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# Double Sided Moral Hazard and Share Contracts in agriculture

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**Abstract—** This paper develops a double-sided moral hazard model of share contract in agriculture, with imperfect quality measurement by the agent and the principal, who contribute to the final good quality in terms of production effort and marketing effort respectively. Using this model, we analyse the implications of the share contract for quantity and quality, often ignored in previous analysis. With the help of a simulation exercise, we prove that the outcome-conditioned share generally weakens the agent's incentive to make effort in quality input. This finding could explain the contractual evidence in some differentiated markets such as the wine market, where bottle-price conditioned contracts are rarely used.

**Keywords—** share-contract, double moral-hazard, quality.

## I. INTRODUCTION

The agri-food system is undergoing a fundamental transformation that is altering traditional marketing relationships to better serve customer needs. These changes are drawing customers, processors and growers into increasing coordination relationships, improving the flow of information up the supply chain and enabling firms to better meet customer needs.

The question of quality is becoming a central point in the agricultural sector. Indeed, the competitiveness of food companies in national and international markets depends upon their ability to adopt production processes which meet quality requirements.

It is well known that the best way for a processor to prevent quality failures is to make sure that he acquires high-quality inputs. But is also undeniable that moral hazard problems arise when the higher quality products are more expensive to produce than low quality products and the buyer cannot directly observe quality properties. In this situation, there can be a lack of effort on the part of the supplier. That is, a supplier promises to exert effort to enhance quality but does not do so. Because quality measurement is subject to diagnostic and sampling error, a buyer cannot be sure that a supplier has fulfilled its promise to deliver quality food inputs.

What contract drives growers to act in the interest of processors? The principal-agent model is without question a

dominant theoretical framework in the study of incentives and contracts. In order to provide an incentive for the agent to make an appropriate effort level, much of the literature on principal-agent relationships has proposed a share contract based upon verifiable measures of performance as the optimal scheme compensation under moral hazard [1, 2].

Despite the importance of this outcome-based performance contract for some agricultural commodities such as fresh fruit and vegetables [3], for others the use of this type of contract is rarely observed. A convincing evidence of this statement is present in viticulture, where share contracts are rarely used. Thus a central question, and one which will be the focus of this paper, is to explain why share contracts are used in certain situations but not in others.

To answer this question it is worth reminding that a common assumption adopted in the standard moral-hazard literature is that the principal is passive as far as production is concerned. In many principal-agent relationships, however, the principal do have some choice variables (e.g., local advertising, sales effort and similar variables) that substantially affect the product's performance and hence, the price that consumers are willing to pay. Then there is a double moral hazard problem that surprisingly many previous studies have ignored. Exceptions include [4] y [5].

To fill this gap, we study the characteristics of share contracts for a given principal-agent relationship. We consider a risk-averse agent who not only he makes an effort in input quantity, but also in input quality. On the other hand, a neutral-averse principal takes actions that also affect the output quality. Given that their efforts are unobservable by both parties, there is a double moral-hazard situation in which both parties participate in the final quality perceived by the demand. While the case of the both parties being subject to moral hazard due to supplying unobservable efforts have been considered in the literature, we believe that our specification is new in the literature and more realistic since agents often supply both efforts in quantity and quality. However, the traditional double moral hazard models only include an effort by the agent.

Using this generalized double moral-hazard model, we formally prove that when the processor contributes to the final quality in terms of processing and marketing efforts, the outcome-conditioned share contract generally weakens

the grower's incentive to make his effort in quality. This result helps resolve the anomaly mentioned earlier.

The remainder of the paper is divided into three sections. The following section sets up the model of double moral hazard using this generalized framework. We then carry out a simulation exercise to understand the choice of share contract under a wide variety of circumstances and show the main results. A final section presents a discussion of the implications of the study and suggestions for future research.

## II. THE MODEL AND ASSUMPTIONS

We develop here a generalized double-sided moral hazard model for analyzing a general linear contract for sharing an outcome between a grower and a processor. The quality output depends on the effort levels of both the grower and processor who are both subject to moral hazard.

