Unilateral vs. Bilateral Incentives: Evidence from the U.S. Pork Industry

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Abstract

The idea that individuals adapt their behaviors in response to changes in incentive systems is fundamental to most economic analysis. This paper incorporates the concept of price discovery costs into the incentive theory to offer a theoretical model and empirical evidence on the differential incentive effects of long-term contracts and spot markets. Using the US pork industry case where procuring intertemporally consistent weights of hogs have been critical to pork processors, we show why the effectiveness of *unilaterally* determined and posted incentive price for the hog quality by the pork packers on the intertemporal consistency erodes and why a *bilateral* incentive structure built through long-term hog procurement contracts is demanded, in the presence of volatile hog price and feed price movements. The MGARCH model analysis of USDA AMS data supported our hypotheses that long-term hog procurement contracts would help moderate the erosion relative to the spot markets, resulting greater intertemporal consistency of hog weights.

Keywords: long-term contracts, incentive effects, price discovery costs, MGARCH model

1. Introduction

The reason for the rapid transition from spot markets to long-term contracts in the market for slaughter hogs remains an unresolved puzzle although it has been the subject of great interest from agricultural economists, politicians, and industry participants alike. In a Congressionally-mandated study by USDA GIPSA, Vukina, et al., (2007) provide a rich descriptive analysis and focus on the broader economic impacts of the various types of contracts and vertical integration, along the lines of Xia and Sexton (2004), and Wang and Jaenicke (2006). While the analysis of the effect of contract diffusion on market performance is itself integral to understanding the changes at the market structure level, comparative studies on spot markets and long-term contracts at the transaction level will also enhance our understanding of how the two organization forms differ.

This paper employs incentive theory and the concept of price discovery costs to offer a theoretical model and empirical evidence on the differential incentive effects of the two alternate organizational forms on the intertemporal quality of hogs in the production-processing stage of the pork value chain. While the existing literature on the incentive effects of contracts on economic outcomes focuses on labor or management contracts (see Chiappori and Salanie, 2003, for a survey of the empirical literature), we examine the differential incentive effects of long-term procurement contracts versus spot transactions where a buyer and a seller are independent firm operators.

One of the fundamental differences between labor contracts and commercial contracts lies in the reward determination mechanism. Determining the reward for a worker's efforts under a labor contract requires the firm owner's deliberate design to isolate the noise term in the relation between the unobservable efforts and observed outputs of the worker (Hart and Holmstrom, 1987). In contrast, determining rewards for sellers' efforts under spot markets rely largely on

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competitive bidding, which forces them to adhere to incentives for minimizing costs (Tadelis and Bajari, 2006). One of the advantages in the competitive market-reward mechanism, therefore, is its ability to reduce a buyer's burden in designing appropriate incentive mechanisms.[1]

The competitive market-reward mechanism, however, does not completely remove the burden from the buyer. It is particularly true when the competitive market-reward mechanism involves difficulties in measuring the true attributes of the products or services to be exchanged (Akerlof, 1970; Barzel, 1982). A seller's incentive to misrepresent the true quality of the products is one of greatest concerns motivating the development of institutional devices, such as product warranties and brand names, or alternative organizational forms, including long-term contracts, revenue-sharing contracts and vertical integration (Barzel, 1982). Moreover, measurement difficulty is not the sole source of trouble.

We advance the concept of price-discovery costs initiated by Coase (1937) and developed by Cheung (1983). Specifically, a buyer's need to design and offer incentives for a seller may also arise when the competitive market-reward mechanism faces the dual task of rewarding a seller's efforts for minimizing the per-unit production costs while also maintaining a certain level of quality attributes of the product over time despite difficulties measuring the true quality of the product. This paper examines those difficulties in dual pricing in the competitive market-reward mechanism. We maintain four assumptions. First, there are a large number of hog producers and pork packers but the ratio of the sellers to buyers is considerably great, which means that a pork packer buys slaughter hogs from a large number of sellers. Second, producers' tasks are to minimize the per-unit production costs and to maintain certain measurable quality attributes of

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[1] For this reason, it is widely observed that bilateral commercial contracting parties enjoy the advantage of using 'reference price' established at the spot markets when they determine the contract price (Joskow, 1988).

the product over time. Third, there is a clear trade-off in the cost-quality relationship. Last, the specifications on the quality dimension of a product vary across buyers.

In this setting, hog buyers can *unilaterally* develop and post an individual scheme for premiums and discounts for the buyer-specific quality dimension of the product while they use the competitive market-reward mechanism to determine base price of standard slaughter hogs. This pricing practice by hog buyers can best describe the change that the U.S. pork industry experienced since the 1980s. The share of hogs sold through pork packer-specific carcass merit evaluation and pricing systems jumped from 11% in 1982 and 25% in 1993 up to 75% by 1999 (USDA-GIPSA, 2001). Individual hog buyers have *unilaterally* designed and posted prices for the buyer-specific quality attributes of hogs, which they then add to the base price of a hog determined by the spot market. Without relying on bilateral contracts, hog buyers expect that the price for quality provides the sellers with incentives to balance efforts to both tasks.

However, a problem arises when the costs for quality are volatile while the price for quality tends to be rigid. The price for quality, a carcass merit program, is not as dynamic as the base price of a hog determined by the competitive market-reward mechanism. This asymmetry may erode the relative intensity of the quality incentives, upsetting the balance in directing the producer's efforts toward both tasks. This is likely to occur when premiums and discounts for quality are *unilaterally* determined and posted by individual buyers and the costs of maintaining certain quality attributes of a product are volatile. In this circumstance, a buyer may want to lock-in their relationships with sellers to provide sllers with *bilateral* incentives for intertemporally consistent hog quality, which is considered an essential element of the long-term hog procurement contracts observed in the U.S. pork industry.

We incorporate this pricing framework into the U.S. pork industry. In particular, we start with survey results reported by Hayenga, et al. (2000) concerning the 13 largest pork processors'

motivations for the use of long-term hog procurement contracts. The survey results indicate that securing consistent quality hogs ranked first.[2] Elements of quality consistency of slaughter hogs includes hog weight, percent lean, and difficult-to-measure quality attributes such as meat color, marbling, and water holding. We focus on consistency in hog weights as a critical element of hog quality consistency.

Consistency in hog weights consists of two dimensions: spatial and intertemporal. Spatial consistency in hog weights means consistency in the weights of hogs delivered to a specific slaughter plant on a given date, while intertemporal consistency denotes consistency in the weights of hogs delivered across time. One may argue that spatial consistency can be achieved to some degree with premiums and discounts targeting a certain range of hog weights. We would agree, but our focus is rather on the intertemporal consistency dimension. We maintain that carcass merit programs used within spot markets are not sufficient to achieve intertemporal consistency because the incentive prices for maintaining a certain range of hog weights that are specified in a carcass merit program are vulnerable to the volatile nature of costs to produce consistency in hog weights over time.

Based on this argument, we account for the two bilateral incentive structures in observed long-term hog procurement contracts: (1) intertemporal performance evaluation with inducement; and (2) contract price structures reducing the volatility of the production costs. The logic behind the intertemporal performance evaluation with inducement is that an incentive mechanism providing future premiums or penalties based on a cumulative measure of a

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[2] The survey results indicate that securing more consistent quality hogs ranked first, followed closely by securing higher-quality hogs and assuring food safety. The next group of three motivations includes reduction of plant operating expenses, week-to-week supply or price management, and reduced search costs. This survey result is also consistent with other survey results, including Vukina et al. (2007), among others.

producer's hog weight variance performance over a defined period of time shadows today's behavior. The second bilateral incentive structure includes a window price or cost-plus price as a base price determination for a certain amount of contracted hogs, which reduces the volatility in the base-hog price paid to or feed price incurred by the hog producer. We argue that the reduction of volatility in the hog or feed price helps to reduce the variance of hog weights, and offer empirical evidence to support this claim.

