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THE COMPETITIVE FIRM'S WILLINGNESS TO PAY FOR INFORMATION

1989

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AAEA 89

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ABSTRACT

We examine the competitive firm's willingness to pay for a perfect price forecast. The conventional compensating variation measure can understate the value to risk-averse firms of such a forecast. A Pareto efficient contract contingent on realized prices dominates and shows that information's value is larger the greater is risk aversion.

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1. Introduction

Public investments in research and extension, weather forecasting, and forecasts of prices and other market conditions must presumably have as their basis some notion of the value of information. A necessary condition for such investments to be justified is that decision makers must make changes in allocative decisions, based on the information, which improve their expected income (or possibly expected utility). Justifying the public provision of information also requires some belief about imperfections in the market for information, as well as an assumption that the public provider of information values the resulting increase in the information user's average welfare. Agricultural economists are familiar with attempts to measure the rate of return to agricultural research, in this context. Similarly, the identification and measurement of the use and benefits from improved information are necessary for an optimal allocation of resources to the gathering and dissemination of information.

In this paper, we examine the value of information using the familiar willingness to pay criterion. We consider what a competitive agricultural producer would pay for a perfect price forecast, and factors affecting its demand for information, in a world where only the price of output is uncertain at the time of planting. The objective is to examine how to measure the value of information. We make use of a hypothetical firm selling information, and establish the characteristics of a Pareto-efficient contract between the seller of information and the agricultural producer. We show that, due to the structure of the optimal contract, the usual compensating variation criterion understates the average value of information.

Due to the public nature of information, a private firm selling information would have difficulty capturing the value of its product. Hence, one may expect that the market for information is subject to failures, and indeed, firms that sell information are rare. As a result, there is likely to be a justification for government provision of information, through agencies such as the USDA. A first step in evaluating the optimal nature and level of investment in forecasting activity by such an agency is to consider the gain it yields to the producer.

In order to focus specifically on the appropriate *method* for valuing information, we consider a very special case, where the firm is buying a *perfect* price forecast. We assume that this forecast has value because it results in improved allocative decisions, concerning the level of production, but ignore the possibility of using the information to take a "speculative" position on a futures exchange (an option which must also be ruled out for the seller of the information!). While unrealistic, this keeps the problem simple and allows comparison with some other results. The interpretation we give to the value of information could be applied in more realistic situations, such as imperfect price forecasts (which might be a way of evaluating the effects on output and producer welfare of introducing a futures market) or forecasts of weather or pest infestations, as well as applications outside agricultural production.

We analyze a single firm in isolation—there are assumed to be no market-level effects of the information, as might occur if information induces all producers to increase production, thereby depressing the market price and reducing (or eliminating) the value of the information (e.g. Antonovitz and Roe; Babcock; Pope, Chavas, and Just). The firm faces risk in the sense defined by Knight—the market price is random, but the probability distribution governing its realizations is known. A more elaborate definition of information would recognize uncertainty about this distribution, and examine how information could be acquired to update the producer's (subjective) prior probability distribution (e.g. Graham-Tomasi). One reason such a case is difficult is that the value of information is dependent upon which of the infinite number of possible prior distributions the producer believes.

2. An Ex Ante Pareto-efficient Contract

Consider a market transaction for the transfer of information from a firm that produces forecasting to a farmer that uses this information in his decision-making process. If he purchases information, the farmer chooses output y to maximize expected utility defined on total net income

$$\max_{y \geq 0} \; E[U(W_F + \pi(y, p) - \eta(p)) \mid I],$$

where I is the information available at time of the decision, π is the profit function with the usual properties, p is the random output price, and W_F is initial wealth of the farmer. The term $\eta(p)$ is the amount paid for the information, which we allow to depend on the realization of the price. Finally, y^I denotes the optimal output level with information, and π^I denotes profits at that output. A farmer that did not purchase information would base decisions on the underlying proability density of p, with y^U the uninformed level of output chosen without possession of the forecast, and π^U the corresponding profits.

The objective function of the firm that sells information is

$$E[V(W_S + \eta(p) - C(I))],$$

where W_S is its initial wealth (including the value of existing contracts with other firms) and C(I) is the cost of producing the forecast. We assume below that $C(I)=C$ is constant; the cost of providing information about the realization of market price does not depend on that price.

The information set I usually contains information about the realization of some random variables denoted by Z, on which p is statistically dependent. Unless there exists perfect correlation between Z and p, the forecast of p is imperfect. As noted earlier, we consider the polar case of perfect information, so the forecast is equivalent to prior knowledge of p. Generalization to imperfect information can follow the lines of Blair and Romano.