To illustrate the proposed methodology, the following case is analysed where both parties maximize a constant absolute risk aversion (CARA) utility function and the stochastic variables are assumed to be normally distributed. Following [6] the problem can be handled as an E-V problem. The detailed assumptions of the model are as follows:

The primary producer: The grower, risk-averse, contributes to the input quantity,  $\bar{q}$ , and input quality,  $\bar{s}$ , in terms of production efforts in both variables,  $q$  and  $s$  respectively, according to:  $\bar{q} = q$  and  $\bar{s} = s\mu_s$ , where  $\mu_s \sim N(1, \sigma_s)$ . Randomness of quality is imputable to its imprecise definition and imprecise measurement.

The processor: The processor, risk-neutral, transforms the raw material (input) into finished product (output). We assume that there are not losses of quantity in the transformation process. That is, the quantity output,  $\bar{Q}$ , will be defined as  $\bar{Q} = f(\bar{q}) = \lambda\bar{q} = \bar{q}$  where  $\lambda = 1$ . Likewise, we further consider that there are no raw material processing costs. Although these unrealistic assumptions are made for the purpose of analytical simplification, they do not take away from the applicability and implications of the model.

This paper assumes that a grower contributes to the final quality output,  $\bar{S}$ , in terms of his effort in input quality,  $s$ , and the processor in terms of processing and marketing

efforts,  $b$ , according to  $\bar{S} = \theta b + s$ , with  $\theta \geq 0$ . The efficiency factor  $\theta$  captures the relevance of the processor's effort in the final quality perceived by the final customer. Since efforts are mutually imperfectly observed and their implication on final output can only imperfectly measured, there is scope for opportunism on both sides.

The price function: the demand function for the processor output is assumed to be linear in its own price,  $P$ , and quality,  $\bar{S}$ :

$$\bar{Q} = f(\bar{S}, P) = \lambda_1 \bar{S} - \lambda_2 P \quad \text{with } \lambda_1 > 0, \lambda_2 > 0 \quad [1]$$

From (1), the inverse demand function facing the processor is given by:

$$P = f(\bar{S}, \bar{Q}) = a\bar{S} - b_1\bar{Q} \quad \text{with} \\ a = \lambda_1/\lambda_2, \quad b = 1/\lambda_2 \quad [2]$$

The cost function: There is a cost associated with each effort because it is unpleasant and forgoes the opportunity to undertake other activities. Input production costs,  $c$ , are a function of the efforts in quantity and quality. As is traditionally the case in models of this kind, we assume marginal production costs regardless of quantity effort volume and quadratically in line with the given level of quality effort [7]:

$$c = c_1 \frac{qs^2}{2} \quad \text{with } c_1 > 0 \quad [3]$$

And similar to the models of franchise, we assume that the private cost of effort for the processor is the same as for the grower. Then, the processor's cost,  $C$ , will be:

$$C = c_1 \frac{Qs^2}{2} \quad \text{with } c_1 > 0 \quad [4]$$

### The double moral hazard model

According to principal-agent theory, when the risk-averse agent faces a trade-off between the provision of incentives and risk sharing, an outcome-conditioned sharing contract can be a second-best pay scheme [8, 9]. This implies a two-part compensation scheme,  $w$ , consisting of (i) a fixed payment,  $\alpha$ , that is independent of the observed outcome, and (ii) an incentive payment that amounts to a positive share,  $\beta$ , of the publicly observable outcome:

1. <sup>1</sup> Given the processor is risk-neutral, we omit the presence of uncertainty in his effort because it does not affect the final results of the model.

$$w = \alpha + \beta xP \quad [5]$$

We consider revenue like performance indicator because it has been demonstrated [10] that when the principal has a greater potential to impact on retail demand due to branding revenue sharing contracts are better to provide appropriate incentives than profit sharing contracts.

When the principal also provides efforts which affect the outcome, the incentive provision for both the agent's action and the principal's own effort level must be taken into account when designing the agent's incentive scheme. In this way, the processor chooses the parameters of the incentive scheme,  $\alpha$  and  $\beta$ , to maximize her expected profit subject to the constraints that both, processor and grower, choose individually their efforts to maximize their certainty equivalent and that the grower attains at least his reservation utility,  $\bar{U}_i$ , i.e.,

$$\underset{\alpha, \beta}{\text{Max}} CE^{\text{Processor}} = (1 - \beta)QP - C - \alpha \quad [6]$$

s.t.

$$\underset{q, s}{\text{Max}} CE^{1^{\text{st}} \text{Producer}} = \alpha + \beta QP - c - \frac{\rho}{2} \sigma_{\beta QP}^2 \quad [7]$$