In following section, we present a model of hog producers' behavior to generate two sets of testable hypotheses concerning the relation between the variances of market prices and hog weights across spot markets and the two different types of long-term contracts. In particular, we show how the quality incentive price unilaterally posted by pork packers is not sufficient to induce hog producers to supply intertemporally consistent weights of slaughter hogs, thus inviting bilateral incentives designed through long-term contracts. In sections 3 and 4, we offer a description of the data sets used and present the results of MGARCH model estimations supporting our hypotheses. Concluding remarks follow.

2. Behavioral Models and Hypotheses

2.1 Hog Weights as a Choice Variable for Producers' Profit Maximization

Achieving consistency in hog quality attributes such as hog weight is one of the greatest challenges in the pork industry not only because it incurs additional costs due to biological variation in growth rates of hogs but also because the individual hog weight itself is a choice variable for producers' profit maximization (Poray, 2002; Boston, et al., 2004). Hog producers determine the weight of individual hogs by adjusting the timing of marketing the hogs within a 3-week marketing window based on the unit price of hogs, feed price, and feed conversion ratio (Poray, 2002). Table 1 illustrates simulation results of feeder pig growth rates and stochastic

parameter distributions in the $13^{th} - 15^{th}$ week after a feeder pig begins to be fed. It highlights two features. First, the weights of hogs in a batch are widely dispersed due to biological variation in their growth rates. Second, there is considerable difference in average hog weights between weeks 13 and 15 on feed. Based on these features, we argue that if hog producers' decisions on timing to market hogs vary with the movement in feed price and unit hog price, the variance of hog weights over time increases.

<Insert Table 1 about here>

We develop a model of producers' decisions on timing to market hogs during the 13th to 15th week after a feeder pig begins on feed (i.e., 85 days $\leq t \leq$ 105 days). The price of a given slaughter hog, i, paid to a hog producer consists of two parts, the base price and the premium or discount associated with the weight of the hog marketed at time t, $w_i(t)$. The base price is determined by the market price of a slaughter hog per pound multiplied by the hog weight, $p^h(w_i(t))$. The weight target premium and discount for hog i is specified in a carcass merit program as follows:

$$p^P(w_i(t)) = \begin{cases} P_I & \text{if } w_i(t) \in [W_b^L, W_b^U] \\ -P_I & \text{if } w_i(t) \notin [W_b^L, W_b^U] \end{cases} \tag{1}$$

where $0 < P_I$, the W_b^L and W_b^U represent the lower and upper bounds of the target weights established by a hog buyer, respectively. We assume there are three cost factors: feed costs, feeder purchase costs, and opportunity costs associated with the decision on timing. Given this framework, the producer's profit function with regard to timing to market of N hogs raised in a batch can be specified as follows:

$$\pi_f(t) = \sum_{i=1}^{N} \left[p_h(t)w_i(t) + p^P(w_i(t)) - \int_0^t p_f(\tau)q_i^f(\tau)d\tau \right] - C^o(t) - C^P \tag{2}$$

where, $p_f(t)$ is feed price per unit at time t, $q_i^f(t)$ is feed quantity consumed by hog i between time t and time t-1, $C^0(t)$ is opportunity costs associated with delaying or bringing forward the timing to market at time t, and C^p is total feeder pig costs. It should also be noted that the total feeder pig cost is fixed during the marketing time horizon. The hog producer's profit function is constructed based on typical hog spot market conditions.

Based on the biological characteristics of hog production, we assume $w_i(t)$ increases at diminishing rate over the adult life of the hog, $\frac{d}{dt}w_i(t) > 0$, $\frac{d^2}{dt^2}w_i(t) < 0$. Therefore, the profit function is concave in w. Conversely, the cumulative feed quantity required for hog raising is convex with regard to time t, $q^f(t) > 0$, $\frac{d}{dt}q_i^f(t) > 0$. We further assume that $p_h(t)$ and $p_h(t)$ are differentiable functions with respect to t.

Before we proceed to derive the first-order condition, it is important to note that the effect of the premium and discount for hog i on hog weight consistency makes the profit function discontinuous at the lower and upper target weights. Under a carcass merit program, the price for quality is paid in the form of premiums and discounts which are made on the in-or-out status of individual hog's carcass weight and lean percentage from the target range unilaterally set by the pork packer. Premiums and discounts are established as a percentage of a base hog price or an absolute monetary value. Therefore, producers have an incentive to sort hogs into a group that meets the target weight and a group that requires further feeding.[3] The premium and discount rates induce hog producers to sell hogs at different times because it may be more profitable to sell some hogs today and keep the remaining hogs on feed for additional days.

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[3] Furthermore, hog producers have incentives to choose an alternative genetics and feeding program which produces a lower variation in the growth rates of individual hogs but with some opportunity costs of the choice.

We show this effect of a carcass merit program by comparing a hog producer's profit functions with and without a carcass merit program, $\pi_0(t)$ and $\pi_f(t)$, respectively. The only difference between these two functions is the existence of the premium and discount. To illustrate, assume $w(t_s^*)$ is the optimal weight of a slaughter hog from the producer' perspective and that $w(t_s^*)$ is less than w_b^L, the lower bound of target hog weights set by a hog buyer. From the buyer's standpoint, the hog should be fed more to meet the target zone, suggesting marketing at time $t_b^* > t_s^*$. This implies that optimal timing to market the hog is different between the buyer and seller and the corresponding profits are also different. Since $\pi_0(t_s^*) > \pi_0(t_b^*)$, clearly the producer has no incentive to choose t_s^* and feed more. For this reason, the buyer introduces a carcass merit program which can be incorporated into the producer's profit function, increasing the likelihood that the seller's decision on timing to market is aligned with the buyer's interests. The introduction of the premium and discount, $\pm P_I$, changes the magnitudes of the two profits as follows: $\pi_0(t_s^*) - P_I$, $\pi_0(t_b^*) + P_I$. Therefore, as long as $\pi_0(t_s^*) - \pi_0(t_b^*) \le 2P_I$, or $\pi_f(t_s^*) \le \pi_f(t_b^*)$, the buyer will maintain an incentive for producers to hit the target weight zone.

In addition, we show what information is required for a hog buyer to discover the optimal magnitude of P_I. If we assume for a moment that unit-hog prices and feed prices at t_b^* and t_s^* are identical, then equation (2) leads the following useful equation that represents the factors influencing the magnitude of P_I:

$$p_h(w(t_s^*) - w(t_b^*)) + p_f(\int_{t_b^*}^{t_s^*} q^f(\tau)d\tau + C^o(t_b^*)) \le 2P_I \tag{3}$$

Equation (3) implies that the optimal magnitude of P_I is determined by incremental feed

conversion ratio ($\frac{\Delta Q^f}{\Delta w}$), the price ratio ($\frac{p_h}{p_f}$), and the opportunity cost associated with a change

in timing to market from t_s^* to t_b^* (we assume the opportunity costs at $t_s^*, C^0(t_b^*)$, are zero). The

opportunity costs may be the costs associated with sorting the hog into a group that requires

further feeding and delaying the start of the next group of hogs in order to feed out the current

batch of hogs to a higher weight. If the distribution of the feed conversion ratio and the

opportunity costs are known, then the buyer will discover the optimal magnitude of P_I.

