

The yield/quality trade-off and contractual choice

Marta Fernández-Olmos*
Jorge Rosell-Martínez**
Manuel Antonio Espitia-Escuer***

* M. FERNÁNDEZ-OLMOS. Department of Business Economics, University of Zaragoza, Zaragoza, Spain (e-mail: maferno@unizar.es).

** J. ROSELL-MARTINEZ. Department of Business Economics, University of Zaragoza, Zaragoza, Spain (e-mail: jrosell@unizar.es).

***M.A. ESPITIA-ESCUER. Department of Business Economics, University of Zaragoza, Zaragoza, Spain (e-mail: espitia@unizar.es).

Selected Paper prepared for presentation at the American Agricultural Economics Association Annual Meeting, Orlando, Fl, July 27-29, 2008.

Copyright 2008 by [Marta Fernández Olmos, Jorge Rosell Martínez, Manuel Antonio Espitia Escuer]. All rights reserved. Readers may make verbatim copies of this document for non-commercial purposes by any means, provided that this copyright notice appears on all such copies.

With the constant pressure to meet consumer demands and the need to be competitive, the question of quality is becoming a central point in agro-food chains organization. It is well known that quality is dependent upon the characteristics on inputs obtained from growers. But the action of the grower in producing a quality product is rarely observed by the processor, which generates moral hazard problems. Consequently, once a processor decides to acquire his input needs, a difficult question must be resolved. Should his input be acquired via contract with growers, or is it more efficient to buy it on the spot market?

The study of vertical relationships has come to be dominated by the principal-agent framework in agriculture (Otsuka, Chuma and Hayami, 1992). From this theory, it is well known that when measuring grower's effort is expensive, an incentive share contract can be appropriate second best in addressing underlying moral hazard problems (Stiglitz, 1974): it provides incentive but only by imposing risk on the grower. Thus, trading off the loss from too little incentive against that from too great risk bearing defines the optimal share contract (Bell and Zusman, 1976; Stiglitz, 1988).

In this approach, protecting input quality has been suggested to be a possible motivation for the use of contracts over the spot market alternative, especially in the presence of imperfect quality measurement (Hueth and Ligon, 1999a,b, 2001, 2002). In particular, Wolf, Hueth and Ligon. (2001) conclude that "contracting can be thought of as an organizational response to an increased demand for quality among increasingly discerning consumers".

Many studies of incentive contracts testing principal-agent framework have found support for this effect of incentive contracts on quality. Among the existing studies, Curtis and McCluskey (2003) analyze a sample of production contracts between potato processors and growers in the Columbia Basin area of Washington and Oregon. The

authors conclude that contracts are effective at increasing potato load quality over the spot market alternative. Carriquiry and Babcock (2004) consider that, in fact, contracts are the only way to induce a risk-averse grower to move away from producing a commodity to producing a high-value product.

In a recent paper, Alexander, Goodhue and Rausser (2007) examine an unusual dataset 14 tomato growers over 4 years to analyze the effect of incentive contracts on behaviour. They find that the processor obtains higher quality tomatoes from contracting than from spot purchases because growers respond to price incentives for quality.

Although these contributions have provided empirical support for the prevalence of incentive contracts to encourage growers to produce greater level of quality over the no contract alternative, it can not be concluded that the processor is better off offering price incentives than not contracting. In fact, Alexander, Goodhue and Rausser (2007) outline that some of their results suggest that offering those incentive contracts does not improve profits. Hence, there would be the possibility that the processor could be not acting optimally, as well as the possibility that their analysis would be mistaken on the basis of their methodology and data.

To identify the solution to this problem, the objective of this paper, we develop theoretically two models of vertical relationships, the incentive contract and the spot market, to implement in the food industry and inspired by previous studies (e.g., Stiglitz, 1974; Holmström, 1979; Shavell, 1979). These models analyze the efficiency of each mechanism by maximizing the total joint certainty equivalent for all processors and producers.

Most of the theoretical models examined in the previous literature suffer from limitations. Although it is well known that agricultural production often presents a

trade-off between the quality of a good and the quantity produced, little attention has been paid to their role in the principal-agent models. And in the standard vertical-product-differentiation models in which quantity and quality have been analyzed (for example, Gabszewicz and Thisse, 1979, 1980; Shaked and Sutton, 1982, 1983), it is implicitly assumed that these variables are independent choices. That is, as any set level of quality, a grower is free to produce as much as is desired. But in practice, it is more realistic to assume that higher quality comes at the cost of lower yields and vice versa. An exception is McCannon (2008), who pioneered a vertical-product-differentiation model to analyze the trade-off between the quality of a good and the quantity produced. Likewise, market prices are higher for high-quality than for lower quality product, but they are inversely related with the total market supply. However, often the models do not consider both issues to determine the price market. Why models have not included the previous aspects is likely attributable to analytical problems.

To fill these gaps, we develop a more general principal-agent model and then we use it to analyse the effects of the incentive contract and the spot market on quantity and quality. We generalize the models by considering the effect of the quality-quantity trade-off and competition.

Using this generalized model, we carry out a simulation exercise, and find that the study of the competence and the quality-quantity trade-off is fundamental to understanding the effects of governance mechanisms. Depending on the characteristics of the relationship involved, the incentive contract can provide a greater level of quality than the spot market but with a smaller level of efficiency. Hence, it would suggest that the actual contracts in use could be not optimal, although they provide greater levels of quality than the spot market. That is, processors could be not acting optimally. While such a result is apparent in the intuitions underlying many earlier papers (for example,

Alexander, Goodhue and Rausser, 2007), we also derive it formally from the optimizing behaviour of processors and producers.

The paper is structured as follows. In the following section, we set up both alternative models of governance choice (incentive contract and spot market) using this generalized framework. We then carry out a simulation exercise to understand the effects of governance mechanism under a wide variety of circumstances. The results of this exercise are used to explain many governance choice related issues. In the final section of this paper, the linkages between governance structures and agricultural policy are discussed.

