Contracting, Captive Supplies, and Price Behavior

by

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Practioner's Abstract
Theoretical and simulation results clarify the role of procurement contracting in determining spot price levels and volatility. A generic model determines market share across quality. Actual supply is specified as price dependent and stochastic. Simulation examines sensitivity of price level and volatility to extent of forward contracting, risk aversion, and ability to adjust spot market demand (recontracting). The results show that as forward contracting increases mean spot price decreases and variance increases. This effect increases as risk aversion decreases and as the extent of recontracting adjustment in spot demand decreases.

KEYWORDS: *PRICE VOLATILITY, FORWARD CONTRACTING, CAPTIVE SUPPLY, BEEF PRICES.*

INTRODUCTION

Contracting is a method[1] for coordination that has been rapidly adopted in particular segments of agricultural markets since 1960's. Past literature has been empirical and has focused on the relationships between transaction price levels (cash market prices) and the extent of contracting as measured by inventories of forward contracted cattle. Ward, et al. (1999) explained that reductions in the supply of available fed cattle due to contracting led to a change in the distribution of available cattle from feedlots to packers and, potentially, a change in the relative bargaining position of feedlots and packers. Jointly, these changes would be expected to affect changes in price behavior. Schroeder et al. (1993) proposed that the main factors determining of price levels are the extent of packers' competitive behavior, the high inelasticity of supply in the short-run, and quality attributes. Both studies found evidence that the spot price level is inversely related to the incidence of contract use.

Few studies have considered the price volatility implications of contracting. Based on a variety of frequencies of price data, Weaver and Natcher (2000a) found evidence of rapid vertical transmission of price volatility within the beef supply chain. The relevance of price volatility follows from the economic costs that result from decisions that are allocatively inefficient (Weaver and Natcher, 2000b). When prices are volatile, decisions made today may be unprofitable tomorrow if tomorrow's price was not correctly anticipated. In other words, uncertainty lies at the root of the economic costs of price volatility.   The goal of this paper is to investigate the linkage between forward contracting and the levels of both price and price volatility.

This paper presents and implements an alternative consideration of the role of captive supplies in spot price determination. Specifically, both price level and price volatility effects are considered. The paper has three objectives: 1) analysis of price performance in markets segmented by procurement contracting, 2) sensitivity analysis of price performance with respect to contract characteristics, and 3) sensitivity analysis of price

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[1] The others include strategic alliances, joint venture, and franchising.

performance with respect to alternative market structures. A game theoretic model is set up that incorporates asymmetric information across feeders/producers and packers/processors.

Given the complexity of relationships, the potential for use of analytic approaches based on parametric methods is limited as an approach to understanding the price level and volatility implications of these dimensions of price determination. Here, a simulation approach is used to generate price series from which inferences are drawn concerning price levels and price volatility across a variety of scenarios. Structural features of the underlying agent and market supply and demand are drawn from a general notion of food system market structure, e.g. beef or milk. Sensitivity of results to specification is explored. The paper contributes to the understanding of the role of procurement contracting, market structural features, and product characteristics as a determinant of the implications of contracting for price levels and volatility. Given that contracting offers an important means of private market coordination, it is essential that its implications be fully understood as a basis for determination of associated price performance.

ECONOMIC THEORY: CONTRACTING, CAPTIVE SUPPLY, AND PRICE VOLATILITY

Two kinds of players are specified in the fed cattle market: the feeder and the packer. Two markets, forward contract market and spot/cash market, are assumed to support all transactions between feeders and packers. Feeders play the role of the suppliers of animals, whereas the downstream packers are buyers. We simplify the model to a two feeders and one packer problem. We assume that the packer has no *a priori* knowledge of whether a feeder will deliver a high- or a low- quality product. This would especially be the case in the cash market where animals are traded on auction markets or purchased by roving buyers that would have little insight into the condition of the animals. We view the propensity for production of quality as a feeder characteristic or type. Feeders may be able to signal their quality (type), and packers can draw the inferences from the actions of feeders. For example, feeders can provide some assurance concerning quality to a potential buyer by showing a certificate which includes breed, feeding and watering records, vet references, and other information or putting labels on their products.

A two-sector general equilibrium model is introduced to examine the effects of contracts on spot market price behavior. The contract market here is subject to adverse selection, which is based on imperfect information concerning meat quality. Forward contracting is designed for quality management of the principal. This notion is illustrated in most animal and fresh fruit market chains, we find quality being hard to observe or verify. Therefore, this is a good assumption in our set up that quality is unobservable or the cost of quality verification is high. We look at how agents effectively signal their quality using a framework *a la* Spence (1973).

