Adjustment Costs of Quality Price and the Value of Long-Term Contracts: the US Pork Industry Case

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ABSTRACT

The paper addresses the choice between long-term contracts and spot-markets, for coordinating the quality of slaughter hogs in the U.S. pork industry. We provide an analytical model accounting for contract choice assuming only both bounded rationality and uncertainty. By analysis of the model, we identify that upstream firms' optimal decision on timing to market live hogs may bring about the goods' suboptimal quality outcome for downstream firms even if optimal quality price is discovered at a time point. This suboptimality may arise when the price for quality is endogenously determined and the volatility of feed and base hog prices is prevalent. Spot markets may not work properly for quality coordination when the frequent change in feed and base hog prices erodes optimality of quality price, and timely adjustments of quality price contingent on the price change are fairly costly. By analyzing long-term hog procurement contracts, we identify two sets of contractual functions to help reduce the adjustment costs on pricing for quality: providing long-term quality incentives and enforcement mechanism for target quality performance; and reallocation of decision rights over hog producers' production practices.

1. Introduction

The use of long-term contracts has been explained by their function as a safeguard against rent-dissipating activities in the context of relationship-specific investments (Williamson, 1975, 1996; Klein, et al., 1978). This transaction cost economics (TCE) explanation on the choice of long-term or formal contracts in procurement practices has also been supported by empirical evidences (Joskow, 1987, for coal industry; Gallick, 1984, for tuna industry; Lyons, 1994, for U.K. engineering subcontracting).

In contrast, Masten's recent studies of contracting in the U.S. trucking industry reveal that the value of long-term contracts may originate from saving the costs to negotiate a price for each transaction in a series by 'intertemporal bundling' of heterogeneous freight transactions (Masten, 2006; Lafontaine and Masten, 2002). Masten claims that the formal contracts' function of economizing on the cost of pricing heterogeneous transactions may explain a class of contracts that involve little in the way of relationship-specific investments, including franchise contracts, equipment lease, distribution and advertising agreements, and software licenses.

Along the lines of Masten's analysis of the use of long-term contracts, we examine economizing benefits of long-term contracts other than the TCE explanation of safeguarding against opportunistic hold-up. However, while Masten emphasizes savings on measurement costs arising from non-contractible attributes of a task in a transaction, we examine savings on price adjustment costs for measurable quality attributes of intermediate goods by the use of long-term contracts in the U.S. pork industry. Specifically, we argue that long-term contracts may be explained by the 'concerted' coordination function of the contracts as compared to the 'spontaneous' coordination function of spot markets.

In order to procure hogs of consistent size across multiple suppliers and through time, for example, a pork processing firm provides an incentive payment to induce hog suppliers to make

an optimal decision (from the pork packer's perspective) on timing to market, which affects the mean and variance outcomes of the sizes of hogs procured. When hog suppliers' decision on timing to market is primarily influenced by the exogenously-determined prices of a "base hog" and feed within a certain marketing time horizon, hog suppliers' decision may result in suboptimal quality outcomes for a hog processor. Given the volatility in these market prices, the processor's incentive payments for quality attributes must adjust to changes in these two exogenously determined prices to preserve the hog supplies' incentive to deliver the desired level of quality. However, the information costs originating fundamentally from human being's bounded rationality (Simon, 1947) hinder the timely adjustment of the quality price[1].

If long-term contracts help reduce the information and adjustment costs of the quality price in spot markets without incurring significant offsetting costs of contracting, transition from spot markets to long-term contracts for procurement of slaughter hogs is likely to take place. We analyze long-term hog procurement contract documents and identify contractual features that provide an inducement for upstream firms to reinforce long-term quality incentives despite short-term market price incentives and reallocate control rights over hog production practices affecting hog quality, all of which are not available to spot contracting. These functional provisions are dissimilar to safeguard functions of contracts whose typical provisions include duration, information disclosure and dispute settlement machinery (Williamson, 1996, p. 104)[2]. This

[1] The information costs of the quality price here refer to costs for a hog procurer to collect and process information about hog suppliers' production functions for quality in order to design an optimal incentive for the buyer-specific hog quality attributes and aptly disseminate suppliers the quality incentive and ones for the suppliers to interpret dissimilar quality incentives proposed by multiple hog buyers to come up with optimal choice of a buyer.

[2] Management literature has paid much attention to functional aspects of contracts such as mitigating coordination concerns and contingency adaptability, as well as safeguarding of investment against misappropriation by partner (Eckhard and Mellewigt, 2005; and Gulati et al., 2005).

contrast highlights the attributes of the product or service as compared to the attributes of assets used in production as an important dimension for economic agents' choice of organizational form.

The information and adjustment costs of quality price that this paper focuses on are part of the costs of relevant price discovery in market transactions (Coase, 1937; Cheung, 1983). Departing from the neoclassical assumption in which prices are given, contracting difficulties associated with pricing have been explored in two lines: studies of determinants for contract payment forms or structure (Lafontaine and Masten, 2002; Bajari and Tadelis, 2001, 2003) and literature investigating factors to influence various price adjustment structures in designing long-term contracts (Joskow, 1988; Crocker and Masten, 1991). This study not only addresses the issue of structuring price and price adjustment terms in long-term contracts, but also attempts to determine the choice between two discrete governance structures: spot markets and long-term contracts.

The research examines the causes and effects of specific contracting costs (Brousseau and Glachant, 2002) on the choice between long-term contract and spot-market for exchange of slaughter hogs between hog producers and processors. Section 2 briefly reports the recent developments of and existing literature on, long-term contracts in the U.S. pork industry and the preliminary results of the analysis of long-term procurement contracts reported to USDA by the 32 largest pork packers. Section 3 provides an analytical model that accounts for the information and adjustment costs of quality price and the value of long-term contracts moderating those costs. In conclusions, we provide a set of testable propositions for the choice of long-term contracts.

2. The Organizational Features of U.S. Hog Transactions and the Analysis of Long-Term Hog Procurement Contracts

2.1 An Overview of the Organizational Features and Existing Literature

The U.S. pork industry experienced dramatic change in organizational form since the early 1990s. Before the decade, slaughter hogs had been transacted mostly through terminal or auction markets, intermediaries such as dealers or order buyers, or packers' plants or buying stations (Lawrence, et al., 1997). However, spot market transactions between the hog production and processing stages dropped significantly from 82.5% of total hog transaction in 1993 to 10.6% in 2005. Over the same period, the use of various hog procurement (marketing) contract transactions increased from 11% to 65.6%. Packers' own production of hogs, including hog procurement by production contracts, also increased from 6.4% to 23.8% in the same period (see Table 1).[3] This paper focuses on the transition from spot markets to long-term marketing contracts and explores the relevant factors which affect the shift.

