
***Contracting to Manage Risk
in Food Supply Chains***

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As many primary material sectors move toward complete market orientation, associated market level risk transferred to producers and processors implies there are new demands for risk management. As GATT and coming WTO agreements induced moves away from national government managed price levels and volatility, many types of raw material production and processing are exposed to input and output price volatility generated across a spectrum of markets ranging from local to international. The implications of this new environment will have long-term consequences for the profitability, risk, solvency, liquidity, and efficiency of these economic activities.

In recognition of this change in market orientation, innovative futures and options instruments have evolved to provide new opportunities for supply chain participants to independently manage price risk. Simultaneously, an array of insurance products has emerged. Insurance-based risk management products are typically designed to insure either producer gross revenue or processor costs of procurement. With important differences across production, financial, and management characteristics of most raw material production and processing operations, the implications of new risk exposure and the demand for risk management can also be expected to vary across this diversity. Two important features of price risk faced by food supply chains are that it is multiple source and it varies continuously across a long planning horizon.

This paper assesses the opportunity for supply chain contracting involving risk management. The presence of risk in any one agent's level of supply or price received impacts procurer costs in the short-run (e.g. through collection costs, capacity utilization, etc.) as well as producer revenues. Further, this risk generates an economic externality across all producers and agents in the supply chain and that may create an incentive for self-regulation through pooling and supply chain contracting. Importantly, supply chain management of risk actively feeds back to the supply chain's performance depending on whether bilateral or multilateral

contracts are used and depending on the transparency of those contracts. This paper considers several aspects of this problem to identify opportunity for supply chain management of risk. In particular, the implications of and incentives for the following forms of risk management are considered: 1) independent by each producer or processor, 2) joint through vertical integration, 3) independent based on incentives, and 4) optimal contracts that link incentives to risk management outcomes. An application to the dairy supply chain will provide the setting. Recent experience in the dairy product supply chain provides an important case for analysis of opportunity for supply chain contracting of risk. In particular, as the dairy sector moves toward market orientation in determination of prices, both producers and processors have an interest in managing both price and throughput risk.

In this paper, we consider this opportunity. First, opportunities for independent risk management at any point in a supply chain will be assessed. Second, opportunities for coordination of supply chain management of risk is evaluated. Cooperative, producer directed, and processor directed alternatives are evaluated. Using dairy price risk management as an illustration, this paper overviews and assesses the current opportunity for enhanced supply chain management of price or other risk through coordination across supplier pools and the procurer in the food system. The paper builds on ongoing nationally funded research in the U.S. that involves substantial collaboration with the private sector.

Overview: Opportunity for Managing Risk in Supply Chains

First, some background on the general problem

Economists have long argued that decentralized markets are efficient means for moving goods from producers to consumers. In the real world, the economic distance between producers and consumers is a tangled course of various production and marketing activities managed by a vertically related chain of enterprises. Nonetheless, economists argue that when prices at each link in such a supply chain are determined in competitive markets, prices along the supply chain will transmit signals of what is needed, where and when. However, this assumption of competitive markets along the supply chain becomes unrealistic when the conceptual picture is complicated by several important features of food supply chains.

The quantity produced at most nodes of food supply chains is not perfectly controllable by the managers at that node. This implies the available supply at upstream nodes are uncertain, rendering procurement a problem that is characterized by risk of discovery of input streams that will not fully occupy capacity and unpredictable search costs for gathering and assembling available input supplies. Second, the quality characteristics of “food” as it passes along the supply chain are not fixed. In fact, food products (including raw ag products) are highly differentiated by a wide spectrum of quality characteristics. Third, production and transformation activities along the food supply chain are not instantaneously completed implying

the price of goods along the supply chain are uncertain at the time production decisions are made and resources are committed.

In each case, these complications can be viewed as features or characteristics of the food product that are not “priced” by a market. In the absence of pricing of these characteristics, their supply is not likely to equal their demand along the food supply chain. Without prices, producers have no idea of how much of each characteristic to produce and have no means of communicating their needs to other producers along the supply chain. The result is that the food supply chain fails to perform, i.e. produce quantities, qualities, and economic value that best utilizes scarce resources to attain maximum value added along the food supply chain.