In this model, we consider price as determined through a series of four successive periods. In the first, nature generates a random draw that determines the true type for each of two feeders. We assume type indicates the quality of output produced by the feeder. Each feeder has a type w in a finite set Ω. Further, we assume for the time being

that types are independent. At the beginning of the game, each feeder is assumed to know his type but is given no information about his opponents' type. The packer has no information about feeder type. In the second period of the process, feeders and the packer make decisions, setting their planned supply and demand of animals, respectively. We assume each quality of meat has a market outlet.

In the third period, the forward contract market is opened. Here, the value of the forward contract market to feeders is assumed to include management of price risk exposure through fixing the output price for at least a portion of the output. From the packer perspective, contracting offers control of input supply quantity and quality. Although the packer has no knowledge of feeder type, we suppose that feeders have a natural incentive to signal quality in an attempt to access higher prices in the market for high quality product. Thus, the high quality feeder has an incentive to "signal" or reveal type to avoid inaccurate assessment of quality in the market. At the same time, low quality feeders have an incentive to provide a false signal that their quality (type) is high rather than low. Within this specification, the existence of the forward contract market follows from its ability to differentiate prices by quality. We assume the packer as a buyer is able to verify quality only after delivery. Thus, *ex ante*, the packer faces the risk of accepting as true the false signals from low quality feeders. To manage this risk, it follows that packers have an incentive to differentiate across quality by paying higher forward contract prices for high quality meat when a truthful signal is offered. Given both feeder and packer have incentives to differentiate prices by quality, the success of the forward market relies on finding a mechanism that discourages low quality feeders from falsely signaling. Based on this specification, the problem dissolves into a contracting problem in which high quality feeders and packers negotiate and sign contracts that specify quantity of animals (number and live weight), price, and the indemnity mechanism that is triggered when products do not satisfy the signaled quality.

In the fourth period, all animals have been fed to their market weight and uncertainty over availability of total supply is resolved. We allow the packer to adjust his planned demand in response to change in spot price information between the planning period and this closing period where spot price is determined. We assume that the production of quantity is stochastic. Animals that were not contracted in earlier periods are assumed marketed in a competitive spot market. In this initial model, we assume the probability of either feeder type animal going to the spot market is equal. That is, the feeders are assumed to have diffuse priors concerning the data generating process we label as nature. The spot market is assumed to be an anonymous auction market where animal type is not observable at a reasonable cost. Thus, the only information available to the packer concerning quality is that which can be elicited through effective contracts that encourage truthtelling concerning quality.

The goal of our model is to focus on the functions and the effects of forward contracting in transactions and price levels and volatility. By applying the "intuitive criterion" of Cho-Kreps (1987), there is only one equilibrium emerge, namely a separating equilibrium in which the high quality feeder chooses a least-cost announcement of quality type to signal type while at the same time not attracting the low

quality feeder to pretend he is of high quality, whereas the low quality one chooses no signal at all. In practice, this announcement might be thought of as a certificate that declares quality level.

THEORETICAL SPECIFICATION AND ANALYSIS

W consider a two-type model and examine the separating equilibrium. The fact that we can separate the feeders in our model follows from the existence of a signal that provides a basis for differentiation of price paid by the processor by type of the feeder. In this two-type case, low quality is the "base" quality. We specify that the high quality feeder uses an indemnity to enforce/assure an incentive compatibility constraint on the low quality feeder to deter this feeder from providing a false signal to the processor. Faced with this indemnity mechanism, the low quality feeder chooses not to signal, and faces no risk of indemnity payment, accepting the low quality contract price. The high quality feeder, however, chooses to signal and reveals his true type. This unique equilibrium is the most efficient separating perfect Bayesian equilibrium and entails the least cost warranty. Thus, high quality feeder will be assumed to earn the higher contract price.

Two results of Spence's model also follow from our model. First, only the high quality feeder's incentive compatibility constraint is active. This is follows from the fact that the packer can buy low quality meat in the spot market and receives no benefit from forward contracting with a low quality price that exceeds the spot price. Second, only the low quality feeder receives the efficient allocation associated with no signaling cost. In other words, the high quality feeder pays the price of incomplete information in our model.