Existing literature on the organizational change in the pork industry reports survey results of hog producers' or processors' motivations for long-term contracts and vertical integration, such as quantity assurance and quality control for the processors and market outlet assurance and price risk management for the producers (Kliebenstein and Lawrence, 1995; Lawrence, et al., 1997; Hayenga, et al., 2000; USDA GIPSA, 2005). Additionally, some economists have looked at technology shocks as a driving force for the organizational change (Hayenga, 1998; Martinez, 2002; Allen and Lueck, 2002) while others have examined demand shocks in pork product

[3] These data are sourced from information regarding hog transactions for 32 largest packers' procurement of slaughter hogs, which account for 93.5% of total number of slaughter hog as of the end of 1999. Therefore, the statistics tends to underestimate spot market transactions because it does not account for hog transactions made by large number of small pork packers.

markets (Poray, 2002; Martinez and Zering, 2004).

However, little research has focused on long-term contracts help reduce the uncertainty in the quantity and quality of slaughter hogs for processors. As far as quality assurance, many agricultural economists refer to carcass-merit programs, a hog quality measurement and incentive payment scheme, as the main institution used in long-term contracts to facilitate quality assurance (Hayenga, et al., 2000; USDA GIPSA, 2005).[4] Lawrence, et al., (2001) report that carcass-merit programs are sometimes also used in spot market transactions, suggesting the use of such programs is not sufficient to explain the use of long-term contracts. We therefore speculate that there should be distinguished institutional mechanisms to help coordinate hog quality in long-term contracts if the survey reports are correct. Resolving the puzzle requires an analysis of existing contract documents and practices. We examined the provisions of long-term contracts reported to USDA by the 32 largest pork packers under the Livestock Mandatory Reporting Act.

2.2 Preliminary Findings of the Contract Analysis

We identified two sets of common features across long-term hog procurement contracts. First, there are no long-term contracts without carcass-merit programs, but the target quality and the price for quality vary across pork packers or packing plants (see Table 2). The narrowest target range of hog carcass weights is 14 pound (207-221 pounds) while the widest target range is 88 pound (148-236 pounds). The lowest mean of target range of hog weight is 183.5 pound

[4] Carcass merit programs establish a matrix of premiums and discounts for combinations of certain carcass characteristics (e.g., weight, percent lean, back fat), which are then added to the market price of a "base hog" that represents the benchmark or base characteristics of the merit program. Producers receive the net price based on the relevant quality characteristics of the hogs they deliver.

whereas the highest mean is 214 pound. In addition to the heterogeneity of the desired weights across carcass merit programs, the marginal value of quality characteristics also differs across merit programs (see Table 2). This endogeneity of price for quality characteristics contrasts with the exogeneity of the base hog price in terms of information costs in the price determination process. Hog buyers and sellers cheaply utilize the base price of a standard hog to adapt to changes in market circumstances without much knowledge of why and how the prices are determined (Hayek, 1945; Williamson, 1996, pp. 145-166). In contrast, the pricing for quality requires hog buyers to make use of all possible relevant information in order to function efficiently, which may impose information costs on the quality-price makers.

Second, long-term hog procurement contracts contain two sets of provisions to help reduce the information and adaptation costs on pricing for quality (see Table 3 for a more comprehensive summary of the functions of the contract sample). A long-term contract allows for hog buyers to establish a long-term hog quality target, create long-term incentives (a contract premium per head) for hog producers to commit to the target, and enforce their performance of target quality. A long-term contract also permits hog buyers to have decision rights over hog production practices in a way to ensure hog suppliers achieve target quality performance. These coordination instruments utilized through long-term contracts play a supplementary role for the quality incentive scheme, which is not available to spot markets.

3. An Analytical Model for Choice between Spot Markets and Long-Term Contracts with regard to Coordination for Hog Quality

Based on the preliminary findings of the contract analysis, we raise a series of specific questions associated with the choice of long-term contracts. First, why are the auxiliary provisions for hog quality coordination required in addition to carcass-merit program? In other

words, what problems in the quality incentive scheme cause the introduction of the auxiliary instruments? This question would be related to the costs associated with designing and implementing an optimal incentive scheme for measurable quality attributes. Second, what factors influence the costs? Third, how do the auxiliary instruments help reduce the costs? Finally, if pork packers are heterogeneous in terms of the degree of benefits from choosing long-term contracts, what factors influence the heterogeneity of the benefits? We conjecture that factors influencing the benefits also determine the choice of long-term contracts. We offer an analytical model that addresses these questions.

3.1 Upstream firms' actions (decisions) on the production and marketing of slaughter hogs under no quality price

Markets do not perform well when measuring the attributes of the commodity or service being transacted is difficult (Barzel, 1982, 2005; Holmstrom and Milgrom, 1991). The pork industry features exchange of goods sequentially transformed (see Figure 1-A). The quality of products in one stage, therefore, heavily relies on the intermediate goods produced in previous stages of the chain. Efficiently measuring the attributes of intermediate goods enhances the vertical exchange, and otherwise costly measurement hinders market exchange. Measurement difficulty of a product attribute, however, does not matter when the market value of the attribute is low. This was true in the U.S. pork industry until the 1980s (Martinez and Zering, 2004). Prior to the 1980s, there was little value for packers to gain by procuring more homogeneous hog quality characteristics.

In the absence of demand for specific quality attributes (and hence, no quality-specific pricing), hog spot markets succeeded in terms of vertical coordination for optimal resource allocation where one party's optimal decision leads to socially optimal outcome. We show this in the remainder of the subsection. We refer to this case as "no quality price," since we are

interested in modeling the incentive effects of specific pricing structures regardless of the downstream value of the quality characteristics.

Assumption 1.1 (*Biological variation on hog production*): Hog production holds biological features that result in some degree of natural variation in quality attributes of slaughter hogs within a batch or across time points of marketing.