While recognizing this inherent problem, economists have also developed a variety of solutions for this type of “performance failure”. In fact, the performance failure generates substantial incentives to find a fix. One alternative is for the private sector to internalize the management of the characteristics that markets can not price. Over the past several decades the agricultural and food system has seen this solution pursued through vertical integration in the broiler, hog, and beef supply chains. While vertical integration is a solution, it carries with it changes in the “structure of production”, the distribution of firms by size, location, diversification, and ownership. In many cases, political and social preferences may reject this option based on perceptions of such changes in the structure of production. A second solution

involves government intervention to establish grades and standards for the characteristics not priced by the market. For example, safe minimum standards might be set to ensure acceptable quality, or grades might be set to allow a smaller, discrete set of product characteristics to be priced. For example, when oranges are graded by size and spherical shape, a small set of sizes and shapes can be priced. Weaver and Kim (1999) recently demonstrated that while grades and standards improve a supply chain's performance they leave in place significant incentives for vertical integration.

In important alternative solution to this type of supply chain performance failure is the use of contracts. Rather than integrating assets and production processes that may have little in common, contracts offer managers along a supply chain opportunities to communicate their needs and to price them in bilateral or multilateral agreements. Just as a landlord finds it possible to price the condition of a rental property at the close of a lease through a bilateral agreement, producers along a supply chain can use contracts to establish their specific needs and incentives for their attainment.

Now, some background on the case of the dairy supply chain

Dairy presents a rich context for the study of supply chain management of risk. Three types of risk can be defined: price risk, quality risk, and quantity marketed risk. Price risk is typically viewed as simply emerging from time varying prices. While current milk price policy results in producers being paid a monthly average price defined through consideration of the use

of milk delivered, the monthly average prices have traditionally been related to market conditions. Most recently, Class prices under multiple component pricing initiated in January 2000 are based on surveys of prices paid to processors for dairy products. This generates an uncertain milk price.

Under current policy producers are also paid differentially depending on the composition of their milk, in particular for butterfat. Given this composition is uncertain, producers face composition uncertainty in price received. However, milk components can be viewed as separate products and, in general, where composition of supply is uncertain, the market values of those components will also be uncertain.

Quantity produced and available to the producer is also uncertain. Raw milk varies in quality dimensions defined by attributes that have both positive and negative values. Consumers value flavor, shelf life, and nutritional value while processors at various stage value protein, fat, solids such as whey, and negatively value somatic cell, bacterial, and other contamination. An important example of contamination that is of current concern is antibiotic residues. The presence of residues or contaminants in any one agent's supply impacts procurer costs in the short-run and producer revenues in the longer run if they are undetected at the farm gate. Further, when they are detected at the farm, standards establish protocol for diversion of affected milk from the market. This diversion introduces a second dimension of quality implications, uncertain marketed supply. This implies the quantity of milk marketed is not predictable by the processor. These implications generate economic externalities across

producers and processors, creating incentives for regulation or control of quality attributes that have economic value. Options include regulatory approaches such as grades and standards, or private sector strategies such as pooling through either supply chain contracting or vertical integration.

Importantly, supply chain management actively feeds back to the supply chain's performance depending on whether bilateral or multilateral contracts are used and depending on the transparency of those contracts. Recent experience in the dairy product supply chain provides an important case for analysis of the current state of opportunity for supply chain contracting as well as the current state of implementation supply chain contracts. Over the past several years, this product chain has been increasingly exposed to product price, quantity, and quality risks that suggest opportunity for supply chain management through contracting. Food safety, food quality, and price and quantity risk concerns are most important.

To proceed, we consider the opportunity for contracting given quality based risk. However, we present a risk specification of the problem that allows, through reinterpretation, commentary on contracting for price risk or quantity risk.

Microeconomics of quality production

Fitting quality into microeconomics I: The agent's story

Suppose the i^{th} agent (e.g. the dairy farmer) produces an output y_i that has continuously variable quality q_i . We drop the subscript for convenience when it is not necessary. Production occurs through application of a vector of variable inputs, x , as well as a vector of

quality management inputs, z . Production involves two separate processes, one $y(x, z / e)$ that results in a private good output, quantity (y), and one that results in a private good, quality, defined by $q(x, z / e)$. The latter directly impacts the amount of substandard product that must be dumped. In each production process, a vector of variable private inputs, x , and a vector of quality control inputs are applied by the producer. Further, both production processes are impacted by quality altering events, e , that are random. We suppose that $e \sim \mathbf{f}(g, z, q^*)$. Quality events may be defined as either controllable or out of control of the producer. Here, we allow them to be conditional on the quality control inputs z , quality goals q^* , and γ a parameter vector.

