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Contracts in the agricultural sector with moral hazard and hidden information: speculations, truths and risk-sharing

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Francisca Jiménez Jiménez*

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Departamento de Economía Aplicada
Universidad de Jaén
Paraje las Lagunillas s/n
23071 Jaén
email: fjimenez@ujaen.es

* Área de Fundamentos del Análisis Económico. Departamento de Economía Aplicada. Universidad de Jaén.

CONTRACTS IN THE AGRICULTURAL SECTOR WITH MORAL HAZARD AND HIDDEN INFORMATION: SPECULATIONS, TRUTHS AND RISK-SHARING

Francisca Jiménez Jiménez
Economic Theory Unit, Dpt. Of Economics, U. of Jaén

Paraje Las Lagunillas s/n, 23071 Jaén, Spain.
Tel. +00-34-953-212297, Fax. +00-34-953-212222, jimenezf@ujaen.es

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ABSTRACT. The aim of this paper is to analyse the nature of a two-party contractual relationship between an olive oil co-operative society and a producer in the principal-agent framework. In this model, the principal (co-operative firm) delegates to the agent (producer) responsibility for the production of the olive oil. In general, the co-operative firm can't fully observe (or at least cannot verify) the producer's actions. In this context, we analyse the design of an incentives system to the producer to obtain good quality olive and the producer's decisions are brought as far as possible into alignment with co-operative firm wishes (in the quality terms), without the necessity of enforcing costly monitoring mechanisms. Our fundamental object is that the co-operative firm incentives the *quality* of the olive, and *not* the quantity, such as the actual payoffs system does.

KEYWORDS: Optimal Contract, Moral Hazard, Incentives System.

1. INTRODUCTION

There are many economic relations where people may interact under conditions of asymmetric information, and in particular moral hazard (hidden action), in which both parts share risks and where individuals might cheat after signing the contract (e.g. Ross, 1973; Shavell 1979; Grossman and Hart 1983). In the wide literature referenced to incentives systems, it is easy to observe examples, as the relationship stabilised between an insurance company and an insured person, a shareholder and a manager, a lawyer and the client, a employer and the employed. Inclusive, in the public finance context there are studies about the design of a tax that maximises the net public incomes, accepting that the workers might work less if this marginal tax is so high.

In this paper, we look at the issues raised by moral hazard problems in the specific case of a co-operative society and a producer of olive. A principal-agent framework is set up to discuss this relationship. The principal (co-operative firm) delegates to the agent (producer) the harvest production. After that, the agent claims a return for his efforts. This is the basis for the 'contract' between two people. The main feature of this relation use to be that only one part, the producer, influences on the probability distribution of the outcome, such that this outcome is the unique observable variable by the co-operative society to design the contract. We could consider the case where the principal has additional information about agent's effort. This question was initially studied by Harris and Raviv (1976, 1978a) and, then, by Holmström (1979) and Shavell (1979). In this paper, we suppose that this information is not available by the principal.

In this market, the *real problem* is that the most of the co-operative firms don't make quality measures of the olive delivered by the producer but the performance (that is, quantity of oil in each kg. of olive). So, he[1] hasn't any incentive to obtain the best quality olive, since his income doesn't depend on this variable, and the co-operative receives lower incomes in the market. *Our problem* is then to design some form of contract such that: 1) the producer exerts the optimal effort in each nature state, that is, taking into account the different environmental conditions in which the activity is undertaken; 2) he delivers the good quality olive to the co-operative without enforcing any costly monitoring mechanism.

This model is an attempt to extend the results obtained by Holmström (1979). This paper is organised as follows. In section 2, we summarise the most important

[1] We shall refer to the co-operative society as 'she' and to the producer as 'he'.

characteristics of the olive oil market in origin and the effectiveness of the actual transfer system to get better quality oil. In section 3, we present a hybrid principal-agent model, that is, the co-operative can't observe the agent's action (moral hazard) neither the specific conditions in which the olive production is realised (hidden information). In section 4, we solve the model under some particular hypothesis. The section 5 analyses the main results and, finally, the conclusions mention the possible extensions or research trends of this model.