Assumption 1.2 (*Hog production function and two main choice variables*): There are two types of non-labor variable inputs used in production of slaughter hogs: feeds and pigs. Production of a slaughter hog requires one unit of pig and variable quantity of feeds. Certain types of feeds and pigs affect both quantity and quality effectiveness for hog raising. The production function of slaughter hogs with regard to feeds is strictly concave, and there is a seasonal variation in the curvature of the production function. Specifically, feeds cost function per batch with regard to time t can be expressed as follows:

$c_1 = N\sum_{t=1}^{T} P^t AF^t$ --- (1), where P^t is feed price per unit at date t and AF^t is average feed conversion ration across N number of hogs in a batch at time t and exhibits convex function with regard to t, $AF^t = \frac{1}{N}\sum_{n=1}^{N}\Delta Q_{fn}^t$, where ΔQ_{fn}^t denotes incremental feed quantity required for one unit of body mass gain at time t. Different decisions on a time point of marketing slaughter hogs result in different feed costs (See Figure 1-B for hog production timeline). In general, marketing time horizon ranges from 13th to 16th week after a baby pig is born.

Assumption 1.3 (*Hog pricing system*): The buyers and sellers of slaughter hogs are price takers. The goods are priced on the base of unit quantity (e.g., pound), and thereby a hog producer (upstream firm)'s revenue from a hog sold is a linear function of the weight of the good (see Figure 2-A). And an upstream firm's revenue function with regard to time is as follows:

$R_U = p^t\sum_{n=1}^{N} W_n^t$ --- (2), where p^t is a price of slaughter hogs per pound at date t, W_n^t is weight

of n^{th} slaughter hog at date *t*.

Proposition 1.1 (*Selection of certain type of pigs and feeds under no quality price*): With no quality price, optimal decision on selection of pigs and feeds is made by a criterion of maximizing effects of inputs on total weights of slaughter hogs per batch. This decision implies that the variation in hog weights per batch does not matter in the absence of quality price.

Proposition 1.2 (*Decision on the timing to market under no quality price*): With no quality price, optimal decision on the timing to market will be made by marginal weight production of a slaughter hogs with regard to feeds per batch and the prices of feeds and a slaughter hog.

Let's illustrate proposition 1.2. Given production technology or distribution of feed conversion ratio of each pound of live body weight gained within a production time period, an upstream firm's profit function per batch considering only the two cost factors among total cost described above is as follows:

$\underset{t}{Max}\,\pi_U = p^t \sum_{n=1}^{N} W_n^t - \sum_{t=1}^{T} P^t \sum_{n=1}^{N} \Delta Q_{fn}^t - c_2$ ---- (3), where, c_2 is total pig costs, or c_2 = pig price multiplied by *N*.

If total weights of hogs per batch holds a concave function with regard to time *t*, $\sum_{n=1}^{N} W_n^t = l(t)$, $l'(t)>0$, $l''(t)<0$, or conversely, incremental feed quantity per batch has a convex function with regard to time *t*, $\sum_{n=1}^{N} \Delta Q_{fn}^t = m(t)$, $m'(t)<0$, $m''(t)>0$, and p^t and P^t are differentiable functions with regard to *t*, we can get first-order condition as follows:

$p^{t*}\, l'(t^*) + p'(t^*) l(t^*) = \sum_{t=1}^{T} \left(P^{t*} m'(t) \oplus P'(t^*) m(t^*) \right)$ ----(4).

This condition implies that the optimal timing to market hogs is influenced by the incremental change in feed and base hog prices, incremental feed conversion ration per batch, and the slope of the ratio function at time *t.* The optimal decision on the timing to market can be

illustrated by the Figure 2, where marginal weight production value is calculated by a formula, $\frac{p^t \Delta \sum_{n=1}^{N} W_n^t}{P^t}$.

<Insert Figure 2-A, B, C here>

The key implication of the graphical illustration is as follows: the new optimal hog weights of a hog, $W^*_s{}'$, and $W^*_s{}''$, followed by the changes in feed price and hog price are also socially optimal as long as the distribution of hog weights per batch, across sellers, and over time does not much matter for pork packers. Under the little needs for homogeneous products, price volatility of input and output does not add much on the costs of optimal decision making for upstream and downstream firms.

3.2 A Downstream Firm's Behaviors on Hog Quality Pricing

Demand shocks on the pork product markets have been increasing the market value of the two set of attributes of pork products: measurable quality attributes such as size of pork cuts and leanness of pork products; and meat quality attributes difficult to measure, including intra-muscular fat (marbling), muscle color, meat tenderness, and organic or animal welfare-related quality attributes (Smith, 1994; and Martinez and Zering, 2004). Meat quality attributes are difficult to measure have been not rewarded in observed hog spot market and long-term hog procurement contract transactions (Smith, 1994), and slaughter hogs delivered to a pork packer are individually measured and priced. Therefore, we assume that hog sellers' incentives to misrepresent or manipulate the quality of hogs (Barzel, 1982; Holmstrom, 1999) would be insignificant. We ignore the pork quality attributes difficult to measure in most of this paper.

A brief description of carcass-merit program: Regarding measurable quality attributes of pork products, the change in the relative market price of fat in a slaughter hog has forced pork

packers to develop a new measurement method in a way to minimize the measurement error that is defined as the discrepancy between expected weight of a slaughter hog's marketable pork elements based upon estimation and its actual weight. In order to measure the weight of fat and meat parts in a slaughter hog, carcass weight measurement and lean percent or carcass composition estimation methods have been developed.[5] Based on the new quality measurement method, pork packers have adopted a carcass merit program, a quality incentive scheme.

Pricing for the two quality attributes is made on the combination of two categories of quality attributes of an individual hog. 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. Premiums and discounts are established as a form of percentage of base price of a hog or an absolute money amount. In this subsection, we propose two main concepts for pork packers' behaviors on hog quality pricing: product quality specificity and the endogeneity of quality price, based on which, we show how quality price is determined.

Definition 2.1 (*Product quality specificity*): Product quality specificity is defined as the degree to which quality attributes of a product are specified by a buyer of the product and has three components: i) number of quality attributes; and ii) homogeneity of products with regard to a quality attribute; iii) the degree of special usage of a product.

We assume that there are two categories of quality attributes of pork products: size of pork cuts and leanness of pork products. At the hog transaction stage, the two quality attributes of pork products are estimated by measuring carcass weight and lean percentage of a slaughter hog, respectively, which means quality specificity of slaughter hogs is a linear transformation to that of the pork products. We assume that there are little substantial biases and errors on the

[5] The share of hogs sold through carcass merit evaluation and pricing systems jumped from 11% in 1982 and 25% in 1993, to 75% in 1999 (USDA, GIPSA, 2001).

estimation and measurement. The homogeneity of products is measured by the variation of weights and lean percentages of hogs delivered for a certain period of time. The degree of special usage of a pork product is measured by difference between national average carcass weight and the target carcass weight set by an individual pork packer, for example. In summary, hog quality specificity increases with the number of quality attributes of a hog, the inverse value of the variance of weights and lean percentage required by a pork packer, and the mean difference of carcass weights.