The notion that quality can be explicitly managed is the focus of extensive literature in management science under the banner of Total Quality Management (TQM). Though it has received little attention within the context of neoclassical microeconomics, see Chong (1996), De Vany and Saving (1983), Dotchin and Oakland (1992), or Lederer and Rhee (1995). The agent may hold a goal for quality, q^* , or in the tradition of that goal might be the subject of contracting, either implicitly or explicitly.

Marketing Standards and Product Disposal

Marketing standards can be introduced as a quality standard, \bar{q} , such that all product not meeting this standard is dumped. This disposal is not necessarily free (i.e. the technology may exhibit weak disposability in y). The quantity disposed is defined by a disposal function, $D(x, z, \bar{q} / e)$. The disposal function is motivated by the conditions that trigger disposal,

typically a standard that establishes a minimum quality attribute that must be achieved as a condition of marketing. Intuitively, for a dairy application we might define cow specific quality as resulting from application of variable inputs and TQM effort, as well as from the occurrence of the quality event, e . When quality of product associated with the cow falls below the standard, the milk would be dumped, otherwise marketed. Mathematically, the dumped milk would be the integral over cow specific quality conditional on quality meeting or exceeding the standard. We summarize this function as $D=D(x,z, \bar{q} | e)$ satisfying

$$\partial D / \partial \bar{q} > 0, \partial^2 D / \partial \bar{q} \partial y < 0, \partial D / \partial q < 0, \partial^2 D / \partial \bar{q} \partial q < 0$$

Incentives for Quality

Before closing the layout of notation, we generalize the objective of quality management to allow for incentives (λ) for quality attainment $q^l(q, q^*)$ where quality goals q^* may be incorporated to be consistent with TQM type effort, and marketing standards that segment the market.

Producer's Story: Choice of the level of quality to produce

Define the most general form of profits earned from production activities as:

$$\pi = P \tilde{y} + \lambda q^l(q, q^*) - C(q(x, z), y(x, z | e))$$

$$\tilde{y} = y(x, z | e) - D(x, z, q^l | e) \quad (1)$$

Together the market price and the quality incentive define a producer differentiated “settlement” price. In the broiler industry, the quality incentive is most often replaced by one that reflects the producer’s average cost of production compared to a reference, or peer group.

The processor’s story: What level of quality to process?

Suppose that the processor earns profits by producing a single product y^p using a supply of raw product, Y , collected from producers as well as variable inputs, x_p . Aggregate supply is defined as $Y = \sum_{i=1}^n \tilde{y}_i$, the sum of milk marketed, collected across a pool of n producers by prior contract or on an open market. We view \tilde{y}_i as exogenous to the processor, consistent with the producer’s technology being noninstantaneous. Here, we write processor profits as:

$$\pi_p = P_p Y_p - \lambda Q - P_Y Y - C_p(Y_p, Y, Q)$$

where Q is defined as an indicator of pool quality, and \mathbf{I} is reused without subscript as the incentive paid by the processor for quality. As in the producer case, a wide scope of specifications can be considered for Q and \mathbf{I} . For example, Q can be defined as the average quality discounted quantity of product purchased, i.e. $Q = \sum_{i=1}^n q_i y_i / Y$. In general, we assume the processor cost is impacted by the pool quality index. This specification could be generalized. We specify the processing cost function as satisfying

$$\partial^2 C_p / \partial Y^2 > 0, \partial^2 C_p / \partial Q^2 > 0, \partial^2 C_p / \partial Y^2 > 0,$$

and cross-derivatives nonpositive.

We can now see that quality management by the producer impacts the processor in two ways. First, because producer quality management impacts the amount of substandard product, Y , available the pool becomes uncertain for the processor that procures from a fixed pool of processors (e.g. through exclusive processing agreements) Further, procurement cost is uncertain when additional non-pool supplies are needed to fill capacity. Third, when variation in quality above the standard is relevant to the processor, the processor has a direct incentive to attempt to manage the quality delivered by each producer. Further discussion of the theoretical implications of this theory are available from the authors in related papers. To ensure this paper is of manageable scale, we now turn to simulation results.