Models formulation

An important contractual choice question is: Do incentives for quality ensure optimality? Agricultural activities are characterized by a substantial degree of uncertainty frequently in the form of hazardous natural environment, price risk and quality measurement errors (Hueth & Ligon, 1999a, b). In this context, the deterministic profit maximization model is inappropriate and another model should be adopted. A widely accepted framework for analyzing decisions making under risk, especially in agriculture, is the mean-variance approach (e.g., Myers & Thomson, 1989; Chavas & Holt, 1990; Pope & Just, 1991; Coyle, 1992; Andersson, 1995; Gaynor & Gertler, 1995; Duvois & Vukina, 2004), which allows concepts of uncertainty and attitude towards risk to enter the theoretical framework. To illustrate the proposed methodology, we assume that both parties, growers and processors, maximize a constant absolute risk aversion (CARA) utility function and the stochastic variables are normally distributed¹.

The grower and the processor's behaviour

It is assumed that n processors and m growers are symmetrically distributed in the village economy. As is often employed in empirical research in agriculture, growers are modelled as risk averse while processors are modelled as neutral risk landowners² (Allen and Lueck, 1999).

A quality-differentiated input is produced over a crop cycle which is the period of our analysis. The input depends on the effort levels of the grower, who contributes to its quantity, q , and quality, s , in terms of production efforts in these variables, x and e respectively, according to: $q = x$ and $s = e\mu_s$ where $\mu_s \sim N(1, \sigma_s)$. Quality uncertainty is an increasingly important issue in the agricultural sector (Chambers and King, 2002). Randomness of quality is imputable to risky environment and measurements errors. Symmetry restriction regarding the quality variance for all growers is also implemented. Although the quantity is supposed deterministic, the elimination of this uncertainty only implies under-representing the importance of income risk (Fraser, 2001). However, since the random variable is multiplicative, grower's risk premium is also affected by quantity.

There is a cost associated with effort because it is unpleasant and forgoes the opportunity to undertake other activities. The standard vertical-product-differentiation model assumes that the cost is increasing in both quality and quantity, convex in quality, and the marginal cost of production is independent of quality (McCannon, 2008). To introduce the trade-off between quality and quantity, assume instead that $C(x, e) = \frac{c}{2}xe^2$, with $c > 0$; see Champsaur and Rochet (1989) and Giraud-Héraud, Soler and Tanguy, (1999) for examples that have used this cost function.

Processors transform the raw material (input) into finished product (output). We assume that there are not losses of quantity and quality in the transformation process, that is, output quantity (Q) and quality (S) are linear functions of the input quantity and

quality as follows: $Q=q$; $S=s$. 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.

The price function

As we noted earlier, there are a total number of m growers ($k:1\dots m$) of an input, each of whom differentiated in quality. We will denote the quantity and quality produced by grower k by q_k and s_k , respectively. We denote by q_{ik} the quantity of grower k 's input supplied to processor i , where $q_k = \sum_{i=1}^n q_{ik}$. Likewise, there are a total of n processors ($i:1\dots n$) who acquire growers' input. Let Q_{ik} and S_k be defined as processor i 's output quantity and quality derived from grower k 's input. As there is no loss of yield and quality in input processing, $Q_{ik} = q_{ik}$, $S_k = s_k$. Likewise, let Q_i be defined as the total processor i 's supply, where $Q_i = \sum_{k=1}^m Q_{ik}$. Following Lancaster (1979), we distinguish between horizontal and vertical differentiation. Let P_{ik} denote the price at which each processor sells the output derived from the grower i 's raw material. An increase in the output quality improves each consumer's utility (see Mussa and Rosen, 1978). Then, the inverse demand function³ for the processor i 's output derived from grower i 's input is assumed to be linear in his supply, Q_i , and quality, S_k , and symmetrically linear in the supplies of the rest of the competitors as follows:

$$P_{ik} = b_1 S_k - b_2 Q_i - b_3 \sum_{\substack{j \neq i \\ j=1}}^n Q_j \quad \forall i = 1 \dots n \quad k = 1 \dots m$$

Where b_1 , b_2 and b_3 represent, respectively, the own market specific quality effect (vertical differentiation) and the own and each rival market specific effects (horizontal differentiation) with $b_h > 0 \quad h=1\dots 3$.

We have chosen these specific functional forms for the price and cost functions so that the impact of the quality-quantity can be readily observed. On the one hand, the price of a product is greater when a higher quality product is made, but it is more costly, in total cost and marginal cost. On the other hand, the marginal cost of production is assumed to be constant for a given level of quality, but for larger values of the supply the price decreases.

Our formulation of the models⁴ implicitly recognizes the law of supply and demand for both raw material and finished product, that is, the volume demanded will be equivalent to the volume supplied in the regional area.

The Spot Market

To model the spot market, we consider that n processors (indexed by $i:1 \dots n$) compete on the market for processed products by setting quantities. It is assumed that each processor i takes as given the qualities (s_k) and prices (p_k) of raw materials supplied by the m growers (indexed by $k:1 \dots m$). Moreover, each grower competes on the market for raw materials by setting quantities and qualities.

The model is solved by backward induction. The objective function of the i -th processor, assuming that he takes p_k and s_k as given, is defined in equation 1. The processor maximizes his certainty equivalent, CE_i^M , which is equivalent to his expected profit, π_i^M , by choosing quantity for each level of quality produced, q_{ik} . A processor's profit is the revenue generated minus the total cost paid:

$$(1) \quad \underset{Q_{ik}}{\text{Max}} CE_i^M = E \sum_{k=1}^m (Q_{ik} P_{ik} - q_{ik} P_k)$$

Upon expanding the above expression, the following is obtained:

$$(2) \quad \text{Max}_{Q_{ik}} CE_i^M = E \sum_{k=1}^m \left(Q_{ik} \left(b_1 S_k - b_2 \sum_{k=1}^m Q_{ik} - b_3 \sum_{\substack{j=1 \\ j \neq i}}^n \sum_{k=1}^m Q_{jk} \right) - q_{ik} p_k \right)$$

