(1-p)^2 - 4\Delta} + (1-p)\right)(2p+\beta) - 2\Delta}{3\left(\sqrt{(1-p)^2 - 4\Delta} + (1-p)\right)},$$

$$(30\text{-b}) \quad EW_k^c = \beta\left(\frac{(2p+\beta) - 2\Delta}{3} - \frac{2\Delta}{3\left(\sqrt{(1-p)^2 - 4\Delta} + (1-p)\right)}\right) + \delta_c^2\alpha_c^2.$$

2 Discussion of Some Expected Results

Based on our model set-up, we expect the following results:

- The optimal choices of the weight of the spot market price (β) and the price premium of quality attribute (δ_c^2) specified in contracts: Taking the derivative of packer *i*'s total profit function with respect to β and δ_c^2, and then solve these two first order condtions simultaneously will result in the optimal choice of β and δ_c^2. Mathematically, the optimal β and δ_c^2 are implicitly determined by the following two equations:

(31-a) $$\alpha_c^2 \delta_c^2 - \frac{N^2 \beta}{3\left(N - 2n^c\right)^2} \frac{d\, n^c}{d\beta} = \frac{N\, n^c}{3\left(N - 2n^c\right)},$$

(31-b) $$2\alpha_c^2 \delta_c n^c = \frac{N^2 \beta}{3\left(N - 2n^c\right)^2} \frac{d\, n^c}{d\, \delta_c}.$$

where n^c is defined in equation (28).

- Once we solve the optimal price premium of quality attributes specified in contracts, we are able to identify factors which can enhance feeders' efforts in the contract market to induce a higher cattle quality.
- The comparison of profits of feeders in the contract and spot market will tell the conditions under which feeders will always accept the contract in the first stage when the contract is offered by the packer.

3 Concluding Remarks

We use a game-theoretical framework to analyze the coexistence of spot and contract markets in the cattle industry. A duopsony scenario with two packers and *N* feeders is used to reflect the reality in the cattle industry. Our main contribution is to incorporate the risk components and the pricing of hedonic attributes of cattle quality. Our preliminary results show that packers have an incentive to transform bidding strategies in spot markets when a series of hedonic characteristics play some significant roles in establishing cattle prices in contract market. That is, we will show that the effectiveness of contract with TOMP clauses on packer competition in a spot market depends on whether there is a correlation between spot price and hedonic characteristics. The results may shed light on understanding potential effects of captive supplies on market power and may aid in the assessment of the policies designed to enhance competition in the cattle industry.

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