2. EMPIRICAL OBSERVATIONS

2.1. Background information

We have studied a group of olive oil producers that operate in the south of Spain, concretely in Jaén. These producers belong to different olive oil co-operatives, whose behaviour is very similar between them. In terms of institutional characteristics, all oil co-operatives have a partial pooling system. They maintain the sharing of income obtained from the oil sold at the price set by negotiation between co-operatives and traders (oil market in origin), as an increasing function of the quantity of oil delivered by the producer to the co-operative. Consequently, the proportion of the total income that a particular producer receives is greater when his harvest is larger.

On the other hand, the social aim of an oil co-operative is to maximise the income of her members. This is equivalent to maximise her own net income and, then, distribute it between them. So, we're going to try to a co-operative as a benefits maximising firm.

About the skill of the producers, this is particular for each one. However, all of them have an increasing cost function with the level of effort. This variable[2] is very important for the quality of the oil. The harvest time, if the olive proceeds from the tree or from the floor or the harvest method are important factors that influence to the final quality. So, the producer's action has a decisive influence on the oil quality and, then, on the income that the co-operative will get in the oil market. There exists a positive relationship between the level of quality and the price of sold oil.

Other important aspect to note is that the co-operative doesn't realise measures of the quality because this is very costly; she only obtains "informative signals" through the price set.

[2] The effort undertaken by the producer is considered in a wide sense.

Finally, to note that, until now, the co-operative hasn't worried by the distribution of her product, neither if she might to obtain greater benefits offering better quality products. Generally, her behaviour has been oriented to the production, not to the market. Consequently, the income has been lower than what could have been.

2.2. Quality or Quantity Incentives

As we noted above, a producer receives a greater transfer if his oil harvest is larger. However, to analyse the effectiveness of this payoffs scheme from the point of view of the quality, it's necessary to consider the following facts:

In the production process of the oil there exists an optimal time of reap, t*. The quantity of oil contained in an olive increases until t*. After this time, it practically stays constant. However, the oil quality grows until t* but decreases after this moment. On the other hand, the level of effort is an increasing function of the production time until t* but decreasing after this one, since in this latter moment the only effort realised by the producer is the reap. So, he will try to undertake the reap of the harvest after t*, when the cost is lower (the olive is picked up more easily) and the oil production is maximum. So, this producer's action is negative to get better quality oil and limits the possibilities of obtaining a higher income in the negotiation between the co-operative and traders in the oil market.

In this manner, if the co-operative wants to incentive to the producer to exert a higher effort in getting better the quality, she will have to change this transfer scheme.

3. THE MODEL

We consider a two-party contractual relationship between the co-operative (principal) and the producer (agent). This one acts on behalf of the co-operative firm in undertaking the olive production. In this context, the producer's action is only imperfectly observable by the co-operative. Hence there is the possibility of postcontractual opportunism by the agent since the two can't contract on behaviour by the agent. The co-operative firm is likely to observe the outcome of the agent's action (the harvest), which allows her at least to make some inference about what the unobserved actions might have been. So, the problem facing the co-operative firm is the design and the offer of the optimal contract to the producer, who will have to decide if accepts it or not. We suppose that all co-operative firms situated in the same area are in symmetric positions, such that the producer can't go to other firm to deliver his harvest if he doesn't accept the initial contract. On the other hand, he might not deliver it to other firm situated in a different area because the transportation costs are very high. So, the alternative will be to rent his olive land to a third person.