(Grower's incentive compatibility constraint)

$$\alpha + \beta QP - c - \frac{\rho}{2} \sigma_{\beta QP}^2 \geq U_{\min} \quad [8]$$

(Grower's reservation constraint)

$$\underset{b}{\text{Max}} CE^{\text{Processor}} = (1 - \beta)QP - C - \alpha \quad [9]$$

(Processor's incentive compatibility constraint)

We solve the optimization problem in equations (6-9) sequentially. First, we determine the effort choice made by the processor:

$$\underset{b}{\text{Max}} CE^{\text{Processor}} = (1 - \beta)Q(a(\theta b + s) - b_1Q) - c_1 \frac{Qb^2}{2} - \alpha \quad [10]$$

The optimal solution to the processor's decision on effort in equation [10] is

$$\frac{\partial CE^{\text{Processor}}}{\partial b} = (1 - \beta)Q\theta - c_1 Qb = 0 \quad b = \frac{(1 - \beta)a\theta}{c_1} \quad [11]$$

Second, given the processor's choice, we determine the efforts in quantity and quality that maximize grower's certainty equivalent:

$$\underset{q, s}{\text{Max}} CE^{1^{\text{st}} \text{Producer}} = \alpha + \beta Q(a(\theta b + s) - b_1Q) - c_1 \frac{Qs^2}{2} - \frac{\rho}{2} \beta^2 Q^2 a^2 s^2 \sigma_s^2 \quad [12]$$

First-order necessary conditions for maximizing [12] with respect to  $q$  and  $s$  yield:

$$\frac{\partial CE^{1^{\text{st}} \text{Producer}}}{\partial q} = \beta(a(\theta b + s) - 2b_1q) - c_1 \frac{s^2}{2} - \rho \beta^2 q a^2 s^2 \sigma_s^2 = 0 \quad [13]$$

$$\frac{\partial CE^{1^{\text{st}} \text{Producer}}}{\partial s} = \beta qa - c_1 qs - \rho \beta^2 q^2 a^2 s \sigma_s^2 = 0 \quad [14]$$

The reaction functions derived from the above maximization problems are:

$$q = \frac{\beta(a(\theta b + s)) - c_1 \frac{s^2}{2}}{\beta(2b_1 + \rho \beta a^2 s^2 \sigma_s^2)} \quad [15]$$

$$s = \frac{\beta a}{c_1 + \rho \beta^2 q a^2 \sigma_s^2} \quad [16]$$

Substituting the previous expressions,  $q = f(\beta)$  and  $s = f(\beta)$ , into equations [6] and [8] and choosing  $\alpha$  and  $\beta$ , Kuhn-Tucker conditions reveal a boundary solution with  $CE^{1^{\text{st}} \text{processor}} = U_{\min}$ , in [8] implying:

$$\alpha = -\beta QP + c + \frac{\rho}{2} \sigma_{\beta QP}^2 + U_{\min} \quad [17]$$

Finally, substituting [17],  $b = f(\beta)$ ,  $q = f(\beta)$  and  $s = f(\beta)$  into [6] and maximizing with respect to  $\beta$ , it may be obtained the value of  $\beta$  optimal.

### III. SIMULATION

The principal-agent model of [1] has been widely used to analyze various issues in economics. However, it usually remains impossible to explicitly solve the first-order conditions that define the decision variables' values in the

share contract. Quantitative applications of the principal-agent model therefore require numerical solutions.

In this section, we carry out a simulation exercise with a wide range of scenarios, and selected the examples below as being representative of the behaviour we found. We solve Mathematica<sup>2</sup> to solve the model, and use Matlab to draw the planes using the data produced by Mathematica. We initially choose the following parameters:  $a = 1$ ,  $b_1 = 0.00001$  and  $c_1 = 1$ . It should be noted that these initial values are used for convenience and has no special significance here and that simulation results do not change substantially if different values for a, b1 and c1 are used.

In order to capture the effect of principal's effort on quality, a key aspect in this paper, we amend the effort/quality relationship to include not only the grower's effort (agent's), but also processor's effort (principal's),  $\bar{S} = \theta b + \bar{s}$ , where the parameter  $\theta > 0$  is a proxy for the importance of the principal's effort.