Finally, an individual packer's quality specificity of slaughter hogs is determined by its downstream market strategic position or the needs of their customized buyers.[6] From the carcass-merit program practices, it is derived that premium and discount rates, a price for hog quality is established by an individual pork packer (*The endogeneity of quality pricing*).

Assumption 2.1 (*Demand elasticity of pork product quality and the quality specificity*): Demand elasticity of pork product quality has a discrete value and is a positive function of quality specificity of pork products.

$\varepsilon_q^d = f(qs)$ ---(5). $f' \geq 0$, where *qs* denotes quality specificity, *q*, quality, and ε, elasticity.

If we further assume that marginal impact of the quality outcome of a hog on a pork packer (downstream firm)'s revenue (R_D) is a positive function of consumers' demand elasticity of the product' quality, we would have a proposition that marginal impact of the quality outcome of a

[6] Boland, et. al (1995) reports that firms using a differentiation strategy, for example, generally trim fat more closely than do overall cost leaders. A focus-differentiation strategy can be used in the export market to Japan where many processors desire a loin within some narrowly defined weight range and preferably with as little fat as possible. Boland, et al also identified that fresh pork markets have a preferred weight zone for each item which provides quality premium. For example, the average 1991 prices for fresh regular loins were $1.40, $1.46, and $1.12 per lb for 14 to 18, 18 to 22, and more than 22 lbs, respectively (Boland, et. al, 1995).

hog on a pork packer' revenue is a positive function of the quality specificity of the hog (Proposition 2.1: *Marginal impact of the quality outcome of a hog on a pork packer's revenue*).

$$\frac{\partial \sum_j R_D^{t+j}}{\partial q^t} = g\left(\varepsilon_q^d\right) \text{ ---(6), } g' \geq 0 \text{, then, } \frac{\partial \sum_j R_D^{t+j}}{\partial q^t} = g\left(f\left(qs\right)\right) \text{ ---(7).}$$

The proposition 2.1 implies that the revenue of a pork packer whose quality specificity of pork products is high is more influenced by hog producers' action on quality outcomes of slaughter hogs than otherwise.

Quality pricing mechanism

Assumption 2.2 (*Production cost function of hog quality and the quality specificity*): There is a positive relationship between the production costs of hog quality and quality specificity of slaughter hogs. $C(qs) = k(\cdot), k'(\cdot) > 0$ --- (8).

A premium should be no less than marginal production cost of a hog having certain quality specificity and no greater than marginal value of the quality specificity, $\frac{\partial C_U}{\partial W^t} \leq \text{Pr}\,emium \leq \frac{\partial R_D}{\partial W^t}$ --- (9), where W^t denotes a hog weight at the time t within marketing time horizon. Similarly, a discount rate should be no less than marginal loss from accepting an outlier hog. More precisely, the quality compensation scheme induces hog sellers to invest in optimal average weights and minimum variances of hog weights up to the point of the marginal benefit from the quality improvement activities and marginal cost of them being equal. From Assumption 2.1 (*Demand elasticity of pork product quality and the quality specificity*) and Assumption 2.2 (*Production cost function of hog quality and the quality specificity*), it is derived that the magnitude of premium and discount is a positive function of quality specificity of a hog (Proposition 2.2 (*Quality price and quality specificity*)).

Assumption 2.3 (*Bounded rationality*): Human beings have limited cognitive capabilities to

receive, store, and process information (Williamson, 1996).

Proposition 2.3 (*Optimal quality pricing under bounded rationality*): Based on proposition 2.2, optimal quality price may be discovered and implemented by an approximation approach (Simon, 1972) but it comes at the costs of information regarding marginal cost structures of M number of hog sellers and marginal impact of the quality outcome of a hog on a pork packer's revenue, due to Assumption 2.3 (*Bounded rationality*), thereby an optimal quality price is imperfect in terms of containing all relevant information.

3.3 Upstream Firms' Decisions on the Production and Marketing of Slaughter Hogs under Quality Price

3.3.1 Stable Market Environments Case

In this subsection, we exhibit how hog producers' production and marketing behaviors made under quality price are deviated from those under no quality price and the differences in the welfare and organizational consequences. We present the two distinguished results of the analysis under stable and volatile market environments because the subsequent welfare and organizational consequences are dissimilar.

Proposition 3.1 (*Selection of certain type of pigs and feeds under quality price*): Under quality price, optimal decision on selecting certain type of feeds and pigs is made by a criterion of maximizing the total selection effects of the two inputs on both quantity and quality outcomes of slaughter hogs per batch.

Proposition 3.1 is different from proposition 1.1 (*Selection of certain type of pigs and feeds under no quality price*) in terms of the role of information and allocation of decision rights on the selection. Calculating the total selection effects of the two inputs on both quantity and quality outcomes of slaughter hogs is less precise and uncertain than the estimates of only quantity effects because the information on the selection effects of the two inputs on measurable quality

attributes of slaughter hogs is less known. Furthermore, information on the selection effects of the two inputs on a hog's quality attributes difficult to measure aforementioned may become valuable for a pork packer. If pork packers obtain the information more effectively than hog producers do, the probability of shifting decision rights over the selection to pork packers would increase (Jensen and Meckling, 1992).[7]

Proposition 3.2 (*Decision on the timing to market under quality price*): Under quality price, optimal decision on a time point of marketing is made by both marginal quantity and quality outcome of slaughter hogs with regard to feeds per batch, the prices of feeds and slaughter hogs, a premium and discount rate of quality, and the opportunity costs of hog production facilities and labor per unit of time[8].

Proposition 3.3 (*Pareto Improvement effects of quality incentives*): Even if quality price is imperfect, the optimal decision made by upstream firms under stable feeds and slaughter hog price condition will lead to *Pareto Improvement* because of the quality incentive effects.

Figure 3-1 and 3-2 illustrate quality incentive effects on the upstream firms' behavior on the timing to market and the consequent distribution of carcass weights. Particularly, in figure 3-1, the incentive effects account for making the optimal zone flatter, which enables to make them

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[7] This argument seems to be different from Jensen and Meckling's in which they focus on the costs of transferring specific knowledge while we focus on the cheaper position of a pork packer to obtain specific knowledge of the correlation. However, considering the pork packers' increasing competition over genetics and feeding program, the information of the correlation becomes closed to outside of a pork supply chain control by a pork packer, and thereby the information becomes costly to be transferred.