We're going to analyse the model with an unique producer and considering that the co-operative acts as a firm. Let q be a stochastic variable that represents the gross income of the co-operative firm obtained by the output of the production process (market value of the quantity of received oil). This result q is the joint product of the producer's effort level, a, and of uncertainty or random 'nature state', θ. Both participants know the prior probability distribution of this random variable. So, given a, the probability distribution of θ induces to a conditional distribution in q through $q = q(a,\theta)$. So, the correspondence between agent's action, a, and observed outcome, q, is usually not deterministic, since the outcome may be affected by all sorts of other factors as well (e.g. luck). Let $f(q/a)$ be its probability density function. We assume that the support of this distribution is independent of a. This is the approach presented by Mirrless (1974, 1976). In this manner, the probability distribution of q is influenced by a variable a that is controlled by the producer and not observable by the co-operative firm. We suppose that a greater effort level produces a better result, regardless the nature state, and a favourable conditions (a higher θ) too. Then,

$$q = q(a,\theta) \quad \text{such that} \quad q_a > 0 \;,\; q_\theta > 0$$

On the other hand, we suppose an increasing and concave relation between the quality and the effort level. So, a greater quality is associated to a higher effort level and, then, to a better result, q.

Payoffs' functions:

We consider that the producer is risk averse and the co-operative is risk neutral. Their utility functions are given by

Co-operative: $q(a, \theta)$- $s(q(a, \theta))$, where $s(q(a, \theta)$ is the payment offered to the agent.

Producer: $U(s(q(a, \theta),a)=u(s(q(a, \theta))-c(a)$, a von Neuman-Morgenstern expected utility function, additively separable to indicate that the risk aversion doesn't vary with the effort. This utility function is concave in $s(q(a, \theta)$ and convex in a: $u'(.)>0,\ u''(.)<0$

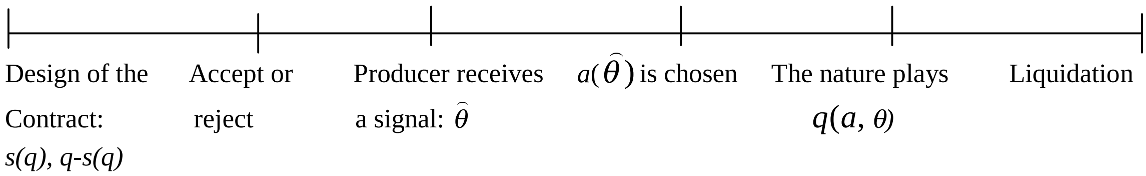
$c'(.)>0,\ c''(.)>0$

The function *c(a)* represents the disutility or cost of agent's action. This function is strictly increasing, continuously differentiable and convex.

The utility function of the co-operative yields her net income. This one doesn't depend directly on the effort level either the nature state, only on *q*.

In this model, we assume that the co-operative has all the bargaining power[3] such that she will try to maximise her expected utility. She'll design the contract making some inference about what the unobserved actions might have been. To ensure the producer's participation, the co-operative must give him in expected terms a level of utility at least so great than that which he could obtain outside the relationship. Let $\underline{U}$ be this level, which is exogenous in the model.

The *timing* of this model is:



This timing represents a sequential play whose solution is given by the concept "Bayesian Subgame Perfect Nash Equilibrium" . Concretely, we have a hybrid model where exists moral hazard and adverse selection. The moral hazard problem is given by the combination of the unobservability of the producer's action and of the uncertainty about the outcome, *q*. On the other hand, the hidden information problem exists because the producer has private information about the conditions under which he'll undertake the activity and, then, will choose his action taking into account this additional information. The co-operative only knows the outcome, *q*, and the probability distribution of the signals, p($\hat{\theta}$). In general, a good harvest indicates a higher effort level under, for example, non-favourable conditions than favourable.

[3] This hipothesis derives from the prior consideration about symmetric co-operatives situated in the same area and high transportation costs to deliver the harvest to other co-operative situated in a different area.

Let $\hat{\theta}$ be the signal received by the producer. We suppose that there exist *m* possible signals with probability function p($\hat{\theta}_j$), j=1...m. This distribution is common knowledge.