Feeder Behavior

In the first period, nature randomly assigns each feeder's type, w. We assume that before this natural assignment, feeders face the same probabilities of each quality type occurring. We consider the outcome situation where one feeder is a high quality type and the other is assigned low quality. After each feeder knows his type as private information, the one with high quality who wants to trade in forward contract market sends a pure signal, x, to the packer to reveal his type. Then, each feeder independently chooses supply that maximizes expected utility of profits, $E[U(\boldsymbol{p})]$. If a feeder is of high quality, his expected utility is as follows:

(1) $EU^{FH}(p_f^H, \tilde{p}_s, w^H; q_f^H, q_s^H, x^H) =$

$$p_f^H(x^H)q_f^{FH} + \tilde{p}_s q_s^{FH} - \boldsymbol{l}\,\mathrm{var}((p_s - c^H)q_s^{FH}) - c^H(q_f^{FH} + q_s^{FH})^2$$

where c^H parameterizes a quadratic cost function. In differentiated notation, the low quality feeder's expected utility is represented as:

(2) $EU^{FL}(p_f^L, \tilde{p}_s, w^L; q_f^L, q_s^L, x^L) =$

$$p_f^L(x^L)q_f^{FL} + \tilde{p}_s q_s^{FL} - \boldsymbol{l}\,\mathrm{var}((p_s - c^L)q_s^{FL}) - c^L(q_f^{FL} + q_s^{FL})^2$$

Notice here that since the spot price reflects the price for average quality, in general, it would be expected that $p_f^L - p_s < 0$. It follows the low quality feeder will not, in general, participate in forward contracting. Exceptions would occur in practice if the low quality feeder chooses to participate in contracting hoping to deceive the buyer or due to strong risk aversion.

Recall that the forward contract market coordinates the transactions between two feeders and one packer as they negotiate to determine the contract price, quantity, and indemnity based on their planned production, q^{Fw} ($w=H, L$), and planned demand, $q^{Pw}*(w=H, L)$. A unique separating equilibrium occurs in the forward contract market. Consider the feeders' optimization problem. Both high- and low quality feeders maximize their expected utility by allocating the total quantity of fed cattle between contract and spot market. The high quality feeder maximizes equation (1), i.e.

$$(3) \qquad \max_{q_f^{FH}, q_s^{FH}, x} EU^{FH}(p_f^H, \tilde{p}_s; q_f^{FH}, q_s^{FH}, x) = p_f^H(x)q_f^{FH} + \tilde{p}_s q_s^{FH}$$
$$- \mathbf{1}\tilde{s}_s^2 (q_s^{FH})^2 - c^H (q_f^{FH} + q_s^{FH})^2 - h(x|w) \qquad .$$

The optimal supply to contract and spot markets, the optimal level of certificate, and the optimal announced type are as follows:

$$(4) \qquad q_s^{FH} = \frac{\tilde{p}_s - p_f^H}{2\mathbf{1}\tilde{s}_s^2} \qquad\qquad \text{[Supply of high quality meat in spot market]}$$

$$(5) \qquad q_f^{FH} = \frac{p_f^H}{2c^H} + \frac{\tilde{p}_s - p_f^H}{2\mathbf{1}\tilde{s}_s^2} \qquad \text{[Supply of high quality meat in forward contract market]}$$

$$(6) \qquad \frac{\partial p_f^H(x)}{\partial x} * q_f^{FH} - \frac{\partial h(x|w)}{\partial x} = 0 \qquad\qquad \text{[Optimal certificate level]}$$

On the other hand, the low quality feeder maximizes expected utility (2) resulting in supply to these markets as follows:

$$(7) \qquad q_s^{FL} = \frac{\tilde{p}_s - p_f^L}{2\mathbf{1}\tilde{s}_s^2} \qquad\qquad \text{[Supply of low quality meat in spot market]}$$

$$(8) \qquad q_f^{FL} = \frac{p_f^L}{2c^L} + \frac{\tilde{p}_s - p_f^L}{2\mathbf{1}\tilde{s}_s^2} \qquad \text{[Supply of low quality meat in forward contract market]}$$

Equation (6) clarifies that if a contract market exists, $q_f^{FH} > 0$, and $\dfrac{\partial p_f^H(x)}{\partial x} > 0$ because $\dfrac{\partial h(\cdot)}{\partial x} > 0$. This means that announcing the high type earns the high contract price and provides the incentive for the high quality producer to signal. Otherwise, no signaling is necessary.