Taking the first-order necessary condition for a maximum in (2) yields:

$$(3) \quad p_k = b_1 E(s_k) - 2b_2 \sum_{k=1}^m q_{ik} - b_3 \sum_{\substack{j=1 \\ j \neq i}}^n \sum_{k=1}^m q_{jk}$$

Aggregation of (3) across the demands for grower k from the processors yields:

$$(4) \quad p_k = b_1 E(s_k) - \frac{2b_2 + b_3(n-1)}{n} \sum_{k=1}^m q_k$$

The grower k's problem for the derived demand (4) is to choose his effort in quality and quantity to maximize his certainty equivalent CE_k^M :

$$(5) \quad \text{Max}_{x_k, e_k} CE_k^M = E \left(q_k p_k - \frac{c}{2} x_k e_k^2 \right) - \frac{\rho}{2} \sigma_{\pi_k}^2$$

Upon expanding the above expression, the following is obtained:

$$(6) \quad \text{Max}_{x_k, e_k} CE_k^M = q_k \left(b_1 E(s_k) - \frac{2b_2 + b_3(n-1)}{n} \sum_{k=1}^m q_k \right) - \frac{c}{2} x_k e_k^2 - \frac{\rho}{2} q_k^2 b_1^2 e_k^2 \sigma_s^2$$

Taking into account that $q_k = x_k$ and maximizing (6) with respect to x_k and e_k , a system of two equations with two unknowns is obtained:

$$(7a) \quad \frac{\partial CE_k^m}{\partial x_k} = b_1 e_k - \frac{(2b_2 + b_3(n-1))}{n} \left(\sum_{k=1}^m x_k + x_k \right) - \frac{c}{2} e_k^2 - \rho x_k b_1^2 e_k^2 \sigma_s^2 = 0$$

$$(7b) \quad \frac{\partial CE_k^m}{\partial e_k} = x_k b_1 - c x_k e_k - \rho x_k^2 b_1^2 e_k \sigma_s^2 = 0$$

Since processors and growers face common equations, without loss of generality, in what follows we omit the subscript i and k in the variables. Analyzing equation (7a), we see an inverse relation between quantity and quality.

It can not be obtained an explicitly closed-form solution for the values of x and e from the previous equations. Thus, a numerical simulation exercise will be carried out as a solution to this model.

The Incentive Contract

We develop here a generalized moral hazard model for analyzing a general linear contract for sharing an uncertain outcome between a processor and a grower. We assume that in absence of transaction costs⁵ each processor offers each grower an individual contract and that the growers choose their efforts levels non cooperatively. We do not consider the optimal allocation of land ownership between the growers who work with land directly, and their intermediaries who process and sell the growers' output in some downstream market because it does not affect the total joint certainty equivalent.

According to Holmström & Milgrom (1987), when contracting is repeated many times and the agent has discretion in actions, the optimal contract offered to each agent is linear, consisting of (i) a fixed rent, α , which is independent of the observed outcome, and (ii) a share, β , of the observed outcome. Hence, risk-sharing is combined with the incentive effect in this contract. A lower output share exposes the grower to less risk while a higher share gives him greater incentives to supply his effort adequately.

We do not consider the optimal allocation of land ownership between the grower who works with land directly and his intermediary who processes and sells the growers' output in some downstream market because it does not affect the total joint certainty equivalent.

Within this multi-period framework, reputation plays a significant role in contractual enforcement. As growers and processors consider long-term relationships,

the fear of loss of contracting will prevent them from failing to take actions prescribed by the contract (Otsuka, Chuma and Hayami, 1992).

With regard to the performance indicator, the grower's contribution to revenue in the downstream market will be chosen because it provides a more valuable signal regarding the grower's action than the input quality, which is imperfectly measured (Holmström, 1979; Hueth and Ligon, 1999a). This performance measure is frequently found in fresh fruits and vegetables (Hueth and Ligon, 2001). Then, the optimal contract by processor i offered to grower k is:

$$(8) \quad w_{ik} = \alpha_i + \beta_{ik} Q_{ik} P_{ik}$$

Next, building on prior research by Holmström & Milgrom (1987) we model the processor i 's behavior given the growers' optimal response. The processor i chooses the parameters of the linear contract, α_{ik} and β_{ik} , that maximizes her expected profit net of growers' compensation, CE_i^{IC} , subject to the constraints that each grower chooses his efforts in quantity, x_{ik} , and quality, e_k , to maximize his expected utility, CE_k^{IC} , (incentive constraint) and that each grower attains with each contract at least his reservation utility, U_{ik}^{\min} (participation constraint). These constraints ensure individual and incentive compatibility in form of a Nash equilibrium, where agents choose their respective efforts levels individually and non-cooperatively. Then, the maximization problem for a representative processor i becomes

$$(9) \quad \underset{\alpha_{ik}, \beta_{ik}}{\text{Max}} CE_i^{IC} = E \sum_{k=1}^m (Q_{ik} P_{ik} - w_{ik})$$

Subject to

$$(10) \quad \underset{x_{ik}, e_k}{\text{Max}} CE_k^{IC} = E \sum_{i=1}^n \left(w_{ik} - \frac{c}{2} x_{ik} e_k^2 \right) - \sum_{i=1}^n \frac{\rho_k}{2} \sigma_{w_{ik}}^2$$

$$(11) \quad E \left(w_{ik} - \frac{c}{2} x_{ik} e_k^2 \right) - \frac{\rho_k}{2} \sigma_{w_{ik}}^2 \geq U_{ik}^{\min} \quad \forall k = 1 \dots m$$

The optimization problem in equations (9)-(11) can be solved sequentially. First, the optimal solutions to the grower's decision on efforts in quantity and quality in equation (10) are obtained:

$$\text{Max}_{x_{ik}, e_k} CE_{ik}^{IC} = E \sum_{i=1}^n \left(\alpha_i + \beta_i Q_{ik} \left(b_1 S_k - b_2 \sum_{k=1}^m Q_{ik} - b_3 \sum_{\substack{j=1 \\ j \neq i}}^n \sum_{k=1}^m Q_{jk} \right) - \frac{c}{2} x_{ik} e_k^2 \right) - \sum_{i=1}^n \frac{\rho_k}{2} \beta_i^2 Q_{ik}^2 b_1^2 e_k^2 \sigma_s^2$$