This argument is derived from the assumption that the unit-hog price and feed price are

constant. However, this assumption is not realistic. Our main analysis concerns the implications

that result from the introduction of a more realistic assumption that hog and feed prices are

volatile. To show the relationship between the changes in the hog and feed prices and slaughter

hog weights, we first derive the following first-order condition:

$$\sum_{i=1}^{N}\left[\frac{\partial p_h}{\partial t}w_i(t)+\frac{\partial w_i}{\partial t}p_h(t)-p_f(t)q_i^f(t)\right]-\frac{dC^o}{dt}(t)=0 \tag{4}$$

This condition implies that the optimal timing to market hogs is influenced by the

incremental change in feed and slaughter hog prices, incremental feed conversion ratio per batch,

and the slope of the ratio function at time t as well as the absolute magnitude of those variables.

Given that hog producers make a decision on timing to market hogs within the 13th-15th week

after feeder pigs begin on feed, an increase in the hog price or decrease in the feed price forces

them to delay the timing to market hogs. Similarly, a decrease in the hog price or increase in the

feed price leads producers to hasten the marketing of hogs. Therefore, it can be stated that the

variation in hog weights is time-varying and positively associated with the time-varying

variances of the feed price and hog price, which can be expressed as follows:

$$\sigma_{w_S}^2 = f\left(\sigma_h^2, \sigma_f^2\right) \tag{5}$$

where $\sigma_{w_S}^2$ is a time-varying variance of hog weights marketed through spot markets, σ_h^2 and σ_f^2 are time-varying variances of base-hog price and feed price, respectively.

To address this relationship more formally, we can use the profit function to develop a model that links the variance in the slaughter weight (σ_w^2) to the variances of the spot hog price (σ_h^2) and the input or feed cost (σ_f^2). To begin, we let the profit maximizing weight be $w\left(p_h, p_f\right)$, and the associated profit function may be stated in general form as $\pi\left(w\left(p_h, p_f\right), p_h, p_f\right)$. Based on the established properties of profit functions (Proposition 5.C.1, Mas-Colell, Whinston, and Green, 1995), we know that π is concave in w and convex in p_h and p_f, and we assume that these properties are strict such that

$$\frac{\partial^2 \pi}{\partial w^2} < 0 \qquad\qquad \frac{\partial^2 \pi}{\partial p_h^2} > 0 \qquad\qquad \frac{\partial^2 \pi}{\partial p_f^2} > 0$$

By Taylor's theorem (Theorem 30.8, Simon and Blume, 1994), we can form a second-order approximation to the profit function about the means of the arguments as

$$\begin{aligned}\pi\left(w, p_h, p_f\right) = \pi\left(\mu_w, \mu_h, \mu_f\right) &+ \frac{\partial \pi}{\partial w}\left(w - \mu_w\right) + \frac{\partial \pi}{\partial p_h}\left(p_h - \mu_h\right) + \frac{\partial \pi}{\partial p_f}\left(p_f - \mu_f\right) \\ &+ \frac{\partial^2 \pi}{\partial w^2}\left(w - \mu_w\right)^2 + \frac{\partial^2 \pi}{\partial p_h^2}\left(p_h - \mu_h\right)^2 + \frac{\partial^2 \pi}{\partial p_f^2}\left(p_f - \mu_f\right)^2\end{aligned} \tag{6}$$

where μ_w, μ_h, and μ_f are the mean values of the weight and price variables. We have omitted the cross-partial derivatives from the second-order term of the approximation in order to keep the notation simple, but these terms are included in our econometric model of the variance relationship (see the next section).

Next, we assume the expected profit equals zero such that $E\left[\pi\left(w, p_h, p_f\right)\right] = 0$ (i.e., there

are no excess profits in hog production) and that the profit at the mean weight and price levels is a constant $\pi\left(\mu_{w},\mu_{h},\mu_{f}\right)=\pi_{0}$. The expected value of the first-order (mean-deviation) terms equals zero, and the expected value of the second-order terms equals the variances of the associated variables. Thus, we have

$$\pi_{0}+\frac{\partial^{2}\pi}{\partial w^{2}}\sigma_{w}^{2}+\frac{\partial^{2}\pi}{\partial p_{h}^{2}}\sigma_{h}^{2}+\frac{\partial^{2}\pi}{\partial p_{f}^{2}}\sigma_{f}^{2}=0$$

which may be solved for the weight variance as

$$\sigma_{w}^{2}=-\pi_{0}\left(\frac{\partial^{2}\pi}{\partial w^{2}}\right)^{-1}-\frac{\partial^{2}\pi}{\partial p_{h}^{2}}\left(\frac{\partial^{2}\pi}{\partial w^{2}}\right)^{-1}\sigma_{h}^{2}-\frac{\partial^{2}\pi}{\partial p_{f}^{2}}\left(\frac{\partial^{2}\pi}{\partial w^{2}}\right)^{-1}\sigma_{f}^{2}$$

Based on the concavity/convexity properties of the profit function, we can see that

$$-\frac{\partial^{2}\pi}{\partial p_{h}^{2}}\left(\frac{\partial^{2}\pi}{\partial w^{2}}\right)^{-1}>0 \qquad\qquad -\frac{\partial^{2}\pi}{\partial p_{f}^{2}}\left(\frac{\partial^{2}\pi}{\partial w^{2}}\right)^{-1}>0 \qquad\qquad (7)$$

such that the marginal effects of σ_{h}^{2} and σ_{f}^{2} on σ_{w}^{2} are positive. Therefore, an increase in the hog price variance or the feed cost variance is expected to increase the hog weight variance.

2.2 Erosion Effects of Incentive Price for Weight Consistency

Combining equation (2) and equations (7) from the previous subsection, we show the erosion effects on carcass merit programs arising from the volatility of the hog and feed prices. While premiums and discounts in the carcass merit program provide producers with incentives to control biological variation in growth rates of hogs, we argue that fluctuations in base-hog price and feed price erode the incentive effects of the carcass merit program. For example, an increase in the feed price may weaken the quality incentive scheme since the feed price increase encourages producers to deliver hogs at weights less than desired by a pork packer. Similarly, an

increase in the base hog price pushes producers to feed more, which may result in overweight

hogs. Thus, given any quality pricing structure, changes in the market price of a base-hog or in

the feed price will change the net return for producers. Depending on the nature of the quality

price matrix and the relative magnitude of the market price fluctuations, producers may no

longer have incentive to deliver hogs at the desired weights.[4] Thus, the market price volatility

induces an erosion effect on the quality price incentives.

Figure 1 illustrates the case described above. The y-axis represents the net value of hog

weight, expressed in equation (1). Given the first term is a concave function and the second term

is a convex function, the net value of hog weight with regard to time t during a hog production

period at the finishing stage is a concave function (assuming the feed and base hog prices are

constant). The net value of hog weight increases with hog weight, but increases at a diminishing

rate over the adult life of the hog. Eventually the net value may begin to decrease since the feed

quantity per unit of weight gain increases after a certain point for a mature hog. So a producer

markets at the peak of the function. Figure 1 also includes the lower and upper bound of the

target range of weight set by a hog buyer and the dotted line represents the adjustments to the net

value function associated with the premiums and discounts over the target weight range. This

incentive increases the marginal net value of "feeding out" smaller hogs to attain the target

weight range and decreases the marginal net value of continuing to feed hogs beyond the desired

weight range, and thereby the density function of hogs marketed in the desired weight range

shifts rightward.