Packer Behavior

To allow for simulations of interest, we suppose that packer capacity for processing each quality type is fixed, defined as q^{PH*} and q^{PL*}, the target levels of slaughter for a given time period. Without loss of generality, we also parameterize the packer's hedge ration, the proportion $\boldsymbol{b}$ of purchased from contract market for both high- and low quality meat. In other words, the proportion $1-\boldsymbol{b}$ is planned to be traded in spot market. We define $\boldsymbol{b}$ as exogenously determined in this specification to allow simulation across a range of values for this hedge ratio. Hence, the packer's demands in forward contract market for either quality and in spot market are as follows:

(9) $\qquad q_f^{Pw} = \boldsymbol{b} q^{Pw*}, w = H, L,$

(10) $\qquad q_s^{P} = (1-\boldsymbol{b})(q^{PH*} + q^{PL*})$

Market Equilibrium

After forward contracts are signed, the production shock occurs. As the delivery date approaches, the spot market absorbs all remaining transactions. To proceed, note that the spot market equilibrium must be considered both from an expectational perspective as well as from an actual perspective. That is, during the forward market transactions period, an expectational spot market equilibrium occurs determining the expected spot price that equates expected supply from equation (4), (5), (7) and (8) and demand from equation (9) and (10) for either quality in forward contract and spot markets, as in equations (11) and (12).

(11) $\qquad q_f^{Fw} = \dfrac{p_f^{w}}{2c^{w}} + \dfrac{\tilde{p}_s - p_f^{w}}{2\boldsymbol{l}\tilde{\boldsymbol{s}}_s^{2}} = \boldsymbol{b} q^{Pw*}, w = H, L$ [Forward Contract Market equilibrium]

(12) $\qquad \dfrac{\tilde{p}_s - p_f^{H}}{2\boldsymbol{l}\tilde{\boldsymbol{s}}_s^{2}} + \dfrac{\tilde{p}_s - p_f^{L}}{2\boldsymbol{l}\tilde{\boldsymbol{s}}_s^{2}} = (1-\boldsymbol{b})(q^{PH*} + q^{PL*})$ [Anticipated Spot Market Equilibrium]

The resulting contract price function for either quality meat derived from equation (11) is

(13) $\qquad p_f^{w} = \dfrac{2c^{w}\boldsymbol{l}\tilde{\boldsymbol{s}}_s^{2} q^{Pw*}}{\boldsymbol{l}\tilde{\boldsymbol{s}}_s^{2} - c^{w}} \boldsymbol{b} - \dfrac{c^{w}}{\boldsymbol{l}\tilde{\boldsymbol{s}}_s^{2} - c^{w}} \tilde{p}_s, w = H, L.$

This highlights the fact that the forward contract price for each quality type is affected by the packer's hedge ratio, *ß*, and the expected spot price. Equation (12) defines the anticipated equilibrium where total expected supply balances total demand prior to the supply shock and actual quantity is determined in spot market. The left hand side and the right hand side of equation (12) are the planned supply and the planned demand subtracting to the contract portion, respectively. The partial reduced form for the rational expected spot price derived from equation (12) is:

(14) $\qquad \tilde{p}_s = \dfrac{p_f^{H} + p_f^{L}}{2} + \boldsymbol{l}\tilde{\boldsymbol{s}}_s^{2}(1-\boldsymbol{b})(q^{PH*} + q^{PL*})$

Substituting equation (13) into (14) results in the final reduced form for rational expected spot price:

(15) $\quad \tilde{p}_s = \dfrac{\boldsymbol{b}}{A}[c^H \boldsymbol{l} \tilde{\boldsymbol{s}}_s^2 (\boldsymbol{l}\tilde{\boldsymbol{s}}_s^2 - c^L)q^{PH*} + c^L \boldsymbol{l}\tilde{\boldsymbol{s}}_s^2 (\boldsymbol{l}\tilde{\boldsymbol{s}}_s^2 - c^H)q^{PL*}] +$

$\qquad\qquad \dfrac{(1-\boldsymbol{b})}{A}[2\,\boldsymbol{l}\tilde{\boldsymbol{s}}_s^2 (\boldsymbol{l}\tilde{\boldsymbol{s}}_s^2 - c^H)(\boldsymbol{l}\tilde{\boldsymbol{s}}_s^2 - c^L)(q^{PH*} + q^{PL*})],$

where $A \equiv 2(\boldsymbol{l}\tilde{\boldsymbol{s}}_s^2 - c^H)(\boldsymbol{l}\tilde{\boldsymbol{s}}_s^2 - c^L) + c^H(\boldsymbol{l}\tilde{\boldsymbol{s}}_s^2 - c^L) + c^L(\boldsymbol{l}\tilde{\boldsymbol{s}}_s^2 - c^H)$. Notice that the hedge ratio, β, does affect the expected spot price.