Optimizing and substituting the values of Q_{ik} and $E(S_k)$, we obtain:

$$(12) \quad \frac{\partial CE_k^{IC}}{\partial x_{ik}} = \beta_i \left(b_1 e_k - b_2 \left(x_{ik} + \sum_{k=1}^m x_{ik} \right) - b_3 \sum_{\substack{j=1 \\ j \neq i}}^n \sum_{k=1}^m x_{jk} \right) - b_3 \sum_{\substack{j=1 \\ j \neq i}}^n \beta_j x_{jk} - \frac{c}{2} e_k^2 - \rho_k \beta_i^2 x_{ik} b_1^2 s_k^2 \sigma_s^2 = 0$$

$$(13) \quad \frac{\partial CE_k^{IC}}{\partial e_k} = \sum_{i=1}^n \left(\beta_i x_{ik} b_1 - c x_{ik} e_k - \rho_k \beta_i^2 x_{ik}^2 b_1^2 e_k \sigma_s^2 \right) = 0$$

Here, we should substitute equations (12) and (13) into equations (9) and (11) and maximizing with respect to β , the optimal share for the grower would be obtained⁶. Finally, substituting x^* , e^* and β^* into equation (11), we would obtain the optimal fixed rent α^* . But similarly than in the previous model, these equations can not be solved analytically and a numerical simulation exercise is obtained instead.

Simulation and discussion

As we mentioned earlier, the mean-variance approach has been used to analyze various contractual issues. However, it is usually very difficult to explicitly solve the first-order conditions that define the values of the decision variables in the optimal contract. Quantitative applications of mean-variance models require numerical simulations (Robe, 2001).

Theoretically, growers respond to incentives in contracts obtaining greater levels of quality than in the spot market. And in practice, some authors have obtained conclusive support empirically (for example, Curtis and McCluskey 2003, Alexander, Goodhue

and Rausser, 2007). However, given the trade off, often present, between the quality of a good and the quality produced, it can not be assumed that a greater level of quality always lead to a greater level of expected profit.

In this section we undertake some comparative statics in order to see how changes in the number of operators, uncertainty and/or grower's risk aversion can explain that the processor could be not acting optimally with an incentive contract. Our models allow two sets of results. First, there are implications about the consequences of contractual choice in grower's decision variables. Second, the models developed above are used to show the optimality of these contractual mechanisms.

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 use Mathematica⁷ to solve the model, and use Excel to draw the graphs using the data produced by Mathematica. We initially choose the following parameters: $b_1 = 1$, $b_2 = 0.00001$, $b_3 = 0.0001$ and $c = 0.4$. 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 b_1 , b_2 , b_3 and c are used.

It will be seen below that this exercise is able to provide a consistent explanation for many issues relating to governance mechanisms. However, before proceeding, we should note the caveat that this simulation exercise uses restrictive assumptions about the shapes of price and cost functions. Although these seem highly plausible to us for most situations, there may be situations which are not covered by our simulations.

Then, we have three free parameters in our model: the number of growers, n , the number of processors, m , the primary producer's coefficient of absolute risk aversion, ρ , and the variance of input quality, σ_s^2 . It may be worth noting here that the risk premium can be higher for a grower than for another either because he is more risk

averse or because he faces higher variance in his income. Hence, these latter two parameters can be jointly identified, $\rho\sigma_s^2$, as both act on the producer's risk premium in a similar way.

For the purposes of the simulation, we consider an identical number of processors and growers, varying from 1 to 40, in steps of 5. Likewise, we assume that $\rho\sigma_s^2$ to take values 0, 0.000001, 0.00001 and 0.0001⁸. Still larger values for $\rho\sigma_s^2$ do not substantially affect the results of simulation exercise reported in this section. Using the equations explained in the models, we calculate the grower's effort in quantity in each contractual mechanism for each of possible combinations, which is illustrated in Figure 1. This process has been repeated for the grower's effort in quality and the total certain equivalent (see figures 2 and 3, respectively).