We begin with the derivation of an ex ante Pareto-efficient contract (EPC). The ex ante contract we consider specifies, prior to its realization, the amount the buyer of information about p pays the seller for that information. An ex ante contract, $\eta(p)$, is one that specifies that the buyer will pay the seller an amount dependent on the realization of the price p.

What would be the optimal structure of such a contract? A contract is ex ante Pareto-efficient if there exists no other contract that yields at least as much expected utility for both firms and strictly higher expected utility for at least one of the firms. This definition is commonly used in the risk-sharing literature (e.g. Karni). To derive the optimal contract, one needs to solve the following problem in the calculus of variations:

$$\max_{\eta} \int U[w + \pi(y^I, p) - \eta(p)]\, f(p)\, dp$$

subject to

$$\int V[W + \eta(p) - C(I)]\, f(p)\, dp \geq V_0,$$

for any V_0, where $f(p)$ is the probability density function of the output price, known to both parties. The Euler-Lagrange necessary condition is:

$$U' = \lambda V' \quad V \;\; p,$$

where $\lambda \geq 0$ is a constant multiplier which is independent of the realization of the output price. The condition that the ratio of the two marginal utilities should be constant, across all states of nature, is very intuitive. To illustrate, assume that the necessary condition does not hold; in particular, suppose that

$$\frac{U'(p^0)}{V'(p^0)} > \frac{U'(p^1)}{V'(p^1)}$$

where p^0 and p^1 are realizations of the output price in two states. If this is the case, the contract is not Pareto-efficient. Both parties could gain by changing the contract. For instance, let $\varepsilon > 0$ be some arbitrarily small constant. The buyer of the information would gain by an increase in his payment in state 1 by $\varepsilon V'(p^0)$ and a decrease in his payment in state 0 of $\varepsilon V'(p^1)$, while this would leave the seller's expected utility unchanged. A similar analysis could identify a Pareto improvement which benefits the seller.

Blair and Romano, using an ex ante measure, derived sufficient conditions for a risk averter to place a lower value on perfect forecasting than a risk neutral producer. This surprising result was due to the fact that, knowing only that a perfect forecast would be obtained, *and not its realization*, meant that the option was still risky to the buyer of information. With sufficient aversion to risk, the risk averse individual might place less value on such an alternative than one less averse or risk neutral. Their measure of the value of information is the compensating variation (CV) measure, which is defined as

$$EU[\pi(y^U, p)] = EU[\pi(y^I(p), p) - k],$$

where k is the maximum amount that the firm is willing to pay for perfect information. The authors noted that the CV is a natural measure of willingness to pay. Note, however, that with this measure there is an implicit assumption that the contract $\eta(p) = k$, *i.e.* the payment of the buyer to the seller does not depend on the state of the nature (p). The payment is the same regardless of how favorable is the realization of p.

Let us examine the properties of the preferences of the buyer and seller which would make such a contract an optimal one. To be consistent with the optimality condition that we derived above, the contract $\eta(p) = k$ must satisfy

$$\frac{d}{dp}\left[\frac{U'(W_F + \pi - k)}{V'(W_S + k - C)}\right] = 0$$

By expanding this derivative, we can see the following condition must hold;

$$\frac{V'(\cdot)U''(\cdot)\dfrac{\partial \pi}{\partial p} - U'(\cdot)V''(\cdot)\dfrac{\partial W_S + k - C}{\partial p}}{[V'(\cdot)]^2} = 0,$$

Given that changes in output price have no effect on the seller's wealth, it follows that an EPC requires that $U''(\cdot)$ is also equal to zero. Thus, for a fixed payment contract to be optimal, it is necessary that the buyer is risk neutral. Another way to say this is that, if the buyer of information was offered the opportunity to buy perfect information, he would only prefer a fixed payment contract if risk neutral.

In light of this result, it is interesting to reexamine the Blair and Romano results using the new assumption of an optimal contract. The optimality condition above characterizes an important property of the contract, but the explicit form of the contract is difficult to obtain without restrictions on preferences. It is possible to establish some results, however, by assuming that the seller is risk neutral. An optimal contract is characterized by a constant value for the seller's marginal utility of income $U'(w + \pi(P) - \eta(p))$. This implies that the optimal contract is of the form

$$\eta(p) = \pi(p) - c,$$

where c is a constant which is subject to negotiation between the parties. The larger is c, the smaller is the payment for information in each state of the world. Note that, for some very adverse outcomes, the buyer may receive a payment from the seller of information. In this case, the seller of information is also providing a form of income insurance which, because of moral hazard problems, may be difficult for the seller to finance. A more feasible contract might be one in which the payments to the seller are ~~required~~ to be non-negative. If this were the case, the optimal contract would have the payment such that profits would be maintained at some constant k for states of the world generating profits of k or above and would have no payments for information for states of the world where profits are below k. This restriction would only weaken the general nature of the results derived later in the paper. For simplicity, this restriction will be relaxed for the remainer of the paper.