As we noted above, to solve this problem we're going to apply the approach of Mirrless (1974, 76), who considers *q* as a stochastic variable with a distribution function *F(q/a)* parameterised by the producer's action, given the distribution of *θ*. As $q_a > 0$, then $F_a(q/a) < 0$, that is, a greater effort decreases the probabilities of obtaining worse outcomes. If we suppose that for all *a*, $F_a(q/a) < 0$ for each *q*, then an increase in *a* generates an improvement in *q* in the first-order stochastic dominance sense, that is, $F(q/a_1) \leq F(q/a_0)$ for each q, and $a_1 > a_0$.

The optimization problem is written as

$$\underset{a,s(q)}{Max} \qquad E[q(a,\theta) - s(q(a,\theta))]$$

$$s.a. \qquad E[u(s(q(a,\theta))) - c(a)] \geq \underline{U} \qquad \text{(Participation Constraint)}$$

$$\forall \hat{\theta}_j,\ j = 1...m, \quad a^* \in \arg\, max\, E[u(s(q(a,\theta)) - c(a)] \qquad \text{(Incentive Compatibility C.)}$$

$$CPO: \int u(s(q))\, f_a(q/a(\hat{\theta}_j))dq - c'(a) = 0$$

The participation constraint represents the necessary condition to ensure us that the producer accepts the contract and obtains his reserve utility $\underline{U}$, at least.

On the other hand, the incentive compatibility constraint say us that the co-operative takes into account that when the producer faces with a transfer function *s(q(a, θ)),* he chooses the action that is in his best interest. As *a* is a continuous variable, we have to apply the first-order condition approach, that is, replacing the incentive compatibility constraint by the CPO of this maximization problem .

We can observe that the participation constraint is concave in *s*(.) and *a*, since *c(a)* is convex by hypothesis.

The necessary and sufficient condition to the incentive constraint to be concave in *a* is that *c'(a)* is convex, that is, c'''(a) ≥ 0.

4. MODEL SOLUTION

To simplify, we're going to consider only two signals of information, that is, $\hat{\theta}_j$, j=1,2, where $\hat{\theta}_1$ are non-favourable conditions and $\hat{\theta}_2$ favourable conditions. Let *p* be the prior probability of adverse information is received by the producer and, then, (*1-p*) the prior probability of good information.

The optimization problem can be rewritten as

$$\underset{a,s(q)}{Max} \quad p\left[\ \int (q-s(q))\, f(q/a(\hat{\theta}))dq\ \right] + (1-p)\left[\ \int (q-s(q))\, f(q/a(\hat{\theta}))dq\ \right]$$

$$s.a. \quad p\left[\ \int u(s(q))\, f(q/a(\hat{\theta}))dq - c(a)\ \right] + (1-p)\int u(s(q))\, f(q/a((\hat{\theta}))dq - c(a)\ \right] \geq \underline{U}$$

$$p\left[\ \int u(s(q))\, f_a(q/a(\hat{\theta}))dq - c'(a)\ \right] = 0$$

$$(1-p)\left[\ \int u(s(q))\, f_a(q/a(\hat{\theta}))dq - c'(a)\ \right] = 0$$

Let λ be the lagrange multiplier associated to the participation constraint; $\mu(\hat{\theta}_1)$ the multiplier associated to the first incentive constraint; $\mu(\hat{\theta}_2)$ to the second incentive constraint, and *L* the lagrangian of the problem. So, the first-order conditions are written as

$$\frac{\partial L}{\partial s(q)} = -pf(q/a) - (1-p)f(q/a) + \lambda\left[f(q/a)u'(s(q)) + (1-p)f(q/a)u'(s(q))\right]$$
$$+\mu(\hat{\theta}_1)pf_a(q/a)u'(s(q)) + \mu(\hat{\theta}_2)(1-p)f_a(q/a)u'(s(q)) = 0 \qquad [1a]$$