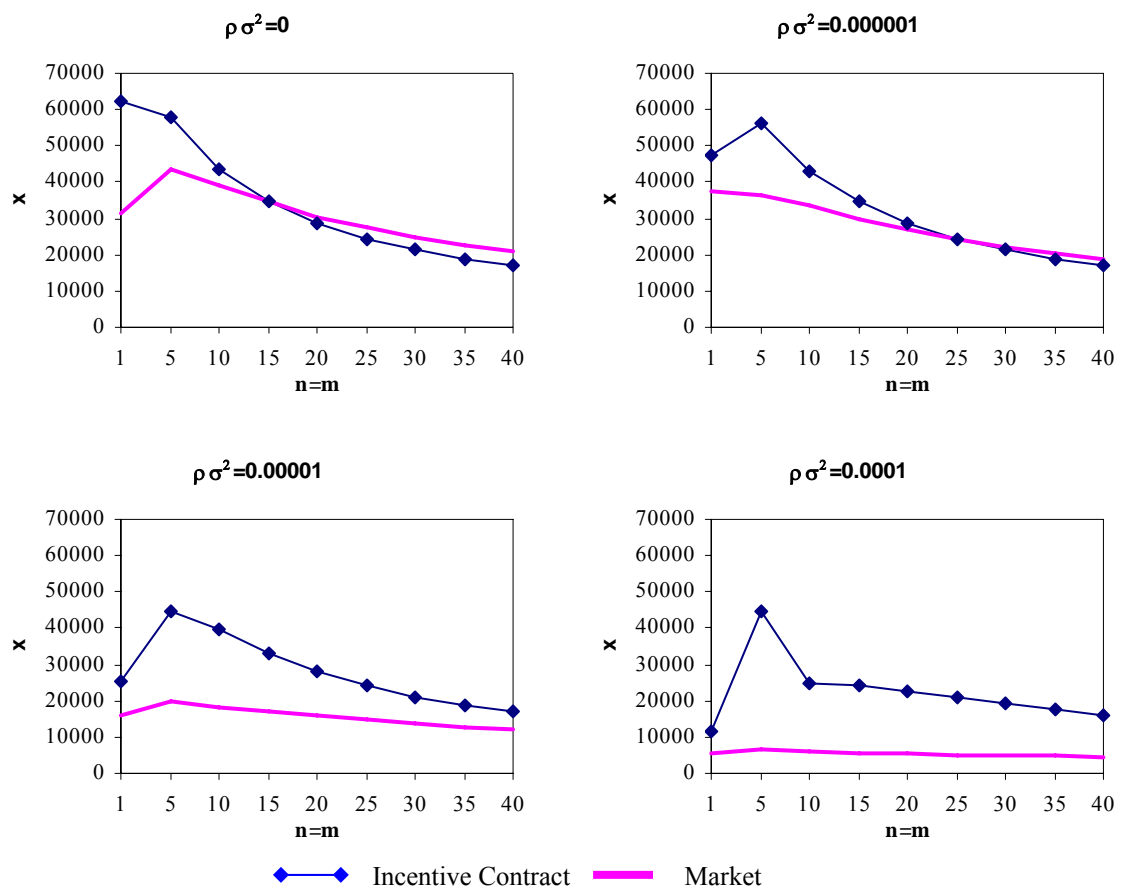


Figure 1. Comparing grower's effort in quantity with incentive contract and spot market

Figure 1 shows that the effect of the spot market on quantity is only greater than that of the incidence contract in sceneries characterized by relevant competition and low levels of growers' risk premium. On the contrary, in situations with imperfect competition the contract is more likely to provide incentive for growers to provide a level of quantity higher than of the spot market. In particular, for an important level of risk premium, independent from the number of operators, the quantity obtained with the incentive contract is greater than that obtained with spot market.

Figure 2 shows the values of quality for both mechanisms for all values of risk premium and number of operators.

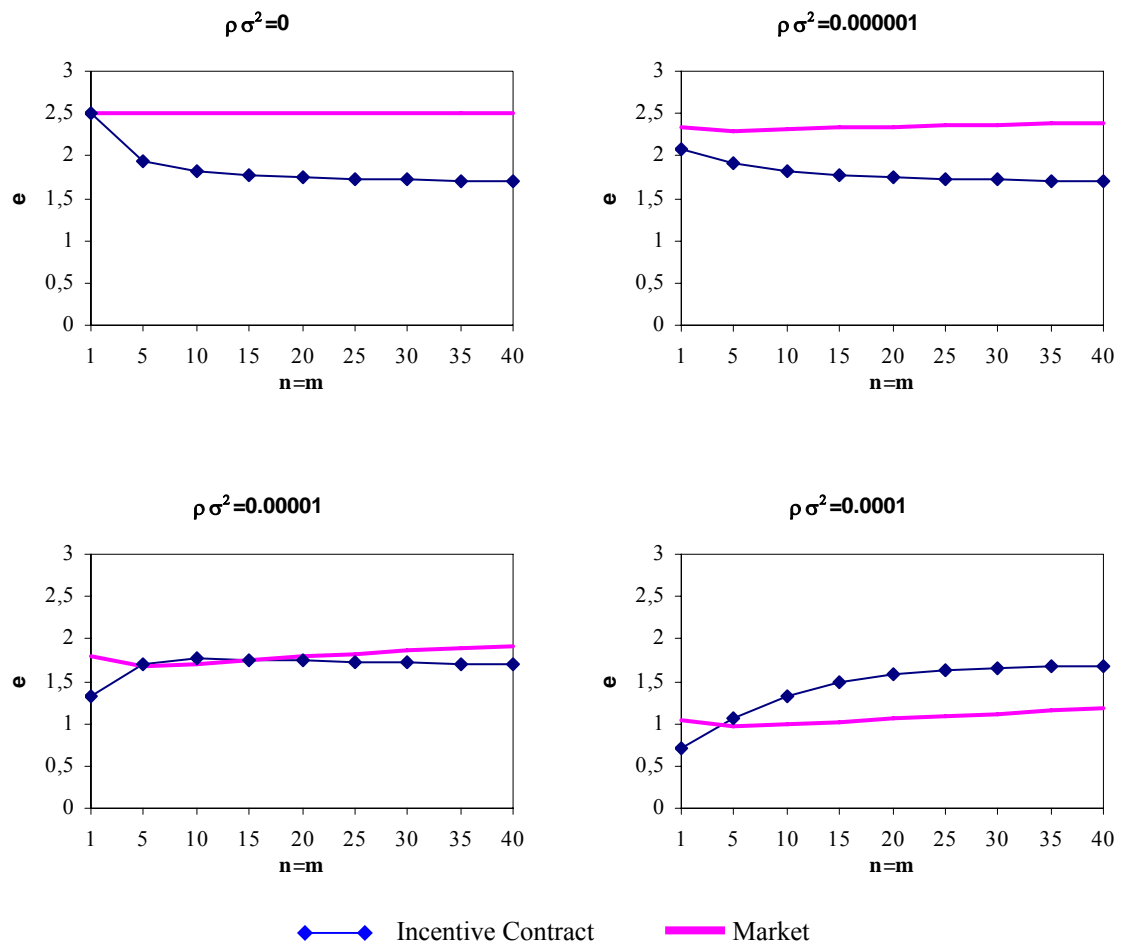
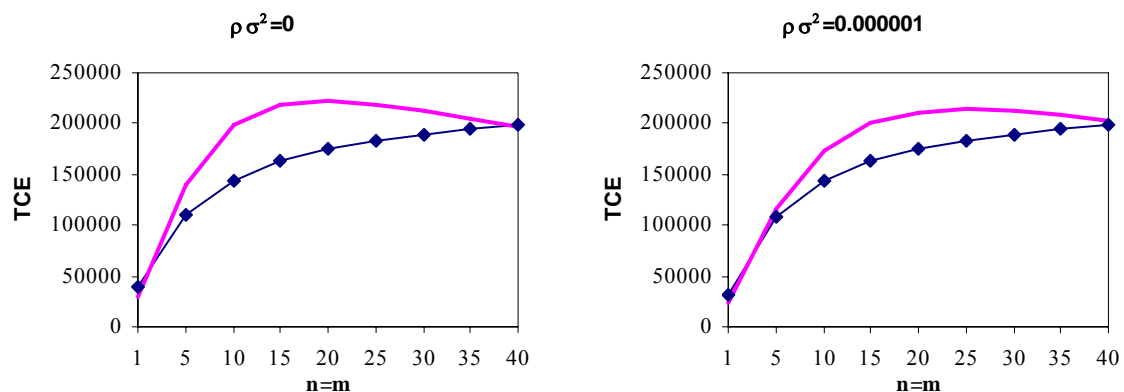