[8] There is a significant economy of scale for the marketing quantity of slaughter hogs at a time point, which means that a tradeoff between reducing variation in quality and transportation costs loss takes place when a hog producer segregates slaughter hogs into ones of mature weights and ones of immature weight, for example. In addition, activities for reducing variation in quality may negatively affect the utilization of production facilities and labor.

more tolerable for inferior hogs to be further fed. Figure 3-2 exhibits how quality incentives create value for processors with specific target distribution of carcass weights determined by their market strategic position. Compared to the distribution under no quality price, the variance of the distribution formed in the presence of quality price is smaller.

<Insert Figure 3-1 and 3-2 here>

3.3.2 Volatile Market Environments Case

Proposition 3.4 (*The erosion effects of the volatility of feeds and base-hog price on optimal quality price*): Under feeds and base-hog price volatility, an upstream firm's an optimal decision on timing to market may lead to a suboptimal outcome of quality for a downstream firm.

Figure 4-A, B, and C illustrate this case. Figure 4-A shows that a high productivity-producer's optimal decision on the timing to market tends to result in marketing a hog of overweight for a pork packer when base price of a slaughter hog is increasing at the marketing time horizon. In contrast, a low productivity-producer's optimal decision may bring about delivering a hog of underweight for a pork packer when base price of hogs is decreasing or feed price is increasing at the marketing time horizon (see Figure 4-B). Both cases result in deviation from target range of carcass weights valuable to a downstream firm. The consequential effects on the distribution of carcass weights are expressed in the figure 4-C. Therefore, upstream firms' optimal decision under the volatility of feed and base-hog prices may result in an insufficient supply quantity of hogs of target quality. We label this deviation as the erosion effects of price volatility.

Intuitively, we can conclude on proposition 3.5 (*Quality specificity and erosion effects*): The higher a pork packer's hog quality specificity, the larger the erosion effects are likely to be. The proposition 3.5 entails that a pork packer with a narrower target range of carcass weights is more

likely to get hurt from the erosion effects.

<Insert Figure 4-A, B, and C here>

3.4 Firms' Behaviors under Long-Term Hog Procurement Contracts

If individual pork packers have a capability to aptly adjust quality prices to the change of feeds and base-hog prices, and the contingent quality prices can be pertinently disseminated without costs,[9] the potential erosion effects arising from the volatility of relevant prices would be remediable without incurring offsetting costs. In reality, however, contingent pricing to be made by individual firms incur non-trivial costs both ex ante and ex post[10]. Therefore, assumption 2.3 (*Bounded rationality*) is legitimate on the quality pricing specifically under volatile market environments.

Capabilities of long-term hog procurement contracts with regard to quality coordination

Long-term hog procurement contracts enable contracting parties to have long-term formal relationship in repeated transactions, periodically assess and enforce the performance of past multiple transactions, and remedy potential losses from the past transactions. The available enforcement mechanism for the past performance for long-term contracts goes with additional payment to sellers to participate in the contracts. We label this payment as inducement for hog producers not to distract from the volatility of feeds and base hog prices while long-term contracts describe it as a contract premium. The inducement for and enforcement of quality performance induce hog producers signed on long-term contracts to adjust their decision to the

[9] Consider costs associated with hog producers' activities of interpreting and comparing contingent quality prices offered by available multiple pork packers.

[10] *Ex post* costs entails errors on the calculation of contingent optimal quality price, from which slaughter hogs of larger variance of carcass weights result, which would erode the future income stream of the pork packer.

downstream party's expectation. These adjustments accumulate into the distributional change of carcass weights. We label this result as the long-term contract effects on erosion (see Figure 5).

From the two previous propositions (proposition 2.1 (*Marginal impact of the quality outcome of a hog on a pork packer's revenue*), proposition 3.5 (*Quality specificity and erosion effects*), it is derived that the benefits from choice of long-term contracts increase with quality specificity of slaughter hogs (Proposition 4.1 (*Quality specificity and the value of long-term contracts*). The benefits comprise the value of improvement on the distribution of carcass weights resulting from transition from spot markets to long-term contracts less any loss from upstream firms' deviation from optimal decision arising from the transition and the direct contracting-cost differences between spot markets and long-term contracts. If contract premium (or inducement) is equivalent to loss from hog producers' deviation from optimal decision, and the last component is ignored, the value of long-term contracts augments with quality specificity. Similarly, another proposition is made: Proposition 4.2 (*Complementarity among quality specificity, inducement, and performance enforcement*): Quality specificity, the magnitude of inducement and stringency of performance enforcement go together.

Another capability of long-term hog procurement contracts is to allow for contract parties to *ex ante* reallocate decision rights over the hog production practices. In order for the potential of the contracts to be employed, two conditions should be satisfied: pork packers should own more relevant knowledge; and the reallocation of decision rights should not invite considerable agency costs (Jensen and Meckling, 1992). Therefore, we suppose that a downstream firm procuring part of the total quantity of slaughter hogs from its own hog production units has more specific information regarding the correlation between the genetics of pigs and characteristics of feeds and the quality outcomes than a downstream firm otherwise or upstream firms do. Furthermore, the costs associated with delegation of the decision rights would reduce as the proportion of

internal procurement enlarge because the pork packer in problem tends to balance between quantity and quality outcomes of the selection out. Consequently, we come up with a proposition that decision rights over selection of the genetics of pigs and feeds in long-term contracts are likely to be allocated to a pork packer operating hog production units (Proposition 4.3 (*The implementation rule for reallocation of the decision rights*)).

<Insert Figure 5 here>

4. Conclusions

Long-term contracts have been viewed largely as a safeguard to protect relationship-specific investments from trading parties' opportunistic behaviors *ex ante* and *ex post*. This paper provides an alternate explanation for the existence of long-term contracts: concerted coordination to reduce adjustment costs of endogenously-determined quality prices under volatile market environments. The intertemporal bundling of repeated transactions (Masten, 2006) through long-term contracts opens a set of coordination instruments not available in spontaneous spot market, but valuable in circumstances where providing optimal quality price contingent on volatile market environments for maximizing joint-profit is costly: contract premium (inducement), long-term enforcement of quality performance, and allocation of decision rights. We expect that our analytical model for the choice of long-term contracts better explains the existing long-term hog procurement contracts than asset specificity or measurement costs saving explanation do.