Then, we have three free parameters in our model: the processor's efficiency factor,  $\theta$ , the grower's coefficient of absolute risk aversion,  $\rho$ , and the variance of input quality,  $\sigma_s^2$ . These latter two parameters can be jointly identified,  $\rho\sigma_s^2$ , as both act on the producer's risk premium in a similar fashion.

To illustrate the analysis it may be worthwhile to consider a first scenario in which the agent is risk-neutral. We then repeat the analysis in an environment with a risk-averse agent.

#### *a) First scenario: risk-neutral agent and principal*

As a benchmark for comparison, we first compute the solution to the agency problem assuming risk neutral agents. For the purposes of the simulation, we consider a fairly wide range of 0 to 0.9, in steps of 0.1, for the efficiency factor  $\theta$ .

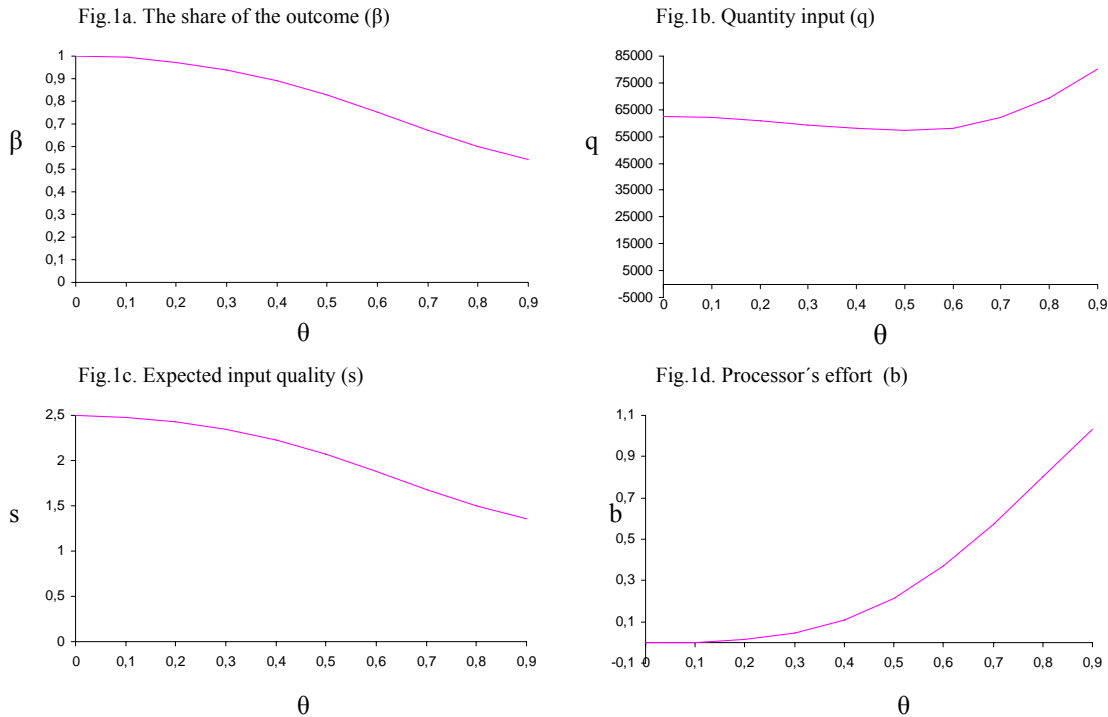
In figure 1a we consider how the share of the outcome,  $\beta$ , varies as a function of the importance of the principal's effort,  $\theta$ . Consistent with the agency theory, the value of  $\beta$  is maximum at  $\theta=0$  when the processor has no interest in the quality and its value is 1, which implies that the agent receives all revenue. Likewise, as franchise contracting models predict, the share of the outcome  $\beta$  is decreasing in  $\theta$ . This result was supported by other studies, for example [11], [12]. All of these papers obtain that when franchisor inputs are more important, less vertical separation is observed, as predicted.

Similarly, figure 1b shows as the grower's effort in quantity varies as the importance of the principal's effort increases. In this same interval of  $\theta$ , [0-0.9], the quantity input curve seems a smooth, gradual and a bit concave, with a minimum at  $\theta=0.5$ .