Next, we solve the actual equilibrium for the spot price, p_s. As we mentioned earlier, all uncertainty becomes certain when the deliver date approaches. At that time, the production shock, v, is realized which is assumed to affect quantity only, not quality, and meanwhile, the packer adjusts his planned demand in response to the actual spot price. The spot price is derived from the actual physical balance of the spot market:

(16) $\quad \dfrac{\tilde{p}_s - p_f^H}{2\boldsymbol{l}\tilde{\boldsymbol{s}}_s^2} + \dfrac{\tilde{p}_s - p_f^L}{2\boldsymbol{l}\tilde{\boldsymbol{s}}_s^2} + v = (1-\boldsymbol{b})(q^{PH*} + q^{PL*}) * \boldsymbol{d}\,p_s$

The left hand side and the right hand side are the actual supply and the actual demand, respectively. The possibility of packer spot price responsiveness is introduced with a demand adjustment term, $\boldsymbol{d}\,p_s$, where $\boldsymbol{d}$ is adjustment of planned spot demand to current spot price. We suppose that $\boldsymbol{d} < 1$ defining it as follows:

$q^P \equiv q^{P*}\boldsymbol{d}\,p_s$

$\boldsymbol{d} = [1 + (\partial q^P / \partial p_s)(\partial p_s / p_s)(1/ q^P)]$

where $\quad \partial q^P / \partial p_s \leq 0$

Thus, as spot market demand is more sensitive to current spot price, $\boldsymbol{d}$ decreases.

In actual equilibrium, the spot price is:

(17) $\quad p_s = \dfrac{1}{\boldsymbol{d}(1-\boldsymbol{b})(q^{PH*} + q^{PL*})}[\dfrac{\tilde{p}_s - p_f^H}{2\boldsymbol{l}\tilde{\boldsymbol{s}}_s^2} + \dfrac{\tilde{p}_s - p_f^L}{2\boldsymbol{l}\tilde{\boldsymbol{s}}_s^2} + v].$

Substituting equations (13) and (15) into (17) yields in general form:

(18) $\quad p_s = p_s(q^{PH*}, q^{PL*}, \tilde{\boldsymbol{s}}_s^2 \,|\, \boldsymbol{b}, \boldsymbol{l}, \boldsymbol{d}, v, c^H, c^L)$

Spot price is determined by packer's planned demand, subjective spot price variance conditional on the hedge ratio, feeder risk aversion, packer spot demand price responsiveness, the supply shock, and production cost parameters. Given the nonlinearity of the final reduced form, analytical results are limited and simulation is motivated as a means of understanding the roles of these factors in determining spot price level and volatility.

SIMULATION STUDIES

Here we limit our consideration to the effects of forward contract characteristics such as the hedge ratio, β, on the level and volatility of fed cattle transaction prices. Whereas many empirical studies have suggested $\dfrac{\partial p_s}{\partial \boldsymbol{b}} < 0$, based on simulation we hope to determine the robustness of this type of result. A second interest is in the effect of the

hedge ratio on the spot price volatility, i.e. the sign of $\dfrac{\partial \boldsymbol{s}_s^2}{\partial \boldsymbol{b}}$. Intuitively, when the

packer's hedge ratio increases, more forward contracting will occur, reducing spot demand. Decreased demand in spot market would likely drive spot prices down. The effect on spot price volatility (measured by instantaneous variance) is more difficult to motivate intuitively. However, equation (18) provides some information. Rewriting equation (17) as:

$$(19) \qquad p_s = \frac{B + v}{\boldsymbol{d}(1 - \boldsymbol{b})(q^{PH*} + q^{PL*})}, \text{ where } B = \frac{\tilde{p}_s - p_f^H}{2\boldsymbol{l}\tilde{\boldsymbol{s}}_s^2} + \frac{\tilde{p}_s - p_f^L}{2\boldsymbol{l}\tilde{\boldsymbol{s}}_s^2}.$$

the variance of spot price is:

$$(20) \qquad \mathrm{var}(p_s) = \boldsymbol{s}_s^2 = \frac{\mathrm{var}(v)}{\boldsymbol{d}^2(1 - \boldsymbol{b})^2(q^{PH*} + q^{PL*})^2}, \text{ where } \mathrm{var}(v)=1.$$

Differentiating equation (20) with respect to *ß*, we find:

$$\frac{\partial \boldsymbol{s}_s^2}{\partial \boldsymbol{b}} = \frac{2}{\boldsymbol{d}^4(1 - \boldsymbol{b})^3(q^{PH*} + q^{PL*})^4} \geq 0$$

So, the hedge ratio would have a positive effect on the variance of spot price in our model. Following similar differentiation, the adjustment in spot demand, $\boldsymbol{d}$, can be shown to be negatively related to the variance of spot price:

$$\frac{\partial \boldsymbol{s}_s^2}{\partial \boldsymbol{d}} = \frac{-2}{\boldsymbol{d}^3(1 - \boldsymbol{b})^4(q^{PH*} + q^{PL*})^4} \leq 0$$

While these relationships are determinant, we explore through simulation a series of other issues of interest.