$$\frac{\partial L}{\partial a} = \int f_a(q/a)(q-s(q))dq + \lambda\left[\int f_a(q/a)u(s(q))dq - c'(a)\right] + \mu(\hat{\theta}_1)p\left[\int\ f_{aa}(q/a)u(s(q))dq\ -\right.$$
$$\left. - c''(a)\ \right] + \mu(\hat{\theta}_2)(1-p)\left[\int f_{aa}(q/a)u(s(q))dq - c''(a)\right] = 0 \qquad [2]$$

$$\frac{\partial L}{\partial \lambda} = \int f\ (q/a)u(s(q))dq - c(a) - \underline{U} = 0 \qquad [3]$$

$$\frac{\partial L}{\partial \mu(\hat{\theta}_1)} = p\left[\int f_a(q/a)u(s(q))dq - c'(a)\right] = 0 \qquad [4]$$

$$\frac{\partial L}{\partial \mu(\hat{\theta}_2)} = (1-p)\left[\int f_a(q/a)u(s(q))dq - c'(a)\right] = 0 \qquad [5]$$

If we aggregate some terms in [1a] we have

$$-f(q/a)+\lambda f(q/a)u'(s(q))+u'(s(q))\left[\mu(\hat{\theta}_1)pf_a(q/a)+\mu(\hat{\theta}_2)(1-p)f_a(q/a)\right]=0$$

And dividing by *u´(s(q))f(q/a)* we obtain

$$\frac{1}{u'(s(q))}=\lambda+\frac{1}{f(q/a)}\left[\mu(\hat{\theta}_1)pf_a(q/a)+\mu(\hat{\theta}_2)(1-p)f_a(q/a)\right] \quad [1b]$$

If we observe [1b] we can see that *s(q)* will depend on the form of $\frac{f_a(q/a)}{f(q/a)}$. As *u´(s(q))* is a decreasing function, the transfer received by the producer, *s(q),* will increase with *q* only under the additional assumption that $\frac{f_a(q/a)}{f(q/a)}$ is an increasing function of *q*. Intuitively, observing higher values of *q* means that it is more plausible that the action taken had been greater. Then, the payoffs' function of the producer will be increasing only if the outcome tends to be better when he realises a higher effort level.

To obtain a *particular solution* more intuitive, we're going to introduce the following specific functions:

$$u(s(q))=2\sqrt{s(q)} \quad ,\forall s(q)>0, \quad donde \quad u'(.)=\frac{1}{\sqrt{s(q)}}\geq 0, \quad u''(.)=-\frac{1}{2s(q)\sqrt{s(q)}}\leq 0$$

$$c(a)=e^a \quad , donde \quad c'(.)>0, \quad c''(.)>0$$

$$q \sim LN(a,\sigma^2)$$

With this probability distribution for *q*, parameterised by the effort level, we assure that $\frac{f_a(q/a)}{f(q/a)}$ is increasing in *q*. Concretely,

$$\left.\begin{array}{l} f(q/a)=\frac{1}{\sqrt{2\pi}\sigma q}e^{-\frac{1}{2}(\frac{\ln q-a}{\sigma})} \quad , \quad q>0 \\ f_a(q/a)=\frac{\ln q-a}{\sigma^2}\frac{1}{\sqrt{2\pi}\sigma q}e^{-\frac{1}{2}(\frac{\ln q-a}{\sigma})^2} \end{array}\right\} \quad \frac{f_a(q/a)}{f(q/a)}=\frac{\ln q-a}{\sigma^2}$$

On the other hand, it seems rationale to think that although the producer realises the minimum level of effort and the conditions are very disfavourable, the co-operative will always receive a minimum but positive quantity of harvest, q_{min}>0. So, for all *q*>0, *s(q)*>0.