Figures 1c and 1d involve the quality efforts of both the agent and the principal, respectively. The shapes of these efforts as a function of the efficiency factor,  $\theta$ , are considered here. Strikingly, when processor's effort is more important in quality, the grower makes less effort. Conversely, the processor's effort in quality is increasing in  $\theta$ , as it can be deduced from equation [10].

<sup>2</sup> The Mathematica commands are available from the authors on request.

Figure 1. Double moral-hazard with risk-neutral agent



*b) Second scenario: risk-averse agent and risk-neutral principal*

In this second scenario parameter estimates were obtained searching over an equally spaced grid of 100 values for each parameter ranging from  $[0, 0.9]$  for  $\theta$  and  $[0, 0.00009]$  for  $\rho\sigma_s^2$ .

Figure 2a shows that as the producer's risk premium (i.e. risk aversion or quality variance)  $\rho\sigma_s^2$  increases, given the value of the  $\theta$ , the share of the outcome,  $\beta$ , decreases. This result supports the prediction made by the principal-agent framework with risk-averse agents (for [13]). In general, an increase in the importance of principal's effort, given the value of the agent's risk premium, will decrease the incidence of  $\beta$ . However, this result is not robust when the efficiency factor converges to zero, in which case the value of  $\beta$  increases.

Analogously, figure 2b represents the behaviour of the input quantity as a function of the efficiency factor,  $\theta$ , and

risk premium,  $\rho\sigma_s^2$ . When  $\theta$  converges to zero, an increase in  $\rho\sigma_s^2$  will decrease the grower's effort in quantity. However, when  $\theta$  increases diverging from zero, the input quantity increases and moreover the negative incidence of an increase in  $\rho\sigma_s^2$  on input quantity goes down.

Figures 2c and 2d involve the quality efforts of both the agent and the principal, respectively. The planes of these efforts as functions of the efficiency factor,  $\theta$ , and risk premium,  $\rho\sigma_s^2$ , are considered here. By observing both graphs, it is easy to deduce that in most cases both efforts vary in opposite sense. That is, when the efficiency factor and/or the risk premium increase, processor's effort increases; on the contrary, primary producer's effort in quality decreases. An exception to this result appears when  $\theta$  converges to zero, in which case both efforts increase as  $\rho\sigma_s^2$  increases.

The simulation exercise throws some light on the relative importance of including in the model that the

agent makes both efforts in quantity and quality, often ignored in previous analysis. As the simulation exercise has demonstrated, when the importance of the principal's effort increases (the only exception is when  $\theta$  converges to zero), the share contract disincentivates the agent to make an effort in quality in favour of effort in quantity.

The results of this simulation exercise could explain why other contracts different from share contracts are used in sectors in which the quality is a key competitive variable. In many products highly differentiated, it is well known that the "lemon problem" exists in their markets. That is, consumers don't know automatically the quality of the product, or the accuracy of the information supplied about the product's characteristics. Consequently, this observed asymmetric information

between processors and consumers can impair the functioning of the product market [14]. The solution carried in many industries has been to create quality signals by the processors. An illustrative example is the wine market, in which consumers rarely are able to distinguish wine's characteristics. Likewise, it is difficult to assess objectively the grape quality [15]. Then, wineries have made an important effort in creating quality signals such as the wine brand [16], exhibition awards [17], expert wine tastes [18,19] and winery visitation [20]. Consistent with our model, it could explain why bottle-price conditioned contracts are infrequently (if ever) applied in the contracting relationship between a grape grower and a winery over the supply of fresh grapes for wine production.

Figure 2. Double-moral hazard model with risk-averse agent

Fig.2a. The share of the outcome ( $\beta$ )

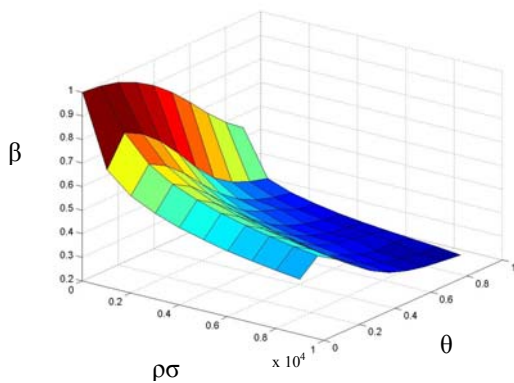


Fig.2b. Quantity input (q)