Simulation Setup

Simulation within this context will allow characterization of relationships that are not otherwise identifiable based on analytic methods. Here, we illustrate this learning process based on hypothetical specification of parameters. To simplify the simulation model, 500 simulated trading periods are considered. The main focus here is to examine the spot price level and its variance and how these are related to the hedge ratio, *ß*. To consider robustness of these results, we also consider sensitivity to the risk aversion parameter, $\boldsymbol{l}$, and the demand adjustment term, $\boldsymbol{d}$.

The simulation procedure is as follows. At the beginning, say period 0, initial values for the parameters $(\boldsymbol{b}, \boldsymbol{l}, \tilde{\boldsymbol{s}}_s^2, \boldsymbol{d}, q^{PH*}, q^{PL*})$ are specified appropriately for the empirical setting of interest. We assume that the random shock, v_t, follows a standard normal distribution with zero mean and unitary variance. The spot price is assumed to follow a prior distribution with the mean defined by equation (15) and a constant variance. In period 1, the forward contract prices for each quality are calculated from equation (13). After the production shock, v_1, is drawn, the spot price for period 1 is derived from equation (18).

From period 2 onward, we specify expectations as a simple lag, i.e. $\tilde{p}_{st} = p_{s,t-1}$. In general,

$$p_{ft}^w = p_{ft}^w(q^{Pw^*}, \tilde{\boldsymbol{s}}_s^2, p_{s,t-1} \mid \boldsymbol{b}, \boldsymbol{l}, c^w), w = H, L$$

$$p_{st} = p_{st}(q^{PH^*}, q^{PL^*}, \tilde{\boldsymbol{s}}_s^2, p_{s,t-1} \mid \boldsymbol{b}, \boldsymbol{l}, \boldsymbol{d}, v_t, c^w)$$

After 500 periods, the mean and the variance of spot price are calculated. In theoretical consideration, the spot price is affected by the hedge ration, *ß*, risk aversion, $\boldsymbol{l}$, and the adjusted demand term, $\boldsymbol{d}$. We reparameterize these to define scenarios that will allow consideration of their effects on spot prices.

Experimental Design and Results

The simulation results in general show that as hedge increases mean of spot price falls, and variance increase. This effect increases as $\boldsymbol{l}$ decreases and as $\boldsymbol{d}$ decreases.

Case 1: $\boldsymbol{l}$ =0.1, 0.5, 0.9 and $\boldsymbol{d}$ =0.1 vs. spot prices

Plot 1 shows that as risk aversion, $\boldsymbol{l}$, decreases, concavity of p_s with respect to the hedge ratio, $\boldsymbol{b}$, increases, i.e. p_s is more sensitive to $\boldsymbol{b}$. Although we specify $\boldsymbol{b}$ as a parameter, in further work we have allowed it to be endogenous. In that case, as $\boldsymbol{l}$ increases, it is intuitive that more would be hedged, so less would be supplied to the spot market. For a given hedge, $\boldsymbol{b}$, it would follow that an increase in $\boldsymbol{l}$ would increase the spot price.

Case 2: $\boldsymbol{l}$ =0.1 and $\boldsymbol{d}$ =0.1, 0.5, 0.9 vs. spot prices

Plot 2 shows that spot prices have reduced responsiveness to the hedge ratio as $\boldsymbol{d}$ increases, i.e. concavity of p_s decreases with increases in $\boldsymbol{d}$. Note that $\boldsymbol{d}$ reflects the adjustment of planned spot demand to current spot price, so as $\boldsymbol{d}$ decreases, the current spot adjustment needed to balance any change in the actual excess demand is accentuated. That is, when $\boldsymbol{d}$ is small, the adjustment in spot price to a change in excess demand increases. It follows that as the previous spot price decreases, the subjective spot price decreases due to our simulation design, and the excess demand drives the mean of spot prices up.

Case 3: $\boldsymbol{l}$ =0.1, 0.5, 0.9 and $\boldsymbol{d}$ =0.1 vs. the variance of spot prices

Plot 3 shows in general, that the volatility (instantaneous variance) of the spot price increases with $\boldsymbol{b}$. That is, as more is hedged out of the spot market, spot prices become more volatile. Further, for a given $\boldsymbol{b}$, the variance of spot price decreases as $\boldsymbol{l}$ increases. This is consistent with theoretical results above. As risk aversion increases, more supply would be hedged, leaving less supply, and a larger proportion of supply that is stochastic, in the spot market.