Figure 2. Comparing grower's effort in quality with incentive contract and spot market

Figure 2 shows that in absence of grower's risk premium, the spot market obtains an effort in quality greater than that of the incentive contract, with the exception of successive monopoly ($n=m=1$), in which the level of quality is similar in both mechanisms. As the grower's risk premium increases, the level of quality in both mechanisms decreases, being this effect much more intense in the spot market than in the incentive contract. This result would support the role of risk-sharing inherent in the incentive contract suggested by some authors (for example, Newberry, 1977; Newberry and Stiglitz, 1979). Hence, as the grower's risk premium increases, the incentive contract is more likely to provide greater levels of quality than the spot market.

It may seem contradictory that with a few operators, the spot market obtains a greater level of quality than the incentive contract for all the values of risk premium considered in this simulation. However, it can be explained with the trade-off between quantity and quality. With high levels of grower's risk premium and small number of operators, the spot market obtains a very low level of quantity (see figure 1). Given the inverse relation between quantity and quality, the level of quality is relevant in comparison with that of the incentive contract.

Finally, in the Figure 3 we have evaluated the total certain equivalent for all values of risk premium and number of operators considered in the simulation exercise.



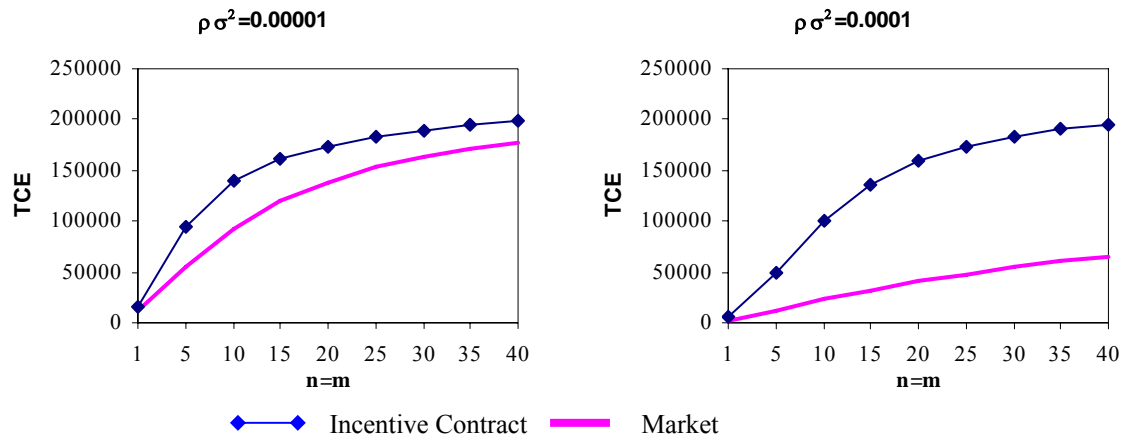


Figure 3. Comparing total certain equivalent with incentive contract and spot market

Observing the figure 3 we see the processors may be either better off or worse off using the incentive contract compared to the spot market depending on the characteristics of the relationship involved. As agency theory predicts, an increase in the magnitude of grower's risk premium increases the appealing of the incentive contract while decreasing the appealing of the spot market, considering the total certain equivalent (see figure 3).

In the first best world with risk-neutral agents and/or absence of uncertainty ($\rho\sigma_s^2=0$), the incentive contract is rarely efficient, only when the number of operators is reduced, nearly successive monopoly. However, in the second best world with risk-averse growers, the spot market becomes less attractive due to the high risk premium supported by the growers in this mechanism.

Then, as grower's risk premium (i.e. risk aversion or output variance) increases, relative preference for incentive contract is likely to increase over spot market. This result is supported by other studies, for example Cheung (1969), Bardhan (1984) and Parthasarthy and Prasad (1974).

Comparing the three figures, we can see cases in which the incentive contract provides a smaller level of quality but a greater level of total certain equivalent than the

spot market (see for example, $n=m<5$ and $\rho\sigma_s^2=0.00001$). Hence, it can be not concluded that the governance mechanism that provides a greater level of quality is the optimal mechanism considering the total certain equivalent.

Likewise, there are situations in which not only does the spot market provides a greater level of quality, but also a greater total certain equivalent than the incentive contract (for example in absence of uncertainty, $\rho\sigma_s^2=0$). This result would suggest that the spot market could be preferred over the incentive contract under several conditions.

Taken together, processors should choose the governance mechanism that maximizes their wealth, not product yield or quality properties. The reason is that it can be concluded that neither a greater level of quality always leads to a greater level of total certain equivalent nor the incentive contract is always more efficient than the spot market.

This simulation exercise could also provide a consistent explanation for some results obtained by Alexander, Goodhue and Rausser (2007). They can not conclude that the benefit of higher quality outweighs the costs of providing the price incentives for the processor. Although the offer of these incentives by the processor might appear to be prima facie evidence that the processor increases profits by offering price incentives for quality, the results of their analysis do not completely support this inference.