More general interpretation of the specification

In the specification above, we had the revenues as

$$R = P \tilde{y} + \lambda q^I(q, q^*) \text{ where } q(x, z | e) \quad e \sim \mathbf{f}(g, z, q^*)$$

We interpreted q^I as an indicator of quality and $D(\cdot)$ as a dumping function. However, to convert this specification to one that focuses on quantity risk, we simply reinterpret q^I as an indicator of achievement of a target quantity of production q^* and q as the deviation from the target production, and define $D(\cdot)$ as a random component of quantity produced. The problem now defines quantity marketed as random where an incentive λ is paid for achievement of a target. Similarly, by redefinition of notation, the problem can be interpreted as considering price risk.

Simulation of Incentives for Supply Chain Coordination

To illustrate the incentives for supply chain coordination, we consider only the case of quality risk. We evaluate the profits attainable by producers, processors, and the supply chain in aggregate under a series of scenarios. To do so, we parameterize our theoretical specification above using standard neoclassical shapes for the underlying functions, details are available from the authors. In each case, we numerically solve the optimization problem given different levels of the quality incentive. For the contract design cases, we numerically solve for the optimal incentive when producers are considered homogeneous, or the nonlinear menu of incentives when producers are heterogeneous. Results are reported graphically in Figures 1-2 and in Table 1 and discussed below.

Case 1: Independent decision-making

Weaver and Kim (1999) present a series of propositions concerning independent decision making, noting that in the absence of incentives, quality will be produced by producers and purchased by processors if it influences productivity and costs. This follows from the producer and processor first-order conditions. As is apparent from Figures 1, for the producer, introduction of an incentive greater than a reservation level, I' , will be attractive, i.e. $(\mathbf{p} | \mathbf{I} > \mathbf{I}') > (\mathbf{p} | \mathbf{I} = 0)$. In Figure 1, profits for the producer are graphed and labeled as Prod (when $\lambda=0$) and ProdL (when $\lambda>0$). We see that profits are increasing and convex in λ . From the producer's perspective, optimal λ is infinite. The exact curvature of the producer

profit function depends on the quality production function specified. Here, we suppose diminishing returns to inputs that yield quality occur slowly.

For the processor, we also find a reservation incentive at which quality incentives generate profits that exceed those attainable in the absence of incentives for quality, $(\mathbf{p}^p | \mathbf{I} < \mathbf{I}^{pr}) > (\mathbf{p}^p | \mathbf{I} = 0)$. In Figure 1, we label the profit function as follows Proc (when $\pi_p | \lambda=0$), ProcL (when $\pi_p | \lambda>0$). For this case, profits are decreasing and concave in the quality incentive. At some level, quality incentives fail to generate increases in marginal revenue and profits fall to levels that make incentives not attractive. The reservation incentive for the processor is noted Lrp in Figure 1.

Before closing, consider the supply chain profits attainable under independent decisions, $\pi_{ISC} = \pi + \pi_p$. In Figure 1, we note $\pi_{ISC} | \lambda=0$ as Tot. It is constant. $\pi_{ISC} | \lambda>0$ is noted TotL and is decreasing and concave in λ , allowing a definition of a reservation quality incentive such that for $\lambda > \lambda^*_{ISC}$, $\pi_{ISC}(\lambda > 0) > \pi_{ISC}(\lambda = 0)$.

Case 2: Joint decision-making: Vertical integration

Vertical integration results in an opportunity for joint profit maximization (i.e. $\max \bar{\mathbf{p}} = \mathbf{p}^p + \mathbf{p}$) and establishes benefits of internalization of the externalities generated by quality that can not be controlled under independent action. In Figure 1, we note profits from vertical integration as VI. The FOC for this problem indicate that when no standards or incentives exist, i.e. $\mathbf{I}=0$ and $D=0$, independent decisions by producers and processors fail to reproduce the necessary conditions for joint profit maximization. This proposition is intuitive,

though powerful. The difference $\bar{p}^* - \bar{p}^P$ defines the incentive for supply chain coordination that is feasibly attained through vertical integration or, in some cases, contracting.