Case 4: $\boldsymbol{l}$ =0.1 and $\boldsymbol{d}$ =0.1, 0.5, 0.9 vs. the variance of spot prices

Plot 4 shows a result that is analogous to those found for case 2. First, as $\boldsymbol{b}$ increases, the volatility of spot prices increases. Plot 4 illustrates that as $\boldsymbol{d}$ decreases (larger adjustment of demand to current spot price), the variance in spot price would increase.

CONCLUSIONS

Three objectives are met in this paper. First, our model shows that procurement contracting indeed plays an important role as a determinant of spot price level and volatility. In our model setting, forward contracting is used as an insurance/risk-smoothing instrument to facilitate market transactions faced with quality uncertainty and involving risk-averse agents. Due to asymmetric information, the existence of forward contracting enhances transaction performance by information-sharing and reduction of transaction costs. Furthermore, our results illustrate that contracting can lead to reduced feeder prices received, not due to market power of packers, but instead due to the residual nature of spot markets that operate in conjunction with forward contracting. We find that as contracting increases, spot price levels decrease and spot price volatility increases.

Secondly, our results clearly illustrate that spot price effects are conditional on contract characteristics. With contracting, spot and forward price effects depend on the specific market conditions. Spot price levels could be increased, decreased, or left unchanged. Based on our illustrative simulation specification, an inverse relationship between the spot market price and the forward contracting is found. Intuitively, forward contracting provides risk-sharing, and sellers may be willing to accept a lower price to have some of the production risk assumed by the purchasing firm, especially while the packers have more market power in noncompetitive market. Further, both our theory and our simulations illustrate increased forward contracting can induce increased spot price volatility. This result is not a universal one, instead it is due to the particular parameterization of the market setting.

Third, we consider the risk aversion, l, and the adjusted demand term, d, as representing market structure to examine the sensitivity of spot price performance. According to the simulation outcomes, the negative relationship between the spot price and forward contracting is amplified as l decreases and diminished as d increases, whereas the positive relationship between the variance of spot price and forward contracting is amplified as l decreases and diminished as d increases. These results are intuitive though also dependent on parameterization. Finally, one policy implication is worthy of further note. In case 4, as demand adjustment response to the current spot price increases (as d increases), the variance of spot price decreases. This suggests the importance of allowance for demand adjustment in the spot market. That is, as contracts or other regulations restrict spot market adjustment to price, spot price volatility will be accentuated.

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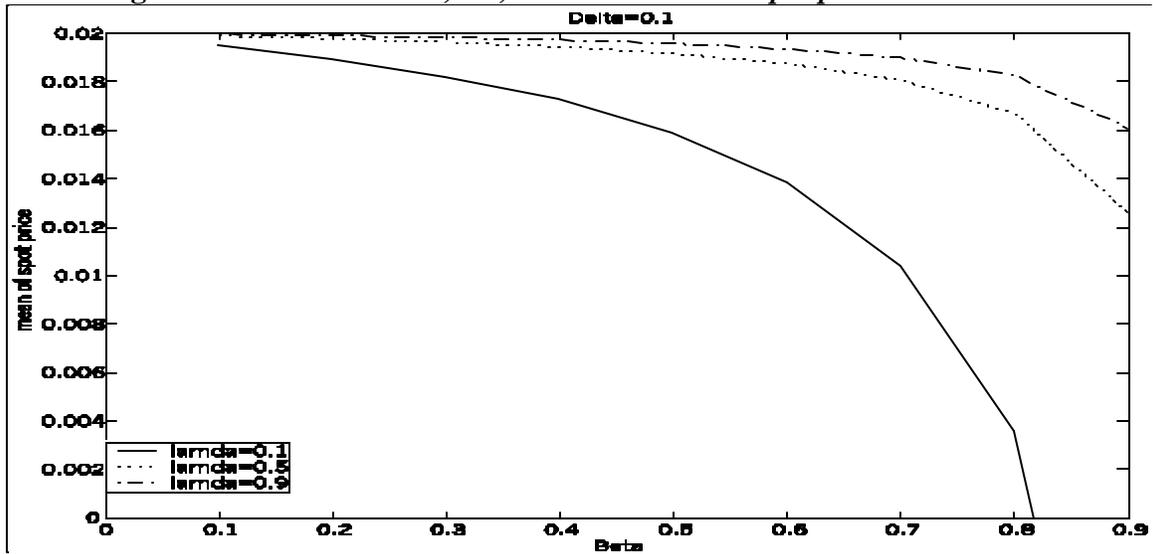**Figure 1: Case 1:** *l ?=0.1, 0.5, 0.9 and d =0.1 vs. spot prices*