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[4] This type of vertical coordination challenge has been scrutinized by Poray (2002) and Anderson and
Trapp (1999). Poray uses a simulation technique to show the mismatch between a processor's desire and a
producer's decision with regard to hog quantity and quality, while Anderson and Trapp estimate net
forgone values resulting from the mismatch in a case where beef producers make a decision on timing to
market. We extend the literature into an analysis of how contracts help lessen the misalignment.

<Insert Figure 1 about here>

However, Figure 1 also shows that a hog producer's optimal decision on the timing to market tends to result in marketing of overweight hogs when the base price of a slaughter hog is increasing at the marketing time horizon. The dashed line represents the change to the net value function associated with an increase in the base hog price or a decrease in the feed price. The new equilibrium hog weight, W_s*', is greater than the upper bound of hog weights targeted by a hog buyer, W_b^U. The erosion effects can be calculated by the difference between the two equilibrium hog weights. We may also imagine the opposite detrimental case of delivering underweight hogs takes place when the base hog price declines or the feed price increase. Either case results in hog weight outcomes that deviate from the target range of carcass weights specified by the hog buyer, which erodes the incentive power of the quality premium and discount scheme expressed by the dotted line. Therefore, we claim that the two inequalities (7) described in the previous subsection hold under a carcass merit program while the magnitude of the effect would be smaller than under no carcass merit program.

2.3 Bilateral Incentives through Long-Term Hog Procurement Contracts

As shown above, a carcass merit program is not fully effective at reducing variation in hog weights because of volatility in the hog and feed prices. In response to this issue, pork packers may adjust the intensity of the quality incentive to changes in market circumstances by manipulating the 'adjustment rate.' However, it is costly for pork packers not only to calculate the optimal 'adjustment rate' conditional on their marginal benefits from and marginal costs of the scheme but also to quickly disseminate the information of the change for a large number of hog suppliers. For those reasons, the packers rarely make frequent changes in the adjustment rate in response to volatile hog and feed market prices. Consequently, the costs associated with the

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quality price rigidity may elicit additional instruments not available through spot markets.

Jang and Sykuta (2009) observe that long-term hog procurement contracts are equipped with two distinctive sets of incentives established under the bilateral relationship to resolve the incentive erosion issue. A large portion of long-term hog procurement contracts include a set of provisions to create and enforce an intertemporal incentive scheme (Contract type I) while some contracts establish a base-hog price determination structure which helps to reduce the impact of price volatility on the decision of timing to market (Contract type II). We first consider contract type I.

Hog buyers use type I contracts to offer intertemporal incentive payments as an inducement for hog producers not to respond to the volatility of feed and base-hog prices when they make decisions on timing to market. Because long-term hog procurement contracts effectively bundle multiple transactions or deliveries, they can be used to create intertemporal incentives to mitigate the incentive erosion problem. Packers establish target quality performance standards for hog producers that span multiple deliveries or periods of time. For instance, performance may be based on the average live or carcass weight per load on a weekly, monthly and/or annual basis. The objective is to achieve the target average of carcass weights and lean percentages and to minimize the standard deviation of individual carcass weights and lean percentage, per load and over the duration of the contract (see Jang and Sykuta, 2009, for more details). The incentive payments may be considered as compensation for foregone benefits from committing on incentives derived from buyers rather than on their unilateral incentives. The *ex post* application of penalties based on the evaluation of intertemporal performance in time-varying variances of hog weights plays a complementary role.

Under this long term contract condition, the total price of slaughter hog i paid to a hog producer, consists of three components: the market price of slaughter hogs per pound; the

premium and discount associated with a carcass merit program; and the intertemporal incentive premium and penalty associated with the standard deviation of hog weights over the duration of the contracts, [5] T. The total price can be expressed as follows: $p_h(t)w_i(t) + p^p(w_i(t)) + p^g(\sigma_w^T))$ where the first two terms are the same as described in the previous subsection, and $p^g(\sigma_w^T)$ is the intertemporal incentive premium and penalty of hog i for weight target as follows:

$$p^g(\sigma_w^T) = \begin{cases} P_g + \theta & \text{if } \sigma_w^T \leq \alpha \\ P_g - \theta & \text{if } \sigma_w^T > \alpha \end{cases} \qquad (8)$$

where σ_w^T is a standard deviation of total hog weights over the duration of the contract, $P_g > 0$, $\theta > 0$, and $\alpha > 0$. The characteristic of θ is different from that of P_I in that θ is offered based on the bundling of intertemporal performance of hog weights whereas P_I is provided based on individual hog weight performance. We have the producer's profit function with regard to timing to market N hogs raised in a batch can be specified as follows:

$$\pi_g(t) = \sum_{i=1}^{N} \left[p_h(t)w_i(t) + p^p(w_i(t)) + p^g(\sigma_w^T) - \int_0^t p_f(\tau)q_i^f(\tau)d\tau \right] - C^o(t) - C^p \qquad (9)$$

Accordingly, we can derive the following first-order condition (assuming the relevant functions are differentiable at t), which is identical to equation (4). More important, for the same reasoning applied to equations (6), we have the following relationship under the intertemporal incentive-penalty condition.

$$\sigma_W^{K1} = g\left(\sigma_h, \sigma_f; \theta\right) \qquad (10)$$

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[5] The average of hog weights can be calculated monthly, quarterly, or yearly, depending on contract specifications. However, the length of time period for the calculation does not affect the nature of intertemporal incentive for weight consistency while it may affect the costs of enforcing the performance.

where σ_w^{K1} stands for time-varying variance of the weights of hogs marketed through contract type I. The long-term bilateral incentive payment and related enforcement which is represented by θ in equation (10), is incorporated into the relation between the two sets of variances. Through the long-term contract, a hog buyer expects that the incentive payments are incorporated into a hog producer's temporal profit function as a control variable to reduce the effects of temporal random shocks of market prices on producers' optimal decisions. In other words, since the producer entering into the contractual relationship with the buyer has an incentive to reduce the variance of weights delivered through the contracts over the contract duration, the impact of the variances of base-hog and feed prices on the variance of the hog weight should be reduced. Therefore, the following hypothesis can be obtained:

Hypothesis 1 (H1): $\dfrac{\partial \sigma_{w_S}^2}{\partial \sigma_h^2} > \dfrac{\partial \sigma_{w_{K1}}^2}{\partial \sigma_h^2}$ and $\dfrac{\partial \sigma_{w_S}^2}{\partial \sigma_f^2} > \dfrac{\partial \sigma_{w_{K1}}^2}{\partial \sigma_f^2}$

The second type of long-term bilateral incentive is the contract price structure that reduces the volatility of base-hog and feed prices applied to both contracting parties, resulting in a lower time-varying variance of hog weights. The contract price structures found in some long-term hog procurement contracts include "cost-plus price," "floor price," "guaranteed minimum price," and "window price." While the structure of base-hog prices found in some long-term contracts like "swine or pork price formula" contracts is based on a spot market hog price at the time of delivery,[6] the base-hog price of "cost-plus price," "floor price," or "guaranteed minimum price" contracts is determined by a formula that includes corn and soymeal prices and a pre-specified

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[6] Therefore, the contract base price determined by "swine or pork price formula" contracts moves together with hog market price and thereby the variance of the contract base price would be nearly identical to that of spot market hog price. In addition, producers under the contracts are exposed to volatility of feed prices as much as are producers under spot markets, other thing being equal.

hog production efficiency plus a fixed payment.[7] The contracts set a minimum (floor) price level reflecting feed prices at the time of delivery (e.g., 6 or 8-week moving average of Omaha corn and Decatur/Central Illinois 44% soymeal prices). Therefore, the floor price moves together with the market feed price at the time of delivery and also has smaller variance.