In Figures 1, we can now analyze the incentives for contracting or vertical integration. We see supply chain profits attainable under vertical integration \bar{p}^* (VI) can not be attained by independent units. In the absence of incentive, the supply chain will generate $\pi_{ISC}(\lambda=0)$ (Tot), leaving in place an incentive for vertical integration $VI^* = \bar{p}^*$ (VI) - $\pi_{ISC}(\lambda=0)$. Even when incentives are introduced, $\pi_{ISC}(\lambda>0)$ (TotL) may approach \bar{p}^* (VI), though will not attain that level of profits. We define the incentive for vertical integration when the alternative is use of incentives as $VIL^* = \bar{p}^*$ (VI) - $\pi_{ISC}(\lambda>0)$. Importantly, Figure 1 clarifies that even when incentives are introduced an incentive for vertical integration remains in place, though our results indicate that in general $VIL^* < VI^*$.

Implications of incentives for quality

A standard result in externality management literature is that there exists an incentive that can induce independent agents to replicate the joint profit maximum. We find the same type of result here. This highlights that while such an incentive, say λ^g , exists, λ^g will not typically maximize social welfare in our supply chain case since its determination would have ignored consumer interest in the level of quality. This result echoes a similar result associated with externality taxes or subsidies. A further problem with such incentives is that their uniformity renders them inefficient, e.g. paying a rent to producers who would produce quality even in the absence of incentives.

The idea of a contract for performance

From the specification above, we see that a natural incentive exists for producers and processors to communicate their interests and coordinate across the supply chain. In a market setting, in the absence of grades and standards, where quality is observable at low cost, quality will be priced creating an incentive to better manage quality. Where quality is unobservable at reasonable cost, further incentives exist for the processor to determine the quality level from the producer. In each case, these opportunities can be exploited through contracting. The potential for contracting is next illustrated by examples. To design a contract that is feasible, it must offer increased profits to both the agency and the agents. Incentives under the contract must induce the agents to participate. Intuitively, this will require that under the contract incentives, the agent earns as much profit as might be available in the absence of the contract incentives. We define that reservation profit as for producers as $\mathbf{p}^r_i = \mathbf{p}_i(\lambda=0)$, and for processors, $\pi^r_p = \pi_p(\lambda=0)$.

Processor as Agency: Uniform bilateral contracts across homogeneous producers

The contract design problem can be written as:

$$\lambda, Y_p \quad \text{Max} \quad \pi_p = PY_p - \lambda Q - PY - C_p(Y_p, Y, Q)$$

$$\text{subject to } \pi^c \geq \pi^r$$

where $\lambda Q = n \lambda(d) q(d)$ $Y = n y(d)$ $Q = q(d)$ and $y(d) q(d)$ solve $\pi^c = \text{Max } \pi = P(1-d)y + \lambda q - C(q, y)$

Not surprisingly, given that the quality incentive is selected to maximize processor profits, it will not typically maximize social welfare. To consider the results from this case, first

note that from the processor perspective, the optimal incentive in the absence of contracting would be $\lambda^{p*} = \lambda$ that solves: $\max \pi_p = PY_p - \lambda Q - PY - C_p(Y_p, Y, Q)$. In Figure 1, this is close to zero though in general it might be any positive number depending on the curvature of ProcL. The difference $\pi^p(\lambda > 0) - \pi^p(\lambda = 0) = \text{ProcL} - \text{Proc}$ defines a strong incentive for the processor to contract, if vertical integration is not feasible.

As an agency, the processor is not free to set $\lambda = \lambda^{p*}$. Instead, in the absence of market power over the producers, the agency must set $\lambda = \lambda_p^c$ such that $\pi^c \geq \pi^r$. That is, such that profits for the producer under the contract's λ exceeds or equals the producer's reservation profits. Based on this constraint, we define the reservation quality incentive for the producer λ^r (noted as Lr in Figure 1) where λ^r solves $\pi(\lambda^r) = \pi^r(\lambda = 0)$. Similarly, we define the reservation incentive for the processor, λ^{pr} (noted Lrp in Figure 1), as the solution of $\pi^p(\lambda^{pr}) = \pi^p(\lambda = 0)$. Given the parameterization illustrated in Figure 1, the optimal contract incentive when the processor is the agency will be: $\lambda_p^c(\text{Lcp}) = \lambda^r$. This results in producer profits equal to that attainable without incentives and processor profits of about 150, see Table 1.