We cautiously argue that the assumption of opportunism is a critical component to explain the boundary of the firm from transaction cost theory perspective, but not a necessary condition to explicate evolution of various inter-firm relationships in markets. Rather, economic agents' development of organization forms economizing on bounded rationality, which results in alignment between organization forms and the underlying transaction attributes, and

impossibility of selective intervention in transaction cost theory (Williamson, 1975, 1985, 1996) are two basic pillars for building a more comprehensive explanation of various inter-firm organization forms. This research contributes an extension of the theory by offering an analytical model and a set of testable propositions involving pricing difficulty, a critical difficulty associated with transactions, for explaining the transition from spot markets to long-term contracts in the US pork industry.

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<Table 1> Percent of U.S. Hogs Procured by Different Organization Forms, 1980-2005

Organization Forms	1980	1993	1999	2002	2005
Spot markets	NA	82.5	35.8	15	11
Marketing contracts	2	11	62.0	64	67
- Short-term	NA	NA	NA	9	9
- Long-term	NA	NA	NA	55	58
Packer-owned	NA	6.4*	NA	19	22

* Data is collected for 1994.

- Data of 1980 are sourced from Martinez and Zering (2004), and those of 1993 and 1999 are based on industry surveys (Hyenga, et al., 1996 and Grimes, et al., 2003). Data of 2002 and 2005 are based on USDA Mandatory Reports.

<Table 2> Diversity of Carcass Merit Programs Partially Observed

Target carcass weight range (pound)	Target lean percent or backfat	The highest available premium
207-221	57%	109% of base price
191-217	0.51-0.60 inches	109%
188-222	backfat 16mm	107%
181-215	0.51-0.90 inches	108%
176-208	54-57%	$5.23
173-217	54-57%	$4.00
173-250	≥60%	112%
173-250		112%
172-195	60%	104%
170-222	0.60-0.79 inches	100% (no premium but discounts)
170-222	>52%	$2.75
170-222	53-54.9%	$0 (no premium but discounts)
168-208	no target	$5.23
164-207	49-61%	$6.00
148-236	60%	104.2%
	no target	

Source: Excerpts from contract summary report (http://scl.gipsa.usda.gov) 20006. 10.11

<Table 3> Classification of observed major provisions of long-term hog procurement contracts based on contractual functions

Contractual Functions	Observed Provisions
Concerted coordination	- Setting quality goals to be implemented over contract duration - Providing long-term quality incentives - Enforcing target quality performance - Reallocating decision rights over hog producers' production practices - Window pricing structure
Safeguards	- Remedy for damage from delivery shortage - Remedy for damage caused by pork packer's default
Adaptability	- Tolerance zone on the variation of delivery quantity - Quantity adjustment - Adjustment of target quality zone and adjustment rate (change of carcass merit program)

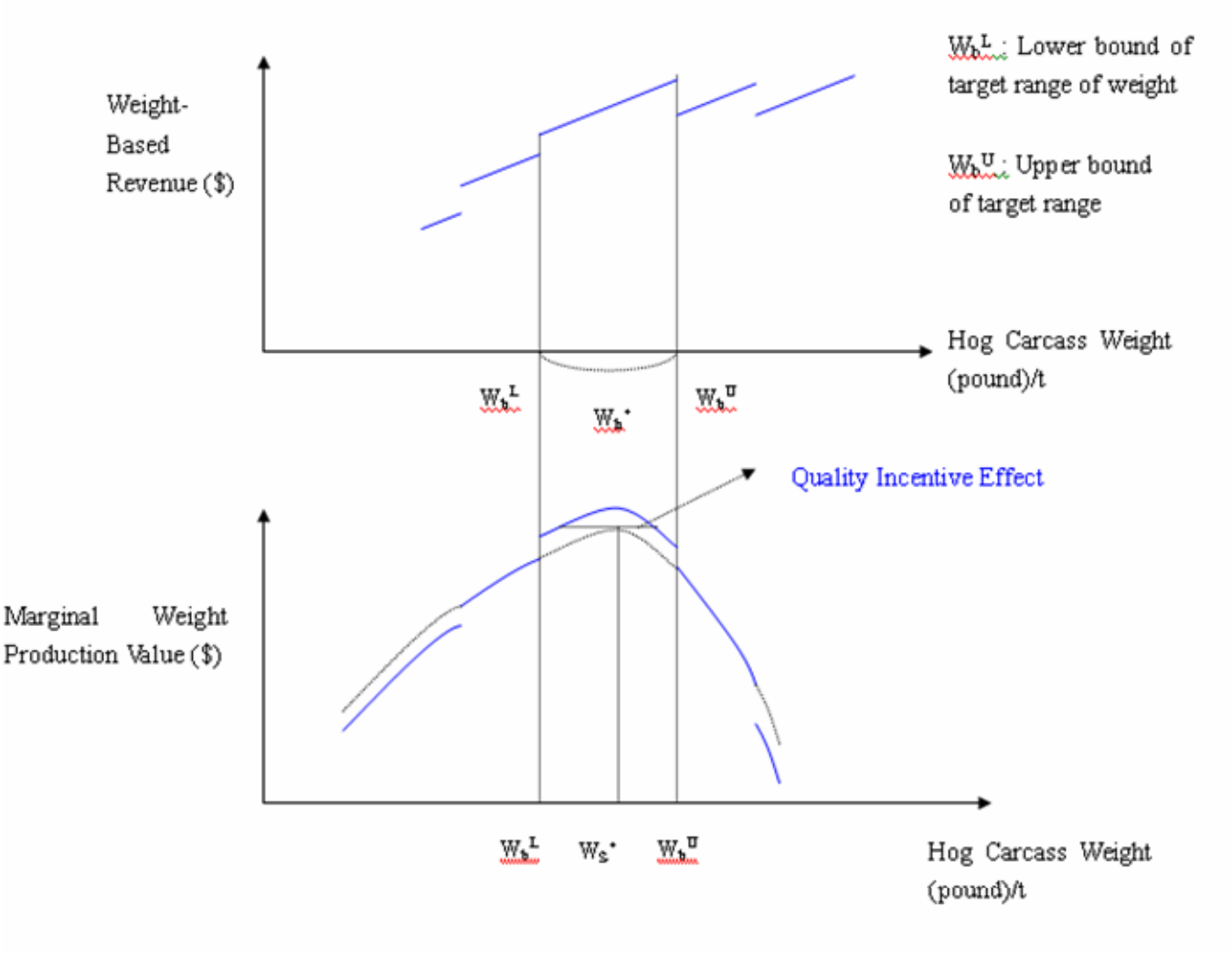
Source: Excerpts from contract summary report (http://scl.gipsa.usda.gov) 20006. 10.11