The principal sources of information for farmers are government agencies. These may be interested in recovering the cost of collecting the information, but in general are indifferent to risk. Hence, in the remainder of the paper we will assume that the seller is risk neutral and that the contract is of the non-constrained form.

As an aside, it is interesting to think of this contract in relation to mechanism design and agricultural policy. Note that the above contract essentially stablizes the buyer's income at the level c. Many mechanisms which are designed to guarantee farmers income tend to be exposed to moral-hazard problems. For this reason, the contract would have to be contingent on p, rather than realized profits. Given the competitive nature of the industry, the payment would be independent of individual behavior. This will eliminate any incentive to shirk. The shortcoming of this approach is that, in order to stablize income, the seller of the information has to know the profit function of the buyer. In a practical sense, an approximate measure of the profit function would remove most of the variation in income.

3. Risk Aversion and the Willingness to Pay for Information

In this section, we take up the relative value of perfect forecasting (information) for farmers with different attitudes towards risk. This is an important issue for policy makers concerned with the distributional consequences of a policy that is based on revealing price information ex ante. For example, what is the benefit from announcing the support prices for U.S. commodity programs before planting, versus making announcements after the crop is seeded? To the extent that farmers may have different degrees of risk aversion, policy decisions regarding information may have distributional implications.

While Blair and Romano limited their discussion to comparisons between risk neutral producers and risk averters, we consider comparisons between different degrees of risk aversion. Under the assumption that the contract is an EPC, the actual payment of the farmer is a function of the state of the world. To compare different levels of risk aversion, we examine how it affects the payment in every state of nature. In Proposition I, we show that the larger is the aversion to risk, the the larger is the amount that the farmer will pay in each state of the world.

Proposition I: For the optimal contract of the form $\eta(p) = \pi - c$, where c is a positive constant, c decreases with any parameter of the utility function, ρ, which increases risk aversion. (The precise definition of the index of risk aversion is due to Diamond and Stiglitz.)

Proof: Assuming that initial wealth is contained in profits, c is defined implicitly by the equation

$$EU(\pi(y^U(\rho), p), \rho) = EU(\pi(y^I(p), p) - (\pi^I - c), \rho)$$

or, since the profits terms cancel,

$$EU(\pi(y^U(\rho), p), \rho) = EU(\bar{\pi}^U - (\bar{\pi}^U - c), \rho).$$

Note that $\bar{\pi}^U - c$ is the farmer's risk premium (RP). Diamond and Stiglitz showed that the risk premium increases with ρ. This implies that

$$\frac{\partial(\bar{\pi}^s - c)}{\partial \rho} \geq 0.$$

Footnote

But, it can be shown using Corollary 2 from Diamond and Stiglitz that

$$\frac{\partial \bar{\pi}^s}{\partial \rho} \leq 0.$$

Hence, it must be the case that

$$\frac{\partial c}{\partial \rho} \geq 0,$$

and the greater is the aversion to risk the smaller is c and the larger is the amount that the farmer will pay in each state of the world. ■

Note that the minimum c which the farmer will agree to is his certainty equivalent of random income. The certainty equivalent decreases with the index of risk aversion; hence, our measure of willingness to pay for information is always increasing with risk aversion.

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This result differs from that in Blair and Romano because the optimal contract is not constant.

We now make use of $\eta(p)$ to measure the value of a perfect forecast. The gain to producers from purchasing information under the terms of the optimal contract is

$$\bar{\pi}^I - [\bar{\pi}^S - RP(\bar{\pi}^S, F)],$$

Say in english

where F denotes the distribution of the output price. The above expression is the total value of the information, when it is evaluated in dollars. It could be shared by the parties or captured entirely by one of them. To see this, we consider the two extremes under the assumption that the cost of producing information C equals zero.

First, suppose that the contract charges the farmer the maximum that he is willing to pay. In that case, c is his certainty equivalent and he is indifferent between the uninformed situation and the informed one. For every realization of p, the farmer pays his informed profits minus the certainty equivalent. The seller of the information is risk neutral, so this random stream of future income is worth to him exactly the above expected value.

Now assume that the farmer captures all of the surplus. The seller receives a price that will leave him indifferent. This will happen if $c = \bar{\pi}^I$, since then the expected value of the payment is zero. Note that in this case the farmer is left with deterministic income equal to π^I. His gain from the purchase of information is the difference between two certainty equivalents, so once more we obtain the above expression.