Conclusions

The use of contracts to induce growers to provide desired quality attributes has become common practice in many agricultural sectors. To solve the apparent asymmetric information problems between processors and independent growers that universally plague these relationships, the majority of contract use high-powered incentives schemes to compensate growers (Curtis and McCluskey, 2003; Dubois and

Vukina, 2004; Alexander Goodhue and Rausser, 2007). While economists have shown increased interest in the effects on quality of these contracts, surprisingly little attention has been paid to the question whether processors are acting optimally.

To fill this gap, we have developed and applied a model of contractual choice in agriculture by analysing the optimality of the incentive contract and the spot market in the framework of a generalized moral hazard model, considering the quantity-quality trade-off and competition.

Specifically, there is a trade-off between yield and quality of many agrarian inputs; higher quality comes at the cost of lower yields and vice versa. Likewise, market prices are higher for high-quality than for lower quality products, but exact price levels are determined by market factors such as the relative supply for each good. Thus, prices and yields appear to be inversely related in the aggregated market. However, the literature on contractual choice has long dealt separately with quality and yield probably because they are inaccessible to solve analytically.

Our analysis illustrates the effects of the incentive contract and spot market on product properties, quality and quantity, on the basis of a simulation exercise. In particular, we analyzed a plausible range of number of operators (growers and processors) and risk premium and carried out a simulation exercise to understand the effects of each mechanism under a wide variety of circumstances.

The exercise throws some light on the relative importance of analysing the quantity/quality trade-off and competition in the analysis of the optimality in governance choice. We can not conclude from our results that the mechanism that provides a greater level of quality is the most efficient mechanism. Likewise, we can not conclude that the processor is always better off offering incentive contracts than trading in the spot market.

On balance, the models developed here provide a satisfactory explanation of why processors should choose the mechanism that maximizes their wealth and not the levels of quality. It could explain some of the results obtained by Alexander Goodhue and Rausser. (2007), which suggested that offering price incentives does not improve processors' profits.

The simulation exercise presented here leaves unanswered many interesting questions in contracting. One important aspect of the problem, which we have not considered, is that many contracts are based on monitoring. We assumed that the processor can not directly observe grower's effort or infer it from knowledge of the output. However, by monitoring him, they can obtain a reasonable estimate of the grower's effort level, and thereby dissuade him from shirking. Some monitoring of growers is often undertaken by processors (Agrawal, 1999).

This paper provides some interesting implications from an agricultural policy perspective.

It is obvious that each grower faces a trade-off between offering high levels of quantity (and low quality) versus high levels quality (and low yield) of his agricultural inputs. Since these attributes are assumed to have an influence on the price received by the growers, the optimal choice is obviously contingent upon the relationship between the quantity/quality trade-off and the received price.

In the event that agricultural policy is geared towards increasing the quality in the agrarian markets, the policy makers could strive to incentive growers to produce quality by regulating the specified maximum yield per acre. However, the situation is complicated by the fact that in order to induce growers to produce quality, they must be offered a compensation for the increase in cost associated with it. And if this compensation for cost increases is not associated with higher spot prices, it is difficult

that growers can receive it. The alternative, and more realistic, strategy for growers and processors is to think how to make that consumers perceive the quality and are willing to pay more for it. Creating a Quality Certified Brand could be a possibility given that it provides consumers with a better understanding of input quality.

Acknowledgements

This paper has been supported by the SEJ2005-07341/ECON project.

This paper was edited in the context of the objectives of the CREVALOR Excellence Research Group recognised by Diputación General de Aragón (Spain).

References

Agrawal, P. "Contractual Structure in Agriculture." *Journal of Economic Behavior and Organization* 39 (1999) : 293-325.

Alexander, C., Goodhue, R., Rausser, G. "Do Incentives for Quality Matter?." *Journal of Agricultural and Applied Economics* (April 2007).

Allen, L., Lueck, D. "The role of risk in contract choice." *The Journal of Law, Economics and Organization*, 15 (1999): 704-736.

Andersson, H. "Primary and secondary producers: Economic implications of contracts in the food marketing chain." *European Review of Agricultural Economics*, 22 (1995): 310-320.

Bardhan, P.K. *Land, labor, and rural poverty: essays in development economics*. Columbia University Press, 1984.

Bell, C., Zusman, P. "A Bargaining Theoretic Approach to Cropsharing Contracts." *American Journal of Agricultural Economics* 66 (1976): 578-588.

Carriquiry, M., Babcock, B. A. "Can Spot and Contract Markets Co-Exist in Agriculture? Unpublished manuscript, Iowa State University (2004).

Chambers, W., King, R. "Changing Agricultural Markets: Industrialization and Vertical Coordination in the Dry Edible Bean Industry." *Review of Agricultural Economics*, 24 (2002): 495-511

Champsaur, P., Rochet, J.C. "Multiproducts duopolists." *Econometrica*, 57 (1989): 533-557.

Chavas, J.P., Holt, T. "Acreage decisions under risk: the case of corn and soybeans." *American Journal of Agricultural Economics*, 72 (1990).

Cheung, S.N.S. *The Theory of Share Tenancy*. University of Chicago Press, Chicago, IL, 1969.

Coughlan, A.T. "Competition and Cooperation in Marketing Channel Choice: Theory and Application." *Marketing Science*, 4 (Spring 1985).

Coyle, B. "Risk Aversion and Price Risk in Duality Models of Production: A Linear Mean-Variance Approach." *American Journal of Agricultural Economics*, 74 (1992): 849-859.

Curtis, K., McCluskey, J. "Contract Incentives in the Processed Potato Industry", *proceedings of the Food Systems, Research Conference, June 26-27, Madison, WI 2003*

Duvois, P., Vukina, T. "Grower Risk Aversion and the Cost of Moral Hazard in Livestock Production Contracts", *American Journal of Agricultural Economics*, 86 (2004): 835-841

Fraser, R. "Using Principal-Agent Theory to deal with Output Slippage in the European Union Set-Aside Policy", *Journal of Agricultural Economics*, 52 (2001): 29-41.