To consider incentives for contracting for quality in the supply chain, consider first the case where no incentive exists. In Figures 1, $\pi(\lambda = 0) = \text{Prod} < \pi(\lambda > \lambda^r) = \text{ProdL}$; $\pi^p(\lambda = 0) = \text{Proc} < \pi^p(\lambda < \lambda^{pr}) = \text{ProcL}$; and $\pi_{\text{ISC}}(\lambda = 0) = \text{Tot} < \pi_{\text{sc}}(\lambda^r < \lambda < \lambda^{pr}) = \text{TotL} < \bar{p}^* = \text{VI}$. Thus, a strong incentive for contracting by both producers and processors will normally exist depending on the technologies faced.

Producer Agency: Homogeneous Producers

The importance of bargaining power can be explored within this framework. Suppose the agents form a pool and establish agency over the processor. In this case, the contract design problem under full information would be:

$$\text{Choose } \lambda, q, y \text{ to solve } \pi^{\text{pool}} = \text{Max } \sum \pi_i = \sum [P(1 - d_i)y_i + \lambda_i q_i - C(q_i, y_i)]$$

$$\text{subject to } \pi_p \geq \pi_p^r$$

$$\text{where } \pi_p = \text{max } \pi_p = PY_p - \lambda Q - PY - C_p(Y_p, Y, Q)$$

$$\lambda Q = \sum \lambda_i(d_i) q_i(d_i) \quad Y = \sum y_i(d_i) \quad Q = \sum q_i(d_i)$$

To simplify for this exposition, we suppose all producers are identical allowing summations to be replaced by a scalar n. To emphasize the conditionality of contracting incentives on the particular parameterization of the problem, note we could parameterize the problem such that no incentives exist for producer pool agency. Instead, we explore the case where incentives exist. In this case, the condition for the contract to be of interest to both the producer pool and the processor is:

$$\pi^{\text{pool}}(\lambda^{\text{pool}}) > n\pi(\lambda=0) \text{ and } \pi_p \geq \pi_p^r.$$

Expressed in terms of reservation quality incentives, this amounts to $\lambda^{\text{pool}} > \lambda^r$ and

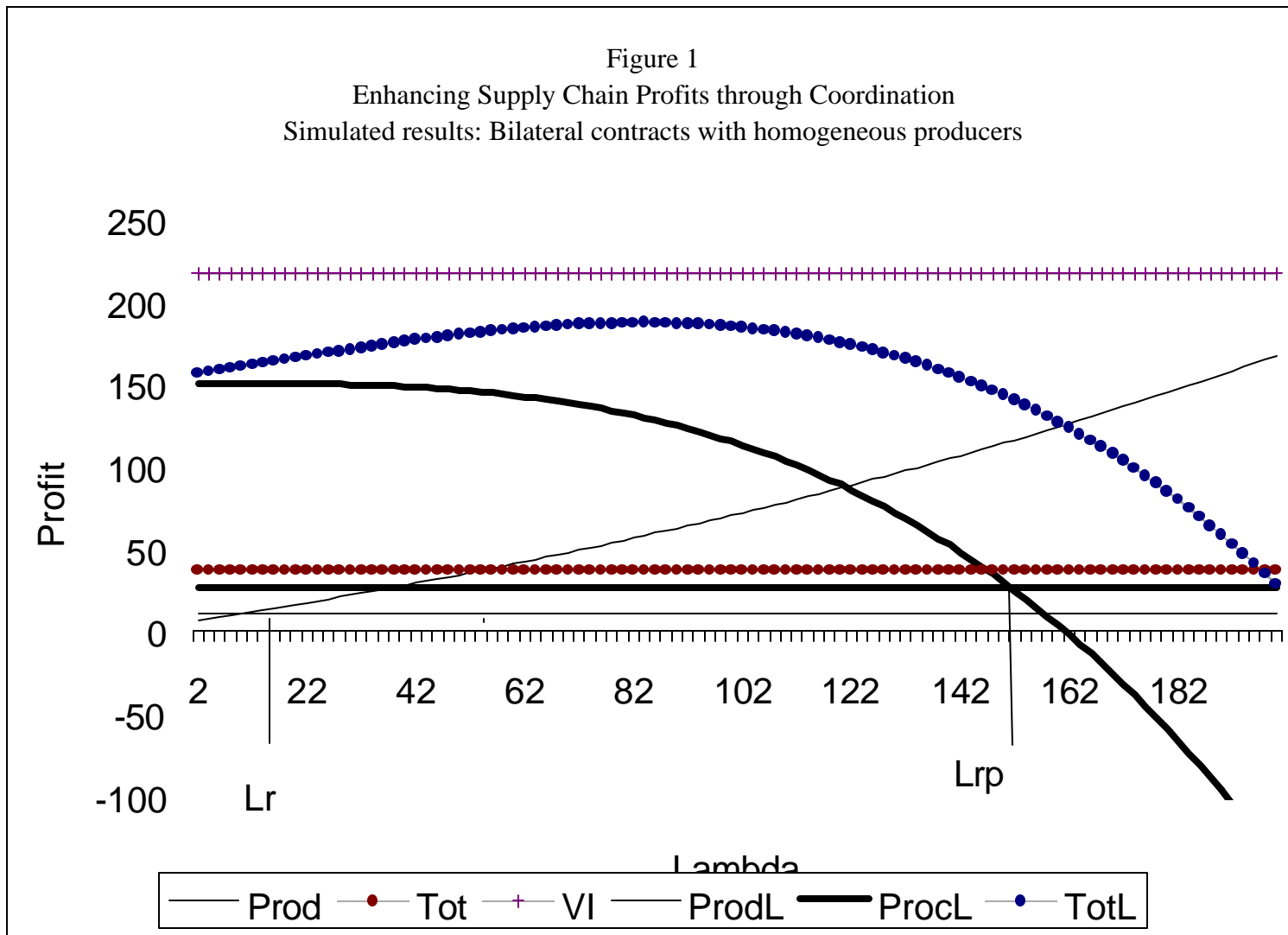
$$\lambda^{\text{pool}} = < \lambda_p^r, \text{ or in terms of Figure 1, } L_r < L_{\text{pool}} < L_{rp}.$$