Although we have shown that the measure of Blair and Romano is based in general on a non-optimal contract, it is still interesting to generalize their result for comparisons of farmers with different degrees of risk aversion. We do so in Proposition II below.

Proposition II: A sufficient condition for the Blair and Romano measure of value of perfect information to decrease (increase) with the degree of risk aversion is that the change from the distribution of profits with the subjective beliefs (π^U), to the distribution of net profits with information is a mean utility preserving increase (decrease) in risk.

Proof: The Blair and Romano measure of the value of perfect forecasting, which we denote by S, is defined implicitly by the following equation

$$EU(\pi(y^s(\rho), p), \rho) = EU(\pi(y^I, p) - S, \rho).$$

We proceed by implicit differentiation of the above equation and, by using the Envelope Theorem, we find

$$S'(\rho) = \frac{EU_\rho(\pi^I - S\ , \rho) - EU_\rho(\pi^s\ , \rho)}{EU_\pi(\pi^I - S\ , \rho)}.$$

Following Diamond and Stiglitz, this derivative can be shown to be positive (negative) if the distribution of informed profits π^I is a mean-preserving increase (decrease) in risk, when compared with the distribution of uninformed profits. ■

There are two points that are worth mentioning. First of all, our result is a direct generalization of the Blair and Romano result. To see that, note that if we perform the above analysis when $\rho = 0$, i.e., when the starting point is risk neutrality, then the maximum $S = \pi^I - \pi^U$ and $U'(\pi)$ is constant and our condition reduces to theirs. Second, we see that if the distribution of net profits with information is a mean utility preserving decrease in risk, then the larger is the aversion to risk the greater is the value that the farmer puts on information.

4. Increasing Risk and the Willingness to Pay for Information

The relationship between the riskiness of the environment and the value of information is the subject of a long debate in the economic literature. Gould derived conditions on the distribution of the random variable in question necessary for the value of information to be maximized, and showed that if the objective function is linear in the random variable, then information is more valuable when the environment is more risky. Although this is certainly intuitive, Laffont used a new definition of increasing risk to show the surprising result that Gould's finding is limited and in general the value of information decreases with his measure of risk. Finally, Hess showed that Laffont's definition of increasing risk is limited to the case where the objective function is not strictly concave in the random variable. He derived a general sufficient condition under which the value of information will increase with risk.

In this section, we establish the intuitive result that the riskier is the environment, the larger is the value of information, when the value of information is measured using the measure we suggested above. In Proposition III, we show that this is indeed the case, assuming only that the producer is risk averse.

Proposition III: Given the optimal contract, an increase in risk, as defined by Rothschild and Stiglitz, increases (decreases) the value of perfect forecasting to a risk-averse (risk-seeking) firm.

Proof: Given the optimal contract and the risk neutrality of the seller, c is defined implicitly by the equation

$$EU(\pi(y^U, p)) = U(c)$$

Thus, the minimum c is given by the certainty equivalent

$$c = U^{-1}(EU(\pi^U).$$

By assumption, U is monotonically increasing and concave (convex) in π. Theorem 2 of Rothschild and Stiglitz implies that the expected value of U decreases (increases) with mean preserving increase in risk, and hence c decreases (increases) with the increase in risk. ■

5. Conclusions

In this paper, we considered the competitive firm under output price risk and examined the value it would attach to a perfect price forecast. We examined the optimal contract between a hypothetical, risk-neutral firm selling the forecast and a representative risk-averse competitive agricultural producer. The factors affecting the firm's willingness to pay for information were explored, such as the effects of increasing risk or of increasing risk aversion. Each was shown to increase the firm's willingness to pay.

Unlike conventional measures based on compensating variation, we showed that the optimal payment for information is not constant with respect to the realization of the output price. In contrast, measures which assign a constant value to the information, regardless of its nature (e.g. Blair and Romano) were shown to be optimal only when the producer buying the information is risk neutral.

We used the structure of the optimal contract to draw implications for the public provision of information. An implication of its sub-optimality as a contract is that the compensating variation measure understates the gain from providing a perfect forecast, when it is possible to make payments for the information contingent on the outcome in the way we examined in the paper. We showed that the optimal contract would charge more for information in years with high prices and, in some extremes, even subsidize users in adverse situations.

The provision of information by the USDA or a marketing authority, through forecasts, announcement of minimum prices, etc., does not follow such an optimal contract approach to the letter. However, if we were to consider applying our measure of the value of information to the case of the USDA, progressive taxation and agricultural support payments do approximate the variable payment characteristic of such a contract. Thus, our optimal contract may overstate somewhat the value of information, to the extent that this approximation is not close, but it is clear that the Blair and Romano measure would understate the value of information in such a setting.

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