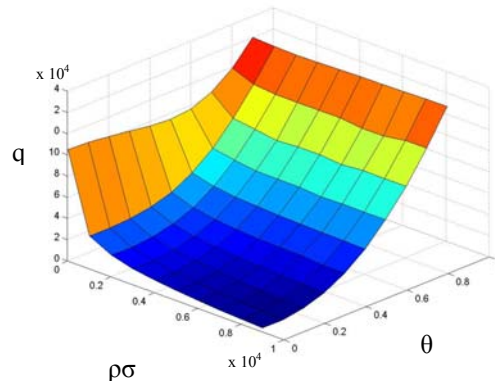


Fig.2c. Expected input quality (s)

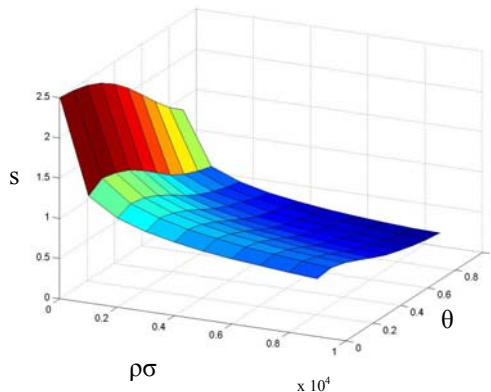
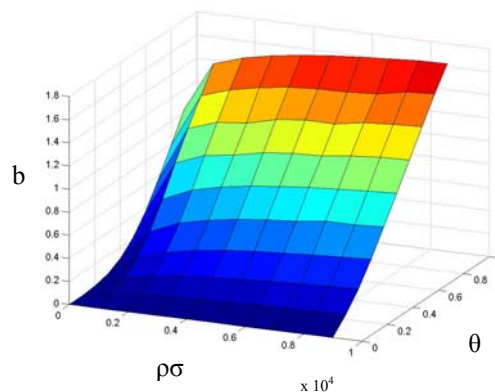


Fig.2d. Processor's effort (b)



#### IV. CONCLUSIONS AND IMPLICATIONS

There is no doubt that firms have increasingly to deal with competitive markets in which quality has become a decisive aspect for competitiveness.

To establish quality in final products it is important to consider the quality of raw materials, produce and structure of the value chain. However, the market for input quality is characterized by imperfect information, which generates moral hazard problems.

This paper combines agency theory with evidence from actual contracts. Although most standard moral hazard models present the conclusion that only share contracts can be optimal in this scenario of imperfect information, the supporting evidence in some sectors has been weak. From this perspective, the primary role of this paper is to understand and rationalize this practice.

Based on the study on agency theory and an examination of the relationship between growers and processors, we have developed a double-moral hazard model to examine the implications in terms of quality derived from outcome-conditioned share contracts. Although this paper is related closely to the classic paper of [13], there is an important aspect that differentiates the model from previous analysis of moral hazard. This paper considers jointly incentives, risk premium, double moral-hazard, quantity and quality in a single model.

We show that under the traditional moral hazard models the consideration of quantity and quality separately may lead to incorrect conclusions. That is, traditional agency models predict that agents respond to incentive contracts by improving their effort in quality [21]. However, with the help of a simulation exercise it has been demonstrated that when the processor takes actions that affects the product's quality perceived by the customer, this contract weakens the primary producer's incentive to make his effort in quality.

It is interesting to note that, although the outcome-conditioned share contract is not explicitly found in practice for some markets, we implicitly observe it in modes of governance in which the primary producers have property rights. In particular, the compensation scheme underlying in the mode of governance of producers organized through co-operatives corresponds to the outcome-conditioned incentive contract. Since the co-operative allows risk-averse producers to participate in decision-making regarding commercial activity, the

problem associated with the informative asymmetries diminishes. Consequently, the impact of the double moral hazard problem also diminishes. Despite this advantage, the cooperative faces important problems such as the free-riding.

One limitation of this analysis is that it is not a dynamic analysis. It does not consider the possibility of a relationship between principal and agent over the time, and hence, it does not take into account reputation effects of insincere behavior. However, in practice, processors tend to contract repeatedly with the producers whom they rely on. This limitation will be considered in future research efforts.

However, because the contract that we examine have features common to other two-party contracts, our findings have implications beyond share-contract and should be of broad interest.

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