The contracts guarantee the minimum price, which means that producers are paid the minimum price when the market hog price is less than the minimum price at the time of delivery. Many of the contracts specify that producers are paid the market hog price or according to a rule of splitting of the difference between the market price and the minimum price when the market price is greater than the guaranteed minimum price.[8] One of the significant implications of the floor price or cost-plus price contracts for producers' decision on the timing to market is that producers have much less incentive to adjust market timing to the changes in the market feed price or the hog price since the contract base prices paid to producers reflect changes in the feed price and are much less volatile than spot market hog prices.

The base-hog price structure of window price contracts is similar to that of the cost-plus price or floor price contracts, except that the floor and ceiling prices are specified at the time of signing on a contract. Some window price contracts fix the ceiling and floor prices while others let the prices change according to the change in the feed price. Some contracts use a splitting rule or ledger account while others do not.[9] Similar to floor price or cost-plus price contracts,

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[7] This price structure is similar to base price escalation (Joskow, 1988) or definite escalator price redetermination (Crocker and Masten, 1991).

[8] However, the base-hog price structure in the contracts is designed in a way that the weighted average price paid under the contracts is equal to that under spot markets using some tools such as a "ledger", a splitting rule, or a careful design of minimum price. A ledger account records the accumulated amount of the negative deviations of hog prices from production costs being equal to that of the positive deviations when contract expires. Contract length tends to align with the time period of hog cycle such as five or ten years and is renewable if the ledger balance remains.

[9] Regardless of specific tools, every window price formula tends to be designed in a way to reduce the variation of contract prices paid and at the same time as to equalize the accumulated amount of negative deviations of market hog prices from the ceiling price with that of the positive deviations of market hog

therefore, window price contracts reduce the producer's incentive to adjust market timing to the changes in market hog price since the contract base price is more stable than the market hog price.[10] Figure 2 exhibits an example of window price performance using actual spot market base-hog prices and a typical window price formula. The volatility of the window price is much smaller than that of the spot market price.

<Insert Figure 2 about here>

Under this long term contract condition, we construct a hog producer's profit function. For simplicity, we analyze window price contracts only. The total price of a slaughter hog i paid to a hog supplier is composed of the adjusted base-hog price per pound and the premium and discount associated with the hog weight w_i and is defined as follows:

$$p_H(t)w_i(t) + p^P(w_i(t))$$

where $p_H(t)$ is the adjusted base price of slaughter hogs per pound under the window price contracts and is defined as follows:

$$p_H(t) = \begin{cases} P_h + \mu + \dfrac{1}{2}(p^h(t) - P_h - \mu) & \text{if } P_h + \mu < p^h(t) \\ p^h(t) & \text{if } P_h - \mu \le p^h(t) \le P_h + \mu \\ P_h - \mu - \dfrac{1}{2}(P_h - \mu - p^h(t)) & \text{if } p^h(t) < P_h - \mu \end{cases} \qquad (11)$$

Where $p^P(w_i(t))$ is the premium and discount of hog i for weight target, which is identical to the specification in equation (1).

Then, we have the producer's profit function with regard to timing to market N hogs raised

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prices from the floor price when contract expires. Similar to the cost-plus price contract case, the contract is renewable if the balance remains.

[10] In addition, some window price contracts where the floor and ceiling prices reflect changes in feed price will help protect the producers from the risk of a high feed price, which serves to make the costs of the producers' commitment on weight consistency more stable.

in a batch can be specified as follows:

$$\pi_h(t) = \sum_{i=1}^{N} \left[p_H(t)w_i(t) + p^P(w_i(t)) - \int_0^t p_f(\tau)q_i^f(\tau)d\tau \right] - C^o(t) - C^P \tag{12}$$

Accordingly, we can derive the following first-order condition (assuming the relevant functions are differentiable at t):

$$\sum_{i=1}^{N} \left[\frac{\partial p_H}{\partial t} w_i(t) + \frac{\partial w_i}{\partial t} p_H(t) - p_f(t)q_i^f(t) \right] - \frac{dC^o}{dt}(t) = 0 \tag{13}$$

This first order condition is similar to that for a hog producer to sell the slaughter hog through spot markets, which is specified in equation (4). The only difference between the two conditions is the impact of the adjusted base-hog price changes on the hog weights. Due to the nature of window price structure, the time-varying variances of the base-hog price paid to the hog producer are reduced relative to those of the base-hog price paid to the hog producer marketed through spot markets. Similarly, cost-plus or floor price contracts would result in lower time-varying variances of the feed price actually incurred to the hog producer relative to the hog producer in the spot markets. As a result, those types of contracts diminish hog producers' incentives to adjust the timing to market of the slaughter hogs to the change in the market prices. In this manner, the pricing structures of the contracts help hog buyers to induce hog producers to market the slaughter hogs in a way to align with pork packers' objective of consistency in hog weights.

Therefore, the second type of bilateral incentives for intertemporal consistency for hog weights can be presented as follows:

$$\sigma^2_{W_{K2}} = h(\sigma^2_H, \sigma^2_F) = h(\sigma^2_h, \sigma^2_f; \mu) \tag{14}$$

where *K2* denotes a contract that uses the window price (or cost-plus or flow price) structures, σ^2_H and σ^2_F stand for time-varying variances of the contract base-hog price paid and contract

feed price incurred, respectively, μ is a parameter influencing the magnitudes of σ_h^2 and σ_f^2

(e.g., controlling the upper and/or lower bound of window price and the flower price or cost-plus

price). The parameter μ in equation (14) functions in a way that the variances of the contract

base-hog price and contract feed price are smaller than the variances of the two market prices,

which is expressed as follows:

$$\sigma_H^2 < \sigma_h^2 \quad \text{and} \quad \sigma_F^2 < \sigma_f^2. \tag{15}$$

As a result, the impacts of the two variances on the time-varying variance of the weights of

hogs marketed through the contracts are smaller than those expected under spot markets

expressed in the equation (5). From these relations, we can obtain the following hypothesis:

$$\textbf{Hypothesis 2 (H2):} \quad \frac{\partial \sigma_{w_S}^2}{\partial \sigma_h^2} > \frac{\partial \sigma_{w_{K2}}^2}{\partial \sigma_h^2} \quad \text{and} \quad \frac{\partial \sigma_{w_S}^2}{\partial \sigma_f^2} > \frac{\partial \sigma_{w_{K2}}^2}{\partial \sigma_f^2}$$

3. Data

We use a unique data set to measure the incentive effects of three alternative organization

forms: spot markets; long-term hog procurement contracts using inducements (Type I); and long-

term contracts using base-hog price structure (Type II). We use a data set available from the

USDA Agricultural Marketing Service under the Livestock Mandatory Reporting Act of 1999

(LMRA).[11] The data were collected from daily reports of 32 pork packers as of December 1999,

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[11] The Livestock Mandatory Price Reporting Act of 1999 represents a government response to demands by livestock producers for more price information at various stages in the marketing chain. USDA's Mandatory Price Reporting (MPR) system was implemented on April 2, 2001. USDA requires federally inspected processing facilities to comply with the MPR reporting schedule if their average annual slaughter over the preceding 5 years reached 100,000 head for hogs. The MPR system requires hog packers to report information three times a day. Given the continuing structural changes in the U.S. meat/livestock industry, MPR focuses on negotiated private purchases and formula and contract sales. Packers must report terms of formula and contract purchases, thereby revealing information previously treated as proprietary.

whose slaughtering capacities account for about 93% of the U.S. total number of hogs slaughtered in federally inspected plants. The data set contains information on prices including carcass base price and average net price; and information on hog quality performance including average live weight and average carcass weight, average lean percent, average backfat, and average loin depth. More important, the daily national aggregate slaughter hog transactions data are classified by negotiated purchases, swine or pork market formula purchases, other market formula purchases, other purchase arrangements, and packer sold (see Table 2 for the classifications of hog procurement contracts). According to the data, the largest portion of slaughter hogs have been exchanged through swine or pork market formula contracts, followed by internal transfer within pork packing firms, and other purchase arrangements including window price or cost-plus contracts (see Table 3).