Given the technologies assumed in the simulation behind Figure 1 we find, the optimal contract incentive $\lambda^{\text{pool}} = \lambda_p^r$. At this incentive level, the processor reservation profit is met,

rendering profit just equal to that available in the absence of contracting. For supply chain profits, $\pi_{sc}^{pool} = \pi^{pool}(\lambda_p^r) + \pi^p(\lambda_p^r)$.

Implications and Conclusions

Grades and standards as mechanisms for managing quality are inherently slow and clumsy. Worse, they fail to provide incentives for private sector led innovation to enhance quality in new directions. Within this context, grades and standards can leave in place strong incentives for firms along the supply chain to vertically integrate as a strategy for assuring quality is supplied as needed. This paper demonstrates the potential benefits of several supply chain management strategies that use contracting to enhance quality productivity of the supply chain. The framework presented has broad applicability for assessing opportunities for managing price, quantity, and quality uncertainty in supply chains. Within the applied setting of managing the dairy supply chain's production of antibiotic residues, the implications of contracting solutions are illustrated. The benefits of improved quality management noted include expansion of industrial demand for commodities as well enhancing and stabilizing prices and farm producer/supplier incomes in the long-term.



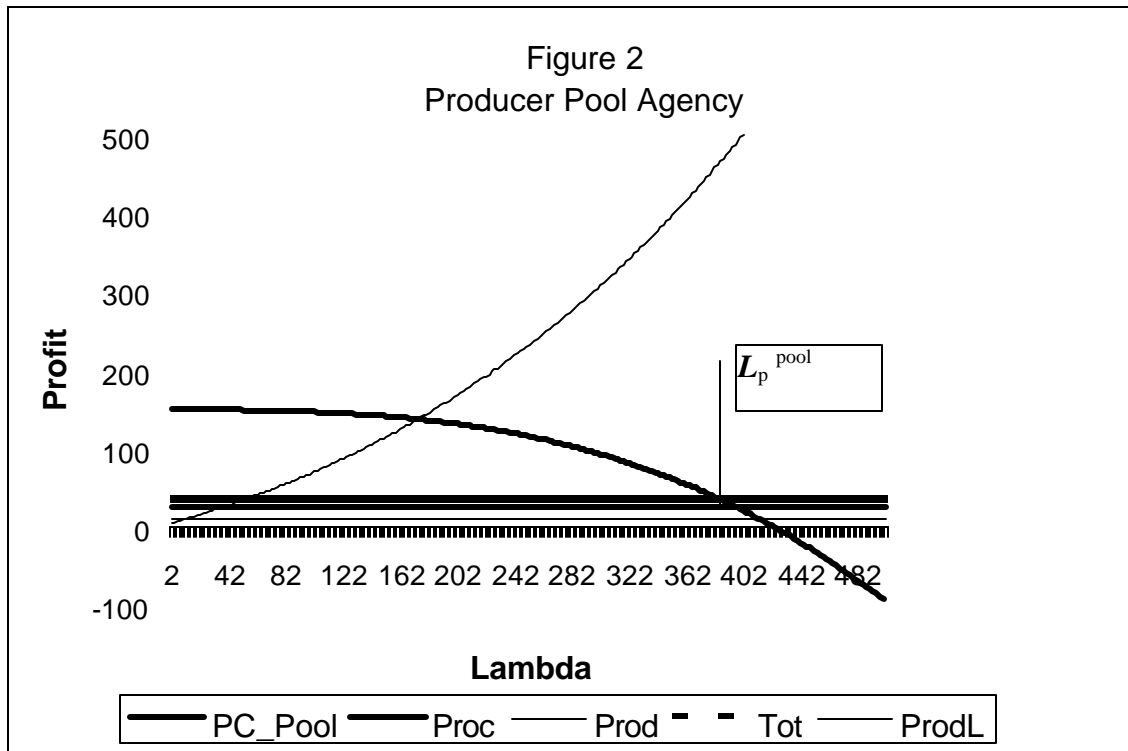


Table 1. Summary of Profit Outcomes

Case	Agency	Agent	Result			$\pi_C = (\pi_A + \pi_B)$
			λ^*	π producer	π_p processor	
1	Processor	Producer	10.238	10.178	149.976	160.154
2	Producer	Processor	151.063	114.531	26.285	140.816
3	Processor	Producer Pool	10.238	10.178	149.928 ¹	160.106
4	Producer Pool	Processor	396.683	481.820	26.285	508.105
5	Independent		0.000	10.178	26.285	36.463
6	Independent (Sum)		84.000	57.386	129.080	184.467
7	Vertical Integration		0.0000	NA	NA	216.643

¹. Increased processing volume generates increased profits.