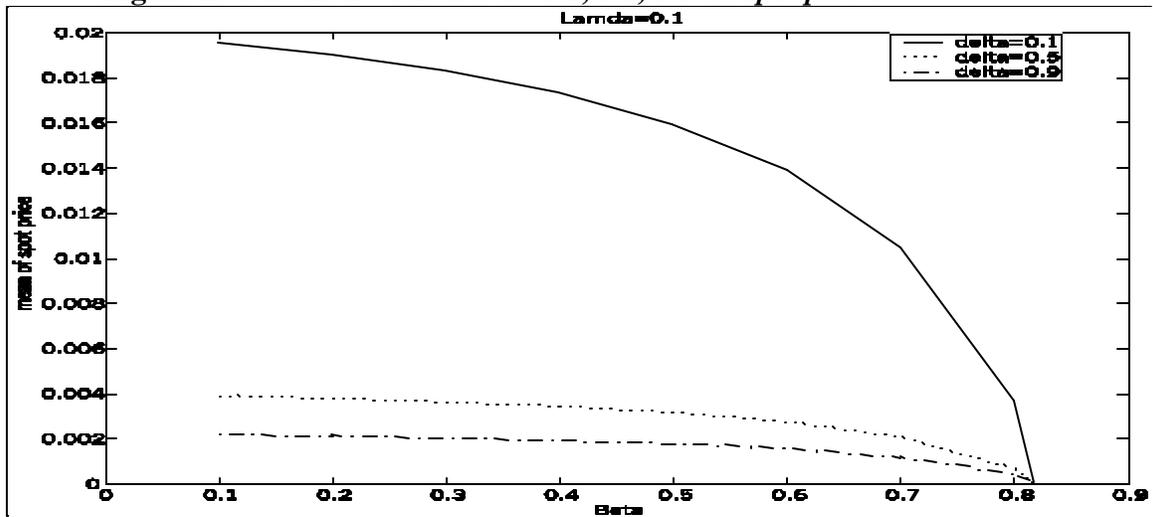**Figure 2: Case 2:** *l =0.1 and d =0.1, 0.5, 0.9 vs. spot prices*

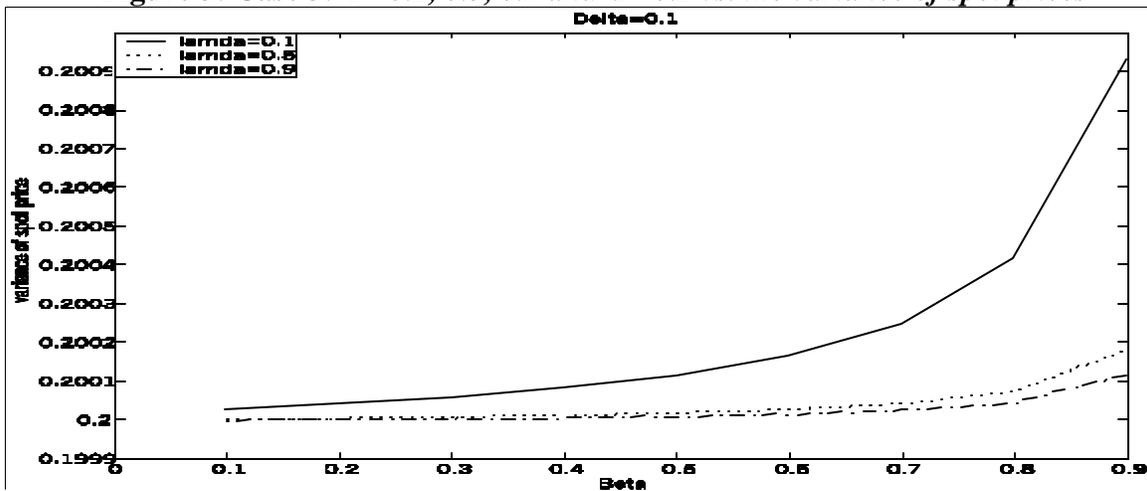**Figure 3: Case 3:** *l =0.1, 0.5, 0.9 and d =0.1 vs. the variance of spot prices*

Figure 4: Case 4: *l =0.1 and d =0.1, 0.5, 0.9 vs. the variance of spot prices*