Based on the data set, we collect weekly data on daily average carcass weight classified by spot or negotiated markets (NW), swine or pork market formula contracts (SMW), and other purchase arrangements (OPW), and carcass base price determined at spot or negotiated purchases (CSP). We also use weekly corn prices (CP) sourced from USDA AMS. The time span of the two data sets is 7 years (2002. 1.1 – 20008. 12.31).

<Insert Table 2 and 3 about here>

4. MGARCH Model Estimation and Testing

To empirically represent the variance relationship developed in the section 2.1, we use the MGARCH framework devised by Engle and Kroner (1993). Given the vector of observed weights and prices at time t ($\mathbf{y}_t$), we use a VAR(p) model to represent the conditional mean of the vector process

$$\mathbf{y}_t = \mathbf{\Lambda}_0 + \sum_{i=1}^{p} \mathbf{\Lambda}_i \mathbf{y}_{t-1} + \mathbf{u}_t$$

and the MGARCH(1,1) model of the conditional error variance structure takes the BEKK form

$$\mathbf{H}_t = \mathbf{H}_0 + \mathbf{\Gamma}' \mathbf{H}_{t-1} \mathbf{\Gamma} + \mathbf{\Delta}' \mathbf{u}_{t-1} \mathbf{u}'_{t-1} \mathbf{\Delta}$$

where $\mathbf{H}_t$ is the conditional covariance matrix of the error process and $\mathbf{\Lambda}$, $\mathbf{\Gamma}$, and $\mathbf{\Delta}$ are conformable (3 x 3) parameter matrices. Under this specification, the conditional variance for variable i at time t (h_{ii}^t) is a function of the conditional variances and covariances for the vector elements at time t-1 plus the lagged errors

$$h_{ii}^t = h_{ii}^0 + \sum_{j=1}^{3} \sum_{k=1}^{3} \Gamma_{ji} \Gamma_{ki} h_{jk}^{t-1} + \sum_{j=1}^{3} \sum_{k=1}^{3} \Delta_{ji} \Delta_{ki} u_{j,t-1} u_{k,t-1}$$

From this expression, we can see that the marginal change in h_{ii}^t with respect to h_{jj}^{t-1} is Γ_{ji}^2. For our purposes, the two key advantages of the BEKK form of the MGARCH model are that the marginal effects are (1) associated with a single estimated parameter (Γ_{ji}^2), which simplifies the tests of H1-H2, and (2) non-negative and correspond to the assumed properties of the underlying profit function.

Before continuing, we note a few practical considerations that we adopt in order to link the theoretical and econometric models. First, we explicitly interpret the main hypotheses of this paper (H1-H2) in terms of the conditional variances rather than the unconditional variances. Given that the profit maximization problem described above is sequentially solved by the hog producers conditional on the information available at the time, we believe the conditional variance properties are more closely related to the underlying behavior than the unconditional variances. Second, the hypotheses were implicitly stated in terms of contemporaneous variance relationships, but the MGARCH(1,1) model links the conditional variances at two points in time.

Accordingly, we assume the changes in the hog price and feed cost variances that influence the optimal-weight decisions made by hog producers occur during the preceding week. Finally, the available observations that may be used to estimate this model are based on highly aggregated data (e.g., market level prices and average weights for slaughter hogs). For this reason, the estimated model cannot represent the marginal effects among the weight and price variances for individual hog producers. However, we assume the relative magnitudes of these variance relationships are proportional in aggregate and disaggregate data, so the information gathered from the estimated MGARCH model is informative about producer-level responses.

Before the VAR-MGARCH model was estimated, the weekly weight and price data were regressed on quarterly and annual dummy variables to remove seasonal and trend effects from the observations. The summary statistics for the original data and the deseasonalized and detrended data are reported in Table 4, and the Dickey-Fuller stationarity test results are reported in Table 5. We strongly reject the unit root hypothesis for each series, and we use the data to compute the maximum likelihood estimates of the VAR-MGARCH model parameters in SAS. Due to the computational challenges associated with these highly nonlinear models, the number of variables in $\mathbf{y}_t$ for each stage was restricted to the key subsets of the variables associated with hypotheses H1 and H2 (i.e., NW-SMW-CSP, NW-OPW-CSP, NW-SMW-CP, and NW-OPW-CP). The lag order for the VAR model was selected under the AIC criterion and was p=2 for each of the four groups. We do not report the complete estimation results due to the large volume of output from the conditional mean and variance components, but we provide summary statistics and the estimates of the key parameters and marginal effects in Tables 6 and 7.

In each case, the fitted VAR-MGARCH models explain a reasonably large share of the unexplained variation in the weight and price variables, and all of the regression models are jointly significant under the stated F test statistic. The stated GAMMA coefficient is the

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maximum likelihood estimate $\hat{\Gamma}_{ji}$ where j represents the price variable (CSP or CP) and i is the index for the weight series of interest (NW, SMW, or OPW). The asymptotic Z test statistic for significance of this coefficient is stated below the parameter estimate, and the estimated marginal effect $\hat{\Gamma}_{ji}^2$ is provided in the next line. From Table 6, the coefficients for the impact of CSP and CP on NW are statistically significant, but the estimates for the impact of CSP and CP on SMW are not significantly different from zero. Thus, this evidence implies that changes in the hog and feed prices may affect the variance of negotiated hog weights, but changes in these variances do not affect the variation in market formula weights.

Furthermore, the estimated marginal effects imply that a unit increase in the hog price variance generates an approximate 0.03 increase in the negotiated hog weight variance, and a unit increase in the corn price variance generates an approximate 0.33 increase in the negotiated hog weight variance. Note that the marginal effects for CSP are much smaller than the marginal effects for CP, which is due to the difference in scale between CSP and CP (i.e., there is more variation in the CSP data). From Table 7, we find that only the marginal effect of the NW variance with respect to changes in the CSP variance is significant, but the marginal effects for NW variance with respect to changes in the CSP and CP variance are roughly comparable to the magnitudes reported in Table 6.

To formally evaluate H1 and H2, we can conduct one-sided Z tests of the observed differences in the marginal effects. Given that the difference in the marginal effects is a nonlinear function of the estimated model parameters, we can use the bivariate delta method (section 5.5, Gallant, 1997) to compute the approximate asymptotic standard errors for these Z test statistics. The resulting one-sided test statistics and their p-values are also reported in Tables 6 and 7. In all four cases enumerated under H1 and H2, the estimated marginal effects

for NW are larger than those for SMW and OPW, so all four of the Z statistics are positive. Based on the one-sided p-values, we also fail to reject the four components of H1 and H2 at the standard levels of significance. In words, we cannot reject the claims that the marginal effects of changes in hog and feed price variation on the negotiated weights are larger than the marginal effects for the contract weight variances.