References

Carpentier, A. and R. D. Weaver (1997), "Damage control productivity: Why Econometrics matters", *American Journal of Agricultural Economics* 79, pp.47-61.

Chong, P. S. (1996), "Modeling total quality management economics", *Total Quality Management* 7(4), pp.433-440.

De Vany, A. S. and T. R. Saving (1983), "The economics of quality", *Journal of Political Economics* 91(6), pp.979-1000.

Dotchin J. A. and J. S. Oakland (1992), "Theories and concepts in total quality management", *Total Quality Management* 3(2), pp.133-145.

Halloway, G. H. (1998), "Contractual arrangements at the farm gate", from *The Industrialization of Agriculture: Vertical coordination in the U.S. food system* edited by J. S. Royer and R. T. Rogers, pp. 115- 132.

Kim, K.C. and Weaver, R.D. *Biodiversity and Landscapes*. Cambridge Press. 1995.

Lederer, P. J. and S. Rhee (1995), "Economics of total quality management", *Journal of Operations Management* 12, pp.353-367.

Vukina, T. and W. E. Foster (1996), "Efficiency gains in broiler production through contract fine tuning", *Poultry Science* 75, pp. 1351-1358.

Weaver, R.D. and Taeho Kim. (1999). "Supply Chain Contracting for Quality: TQM Based Mechanisms" presented at *The Economics of Quality Control in Agriculture* The University of Saskatchewan in Saskatoon, Saskatchewan, Canada December 2nd to 4th, 1999

Weaver, R.D. *U.S. Agricultural Research: Strategic Challenges and Options*. Agricultural Research Institute. Bethesda, MD. 1993.

ⁱ The former approach would be to base it on the physical production technology interpreting it as damage function following Carpentier and Weaver[1997]. Alternatively, it could be defined as price discount function defined to any rule that is of interest to apply.

ⁱⁱ By design this notation has allowed us to focus on negative deviations from a quality goal. By basing that goal on a standard, a more traditional specification is easily derived. We focus on quality goals here to allow consideration of TQM type quality “effort”.