<Figure 1-A> Pork Supply Chain: the Flow of the goods sequentially transformed

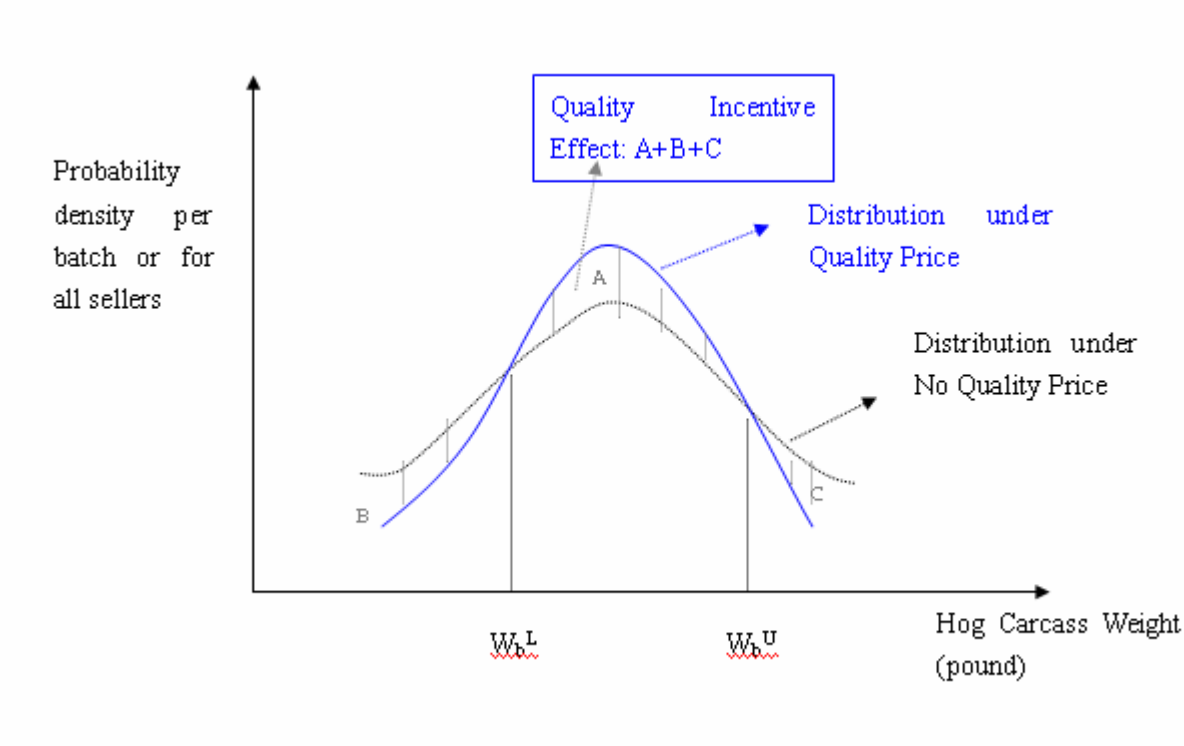
Figure 1-B. Hog Production Timeline

<Figure 2> Upstream Firms' Decision on the Timing to Market under No Quality Price

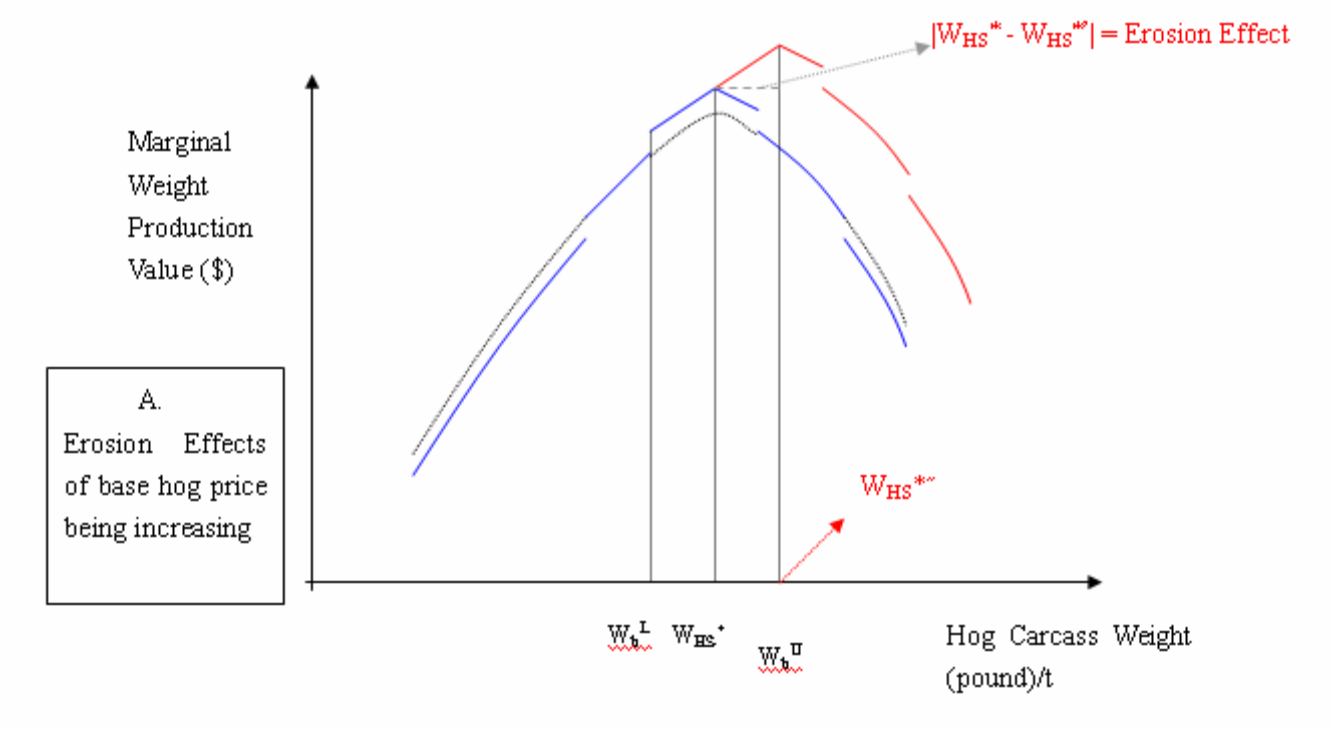
<Figure 3-1> Quality Incentive Effects on Upstream Firms' Decision on the Timing to Market