5. Conclusions

Achieving consistency in hog quality attributes such as hog weight has been one of the greatest challenges in the pork industry not only because it incurs additional costs due to biological variation in growth rates of hogs but because the individual hog weight itself is a choice variable for producers' profit maximization. The existing literature on alternative organization forms in the US pork industry suggests that a carcass merit program, an incentive price scheme for hog quality, reduces the variance of hog weights. However, we have shown that while the carcass merit program *unilaterally* determined and posted by pork packers through spot markets may help to enhance spatial consistency in hog weights (i.e., consistency in the weights of hogs delivered by a hog supplier or multiple suppliers at a given time), it is not effective to achieve the intertemporal consistency of hog weights in the presence of volatile hog price and feed price movements. In particular, the article has developed a behavioral model to account for that the volatility of hog and feed prices that frequently erodes the optimality of unilateral incentive price for hog weight consistency.

Drawing on an analysis of long-term hog procurement contract documents, we have analyzed how the two distinctive types of incentives *bilaterally* agreed through long-term contracts improve the intertemporal consistency of hog weights. The first type of bilateral incentives links the producers' incentives to the target hog weight variance over contract duration while the

second type has to do with a contract base-hog price structure which serves to reduce the volatility of hog and feed prices actually incurred to the contract hog producers. Regardless of the types, the bilateral-incentive instruments are supported by bundling a series of transactions for slaughter hogs with constant flow characteristics, which is one of the key capabilities of long-term contracts. The MGARCH model analysis of USDA AMS data supported our hypotheses that either type of long-term hog procurement contracts would help moderate the erosion relative to the spot markets, resulting in greater intertemporal consistency of hog weights.

Our findings contribute to the existing literature at least two ways. First, the analytical results reveal that the net value of long-term contracts compared to spot markets increases when pork packers face difficulties related to the discovery and timely dissemination of optimal incentive prices for procuring certain quality attributes of hogs. Taking advantage of bundling a series of transactions and initiating lock-in relationship, the hog buyers find a way to economize on the costs of information incurred otherwise. It sheds light on how costly it is to discover an optimal price when the price should be determined beyond market demand and supply quantity dimensions, and thus informs the evolution of modes and design in organizing a particular transaction, which are distinguished from transaction cost considerations which emphasize safeguards against hold-up or misrepresentation incentives based on asset specificity or measurement imperfections.

Second our theoretical and empirical exercise offers a novel method to measure the differential incentive effects of long-term procurement contracts versus spot transactions, which are rarely found in the existing literature. Based on behavioral models that capture key characteristics of distinct incentive structures across spot markets and two types of contracts, our analytical results account for why different organizational forms result in different economic outcomes, not merely describing them. However, the aggregate nature of the data precludes us

from systematically controlling any noise factors from measuring the incentive effects, which may reduce the robustness of our empirical results.

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Table 1. Distribution of Hog Weights per Batch After 13-15 Weeks on Feed

Weight Categories	13 Weeks	14 Weeks	15 Weeks
220 to 225 (163 to 167)	9.03%	2.73%	1.33%
225 to 250 (167 to 185)	53.58%	24.42%	8.26%
250 to 275 (185 to 204)	30.60%	54.44%	52.67%
275 to 300 (204 to 222)	6.78%	18.40%	37.72%
Weighted Average Hog Weight	247 (182.8)	260 (192.3)	269 (199.3)

1. Simulation results of feeder pig growth and stochastic parameter distributions.
2. The numbers in parentheses indicates carcass weights using carcass weight rate of 74% to convert from live weight to carcass weight.
3. Data was collected from feeding trials for 128 barrows grown in a segregated early wean environment at Purdue University by the Animal Science Department.

Source: Poray (2002) pp. 64-65.

Figure 1. Erosion Effects of Price Volatility of Base Hog and Feed on Weight Consistency Incentives

$|W_S^* - W_S^{*'}|$ = Erosion Effect

Net Value of Hog Weight ($)

.... : under no quality price incentives

- - - - - : under quality price incentives

-··-··- : under a circumstance where the base hog price increases or the feed price decreases

$W_S^{*''}$

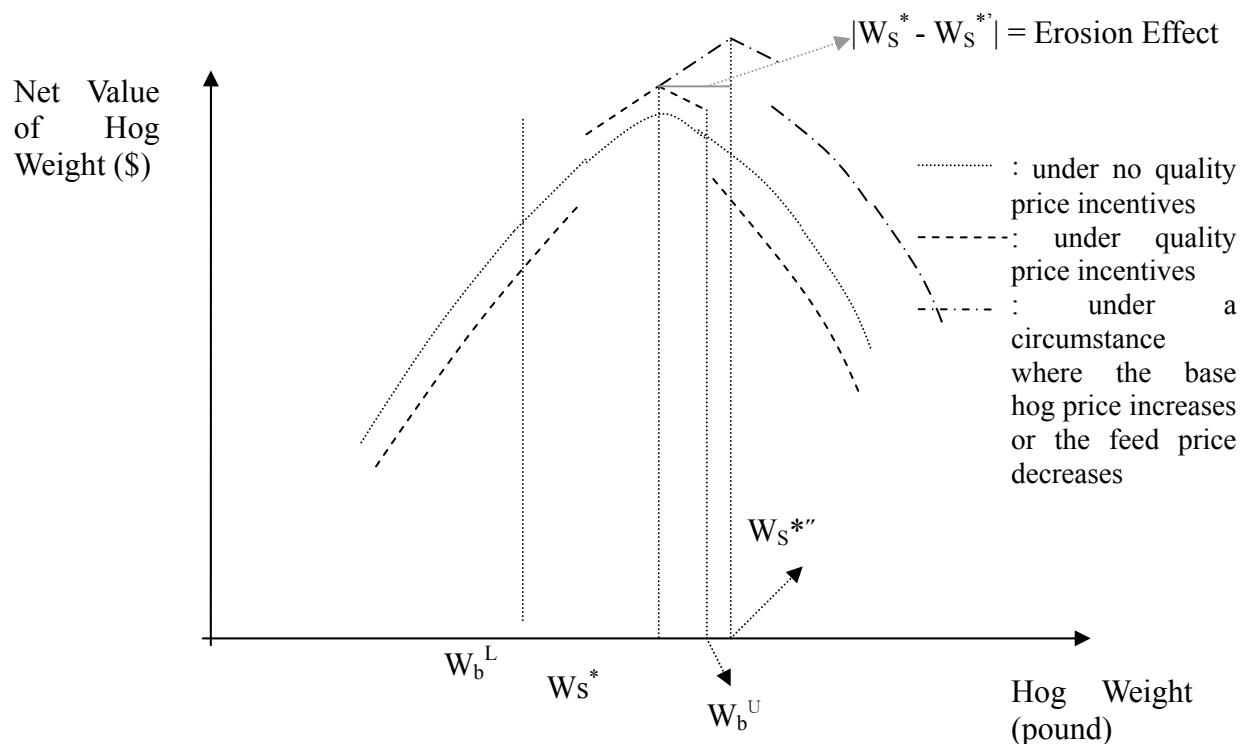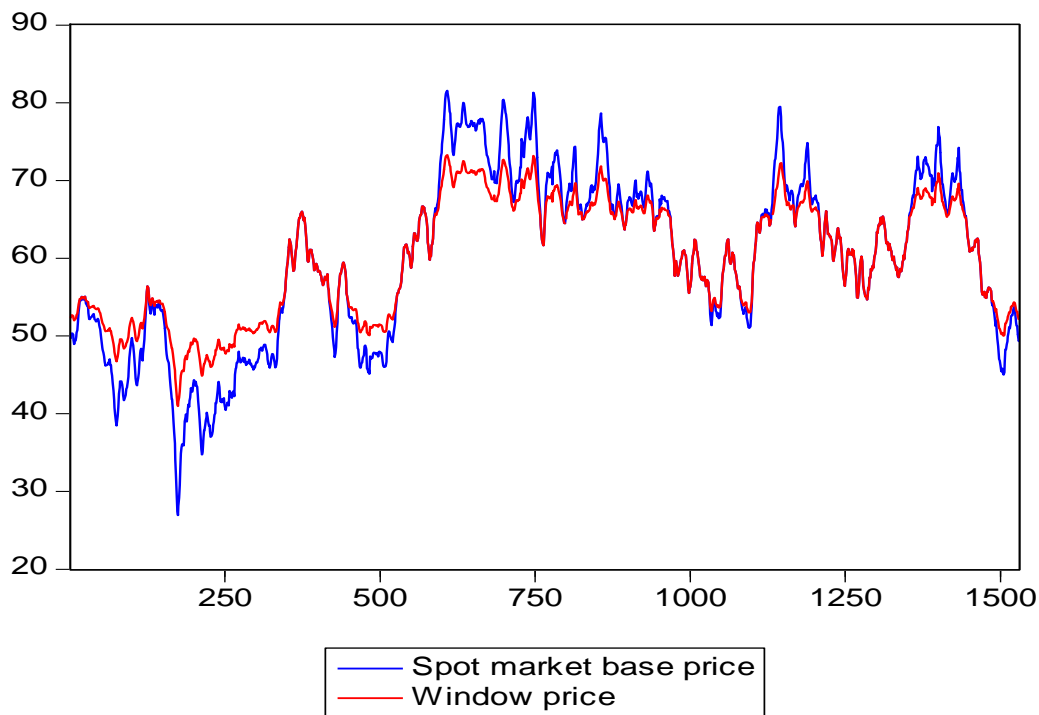W_b^L W_S^* W_b^U