Gabszewicz, J.J., Thisse, J.F. "Entry (and Exit) in a Differentiated Industry." *Journal of Economic Theory*, 22 (1980): 327-338.

Gabszewicz, J.J., Thisse, J.F. "Price Competition, Quality and Income Disparities." *Journal of Economic Theory*, 20 (1979): 340-359.

Gaynor, M., Gertler, P.J. "Moral Hazard and Risk Spreading in Partnerships." *Rand Journal of Economics*, 26 (1995): 591-613.

Giraud-Héraud, É., Soler, L-G., Tanguy, H. "Avoiding double marginalisation in agro-food chains." *European Review of Agricultural Economics*, 26 (1999): 179-198.

Holmström, B. "Moral hazard and observability." *The Bell Journal of Economics*, 10 (1979): 74-91.

Holmström, B., Milgrom, P. "Aggregation and Linearity in the Provision of Intertemporal Incentives." *Econometrica*, 55 (1987): 303-328.

Hueth, B., Ligon, E. "Agricultural supply response under contract." *American Journal of Agricultural Economics*, 81 (1999a): 610-615.

Hueth, B., Ligon, E. "Producer price risk and quality measurement." *American Journal of Agricultural Economics*, 81 (1999b): 512-524.

Hueth, B., Ligon, E. "Agricultural Markets as Relative Performance Evaluation." *American Journal of Agricultural Economics*, 83 (2001): 318-328.

Hueth, B., Ligon, E. "Estimation of an efficient tomato contract." *European Review of Agricultural Economics*, 29 (2002): 237-253.

Jaumandreu, J., Lorences, J. "Modelling price competition under product differentiation and many firms (An application to the Spanish loans market)." *European Economic Review*, 46 (2002): 93-115

Lancaster, K. *Variety, equity, and efficiency*. Columbia University Press, Nueva Cork, 1979

McCannon, B. C. "The Quality-Quantity Trade-off", *Eastern Economic Journal*, 34 (2008): 95-100.

- McGuire, T.W., Staelin, R. "An industry equilibrium analysis of downstream vertical integration." *Marketing Science*, 2 (1983).
- Milgrom, P., Roberts, J. *Economics, Organization, and Management*, London: Prentice-Hall, 1992.
- Mussa, M., Rosen, S. "Monopoly and Product Quality." *Journal of Economic Theory*, 18 (1978): 301-317
- Myers, R.J., Thomson, S.R. "Generalized Optimal Hedge Ratio Estimation." *American Journal of Agricultural Economics*, 71(1989): 858-867.
- Newberry, D. "Risk sharing, sharecropping and uncertain labour markets." *Review of Economic Studies*, 44 (1977): 585-594.
- Newberry, D., Stiglitz, J.E. "The Theory of Commodity Price Stabilisation Rules: Welfare Impacts and Supply Responses." *Economic Journal*, 89 (1979): 799-817.
- Otsuka, K., Chuma, H., Hayami, Y. "Land and labor contracts in agrarian economies: theories and facts", *Journal of Economic Literature* XXX (1992): 1965-2018.
- Parthasarthy, G., Prasad, D.S. "Responses to, and impact of, hyv rice according to land size, hyv rice according to land size and tenure in a delta village, Andhra Pradesh, India". *Developing Economies*, 12 (1974): 182-198.
- Pope, R.D., Just, R.E. "On testing the structure of risk preferences in agricultural supply analysis." *American Journal of Agricultural Economics*, 72 (1991).
- Robe, M. "What can we learn from simulating a standard agency model?." *Economics Letters*, 73 (2001): 137-146.
- Robison, L., Barry, P. *The Competitive Firms Response to Risk*. MacMillan, New York, 1987.
- Shaked, A., Sutton, J. "Natural Oligopolies." *Econometrica*, 51 (1983): 1469-1484.

Shaked, A., Sutton, J. "Relaxing Price Competition Through Product Differentiation." *Review of Economic Studies*, 49 (1982): 3-13.

Shavell, S. "Risk sharing and incentives in the principal and agent relationship." *Bell Journal of Economics*, 10 (1979): 55-73.

Stiglitz, J.E. "Economic Organization, Information, and Development", Handbook of Development Economies, Vol.1, pp.93-159. Amsterdam: North Holland, 1988.

Stiglitz, J.E. "Incentives and risk sharing in agriculture." *Review of Economic Studies* 41 (1974): 209-256.

Wolf, S.B., Hueth, B., Ligon, E. "Policing mechanisms in agricultural contracts." *Rural Sociology*, 66 (2001): 359-381.

¹ The optimal choice for a decision maker faced with uncertainty is the maximization of his expected utility where the expected profit and variance are the arguments of utility. As the expected utility derived from variable profits is equal to the utility derived from the certainty equivalent, CE, the maximization problem can be mathematically written as $CE = E(\pi) - \rho\sigma_{\pi}^2/2$, where the coefficient ($\rho \geq 0$) measures the risk aversion and σ_{π}^2 is the variance of profit (Robison & Barry, 1987).

² A reason for this assumption is that the cost of bearing risk is generally relatively less for the processor than for the grower (Milgrom and Roberts, 1992).

³ Linear demand systems have been used extensively in models of oligopolies, see (Coughlan, 1985; McGuire & Staelin, 1983; Jaumandreu & Lorences, 2002).

⁴ From now on, the superscripts M and IC will indicate the mechanism associated, that is, spot market and incentive contract respectively.

⁵ The assumption of absence of transaction costs is restrictive in the sense that the transaction costs of offering contracts are never zero in practice, and offering individualized contracts will generate higher transaction costs. However, the reason for this restrictiveness is to concentrate on competitive motivations instead.

⁶ Let the Nash equilibrium values be denoted as *.

⁷ The Mathematica commands are available from the authors on request.

⁸ With $\rho\sigma_s^2=0.0001$ the value of the certainty equivalent per processor is very small.