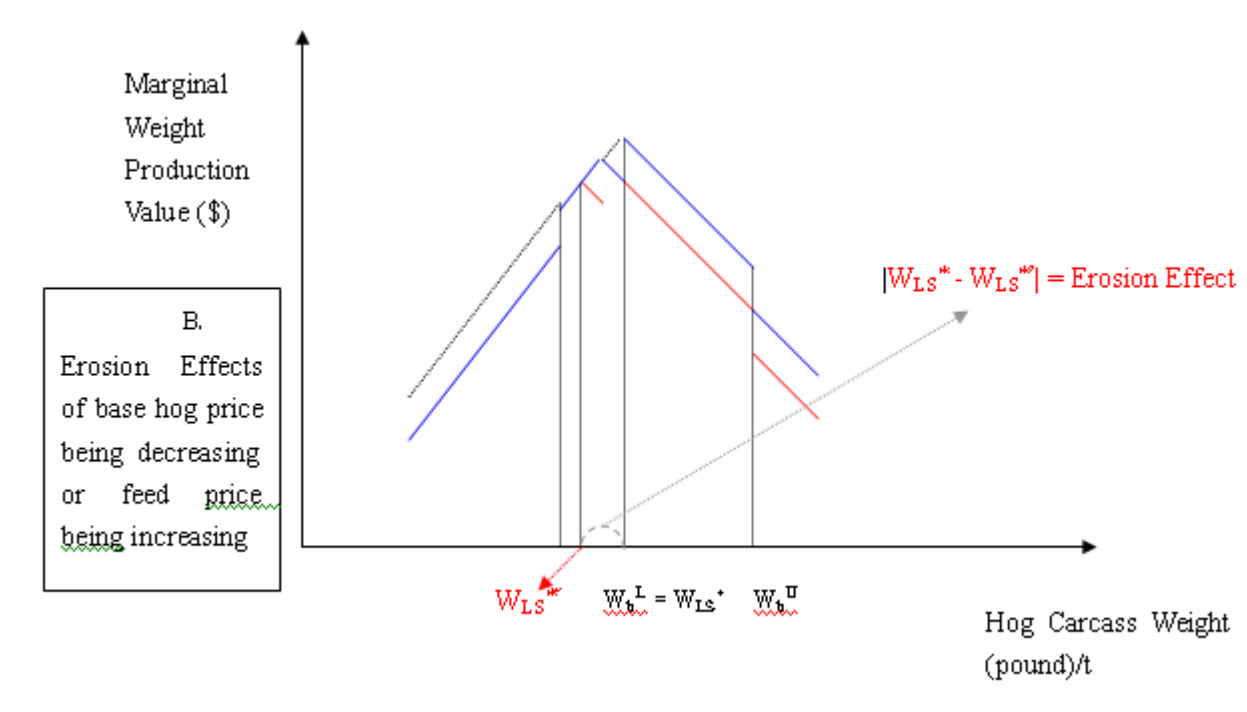


<Figure 3-2> Quality Incentive Effects on Distribution of Carcass Weights

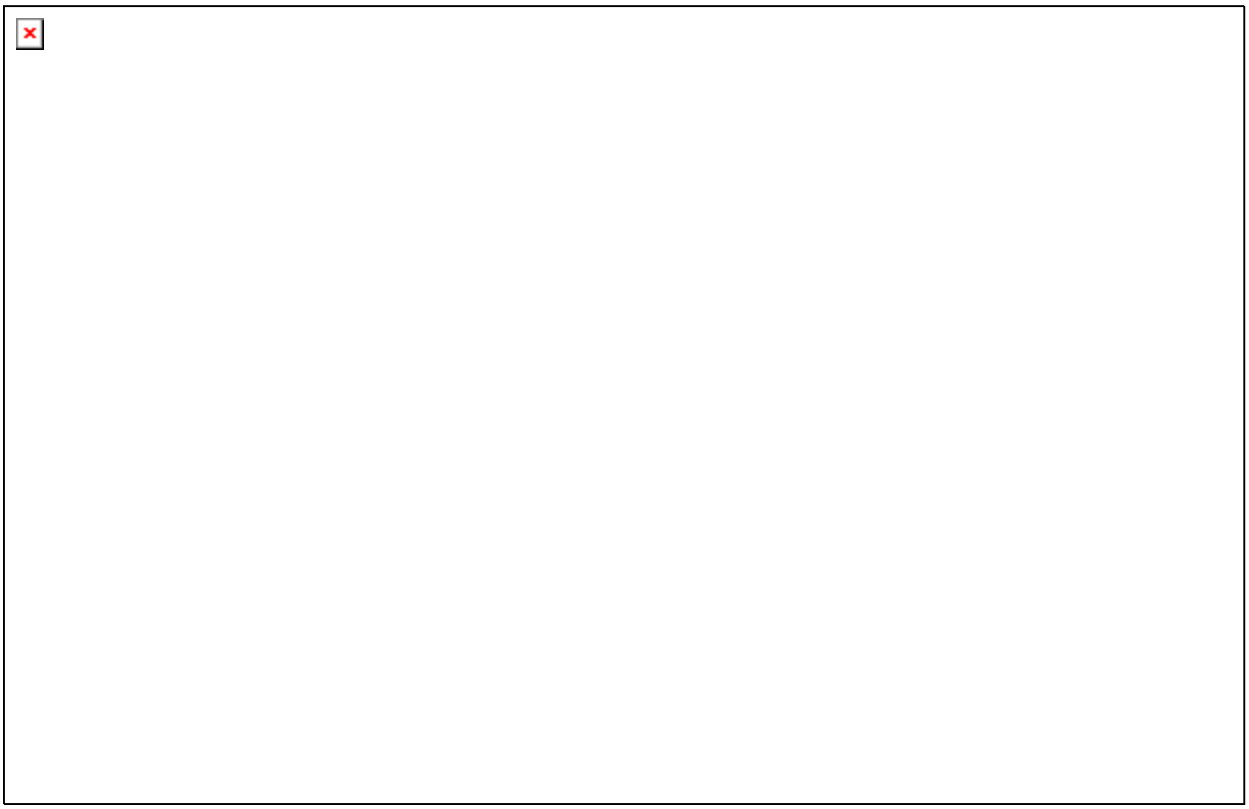


<Figure 4> Erosion Effects of Price Volatility of Base Hog and Feed on Quality Incentives





<Figure 4-1> Erosion Effects on Distribution of Carcass Weights



<Figure 5> Effects of Choice of Long-Term Contracts on Erosion