Hog Weight (pound)

Figure 2. An Example of Window Price Performance

* The window prices are calculated by applying a floor price of $55 and a ceiling price of $65 and an equal splitting rule using actual daily spot market base prices between January 2002 and December 2007 posted at USDA AMS.

Table 2. Classifications of Hog Procurement Contracts by AMS

Swine or pork market formula	Include contracts in which the pricing determination is a formula price based on a market for swine, pork, or a pork product
Other market formula purchase	Include contracts in which the pricing determination is a formula price based on the Chicago Mercantile Exchange Lean Hog futures market
Other purchase arrangements	Include fixed price contracts, cost of production formulas, formula purchases with a floor, window, or ceiling price

Sources: http://marketnews.usda.gov/portal/lg

Table 3. Percent of U.S. Slaughter Hog Transaction through Various Organizational Arrangements

	2002	2003	2004	2005	2006	2007	2008
Negotiated	15	13	11	11	10	9	9
Swine or pork market formula	43	39	40	41	38	38	38
Other market formula	9	8	9	9	8	8	10
Other purchase arrangements	13	19	18	16	16	15	13
Packer-sold	2	2	2	2	6	6	6
Packer-owned	17	19	19	20	22	24	24

Source: http://marketnews.usda.gov/portal/lg

Table 4.   Summary Statistics for the Original and Deseasonalized-detrended Data

Original Data	Sample Average	Sample Median	Standard Deviation	Minimum	Maximum
NW	195.97	196.30	3.04	187.59	202.94
SMW	200.12	200.14	3.21	190.22	206.35
OPW	200.30	200.39	2.85	190.15	207.69
CSP	60.14	60.62	10.94	28.02	86.11
CP	2.77	2.32	1.17	1.46	7.16
Deseasonalized and detrended data					
NW	0.00	-0.08	1.61	-5.70	4.37
SMW	0.00	0.08	1.33	-4.55	3.46
OPW	0.00	0.00	1.33	-3.89	4.12
CSP	0.00	-0.13	6.43	-22.18	18.50
CP	0.00	-0.06	0.47	-1.70	2.01

Table 5. Stationarity Test Results for the Deseasonlized-detrended Data

Variable	Dickey-Fuller stat	p-value
NW	-6.035	0.0000
SMW	-7.145	0.0000
OPW	-6.149	0.0000
CSP	-6.018	0.0000
CP	-3.830	0.0002

Table 6. Summary Estimation Results for Hypothesis 1

	NW	SMW	CSP
Summary statistics	R2 = 0.5375 F = 68.94 (p=0.000)	R2 = 0.4615 F = 50.84 (p=0.000)	R2 = 0.7715 F = 200.32 (p=0.000)
Gamma **Z statistic**	$\hat{\Gamma}_{31}$ = -0.17389 -2.16	$\hat{\Gamma}_{32}$ = 0.01935 0.23	
Marginal effect	$\hat{\Gamma}^2_{31}$ = 0.0302	$\hat{\Gamma}^2_{32}$ = 0.0004	
One-sided Z test of H1, part 1	Z = 2.315 (p=0.9897)		

	NW	SMW	CP
Summary statistics	R2 = 0.5192 F = 64.06 (p=0.000)	R2 = 0.4489 F = 48.33 (p=0.000)	R2 = 0.7991 F = 236.02 (p=0.000)
Gamma **Z statistic**	$\hat{\Gamma}_{31}$ = 0.61455 1.90	$\hat{\Gamma}_{32}$ = 0.10304 0.26	
Marginal effect	$\hat{\Gamma}^2_{31}$ = 0.3777	$\hat{\Gamma}^2_{32}$ = 0.0106	
One-sided Z test of H1, part 2	Z = 1.692 (p=0.9547)		

Table 7.   Summary Estimation Results for Hypothesis 2

	NW	OPW	CSP
Summary statistics	R2 = 0.5321 F = 67.47 (p=0.000)	R2 = 0.5450 F = 71.06 (p=0.000)	R2 = 0.7722 F = 201.15 (p=0.000)
Gamma **Z statistic**	$\hat{\Gamma}_{31}$ = -0.25868 -5.17	$\hat{\Gamma}_{32}$ = 0.03566 0.45	
Marginal effect	$\hat{\Gamma}_{31}^{2}$ = 0.0669	$\hat{\Gamma}_{32}^{2}$ = 0.0013	
One-sided Z test of H2, part 1	Z = 6.266 (p=1.000)		

	NW	OPW	CP
Summary statistics	R2 = 0.5170 F = 63.51 (p=0.000)	R2 = 0.5320 F = 67.44 (p=0.000)	R2 = 0.8023 F = 240.77 (p=0.000)
Gamma **Z statistic**	$\hat{\Gamma}_{31}$ = -0.36730 -0.76	$\hat{\Gamma}_{32}$ = -0.31814 -0.64	
Marginal effect	$\hat{\Gamma}_{31}^{2}$ = 0.1349	$\hat{\Gamma}_{32}^{2}$ = 0.1012	
One-sided Z test of H2, part 2	Z = 0.108 (p=0.5429)		