If we substitute these specific functions in [1b], we obtain the final expression for our transfer function,

$$\sqrt{s(q)} = \lambda + \mu(\hat{\theta}_1)\, p\left(\frac{\ln q - a}{\sigma^2}\right) + \mu(\hat{\theta}_2)(1-p)\left(\frac{\ln q - a}{\sigma^2}\right) \Rightarrow$$

$$s(q) = \left[\lambda + \mu(\hat{\theta}_1)\, p\left(\frac{\ln q - a}{\sigma^2}\right) + \mu(\hat{\theta}_2)(1-p)\left(\frac{\ln q - a}{\sigma^2}\right)\right]^2 \qquad [6]$$

5. INTERPRETATION

Optimal risk sharing under symmetric information requires complete insurance for the producer when the co-operative is risk neutral. That is[4],

$$\frac{1}{u'(s(q))} = \lambda \;\Rightarrow\; s(q) = \lambda^2$$

Moreover, the producer's income will then be independent of his action. This would be the Pareto optimal solution in the case of complete information because if the producer doesn't choose the action specified by the co-operative, he will be detected and she will take a penalty large enough to inhibit the producer from taking an different action. However, if we try to apply this solution to our model with imperfect information, since the co-operative can't observe the agent' action, he will choose the level of effort that is most favourable to him, that is, the minimum. To lead the agent to choose a action more favourable to the co-operative, we must make his income depend on the only observable variable, the outcome *q*. Since this is stochastic, such an arrangement can't share risk optimally. We have considered that the support of the distribution of this variable is independent of *a*. Otherwise, the complete information allocation would be achieved in a trivial way because, in this case, the co-operative could detect with a positive probability any deviation from the action specified by her observing that the outcome realised *q* is not what it should be.

The expression showed in [6] has an intuitive interpretation with respect to increasing of the transfer function. Following to Holmström (1979), our distribution allocation is convex in *q*.

[4] This result derives from solving the optimization problem without the incentive compatibility constraint, such that now the co-operative observes and thus controls *a*.

The ratio $\frac{f_a(q/a)}{f(q/a)}$ shows the deviations from first-best solutions that are larger when this measure is large. Indeed, q is used as an informative signal concerning the value of a chosen by the producer. If this signal is less informative ($\frac{f_a(q/a)}{f(q/a)}$ lower) we certainly can't expect to induce much effort. However, if the signal is very informative ($\frac{f_a(q/a)}{f(q/a)}$ larger) the co-operative will be able to incentive more to the producer to realise the higher effort level. So, this ratio measures how inclined we are to think that the observed value q didn't come from a model whose value is the optimal a. This implies that the producer has to borne some responsibility of his action.

On the other hand, our transfer function [6] depends on the probability of $\widehat{\theta}_j$, j=1,2 is realised and on the effect that enforcing a marginal increase of $a(\widehat{\theta}_j)$ should have over the expected income of the co-operative, that is, $\eta(\widehat{\theta}_j)$. In general, for a given outcome received by the co-operative, a greater probability of receiving disfavourable information about the conditions in which the activity might be realised will determine a greater transfer to the producer because this acts as a signal of a higher level of effort have been undertaken[5].

6. CONCLUSION

We have studied the nature of a two-part contractual relationship under a principal-agent framework in a specific context: the design of an incentive system to get good quality oil. When the co-operative only observes the harvest delivered by the producer and doesn't realise any measure of its quality because this is a costly mechanism, the only contractual variable is the income received by the co-operative in the oil market. Since we have assumed a strictly increasing and concave relation between the quality and the level of effort and a positive relationship between this effort and the co-operative's outcome, a higher income is associated to a greater quality. So, a convex transfer system to the producer, such as it is analysed in this model, gets the co-operative's objective in the quality terms.

[5] If we assume that a higher effort level is always good for the co-operative, regardless the information received by the producer, that is, $\mu(\widehat{\theta}_j)>0$, j=1,2.

Of course, this analysis doesn't consider other interesting questions. An important aspect in this context would be to describe how a repeated co-operative-producer relation opens up new contract possibilities because the uncertainty tends to decrease. Other possible extension would be to analyse the way in which competition among many producers can be exploited by the co-operative or, inclusive, the consideration of many co-operatives and the constitution of the coalitions.

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