ACCOUNTING FOR RISK IN LIVESTOCK IMPROVEMENT PROGRAMS

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INTRODUCTION

Several semantic matters are first broached. The title contains several potential ambiguities which should be addressed forthwith. By 'accounting for', it is taken here to mean that risk is not only discussed as to its measurement but also in the context of what can be done about it. "Risk" is another potentially unclear concept. In fact, it is likely to remain so even after the following but, to pin things down a little, risk is taken here to mean 'uncertainty with teeth.' Non-certainty can be described in many different ways and the English language is rich in words in which are often regarded as close synonyms to risky. These include uncertainty, instability and variability. Risk is close to being synonymous with uncertainty but, whereas uncertainty is a very abstract term which might conveniently be taken to mean non-certainty, the point about risk is that it has consequences for human activity and is thus potentially of concern to human decision makers. Much that is unstable and/or variable might also be described as risky if the uncertain consequences cannot be predicted with complete precision (Quiggin and Anderson 1979). Thus, if something is quite variable but highly predictable, it is not risky in the sense used herein.

The next potential ambiguity in the title concerns the word 'in'. This could be interpreted literally and attention then confined to those risks that indeed are inherent in parts of a livestock improvement program (such as uncertainty about a heritability, for instance). Here, however, the term is interpreted in a more catholic spirit which might be approximated as 'in and around' livestock improvement programs (LIPs).

The plan of this non-empirical paper is as follows. First, an attempt is made to conceptualise the relationship between the many different sources of risk in a LIP. This is then followed by a consideration of some issues involved in measuring risk.

This leads to the next section that describes appropriate stances for dealinq with risk and its consequences. The paper is closed by a discussion of insights that emerge from the foregoing.

Lest these introductory remarks convey a false impression of my confidence in my ability to address the topic to hand, let me share the cogent experience of another agricultural economist, George Ladd, who I would prefer was in my place on this Conference program: "I had spent many hours spread over a period of more than a year studying animal breeding textbooks and lecture notes and talking wih animal breeders, and I understood their textbook definitions. I soon came to realise that they all spoke to me as they would to sophomore students in introductory classes, thus I understood them. But when I listened to them talk among themselves, I was confused most of the time, while they all made perfect sense of what they said to each other. On the other hand, even after they had studied economics diligently and lengthily, I was unable to convey to them ideas that were easily understood by fellow economists. The longer the animal breeders and I worked together, the easier it became for us to communicate. But there always remained that perceptible residue of the uncommunicable. It remained because we had relatively few shared experiences. If I had taken some of their laboratory and field experience courses and worked on their exemplars, and they had taken economics courses and worked on economics exemplars, we would have sharply reduced the size of that residue of the uncommunicable."

CONCEPTUALISING RISK IN LIPs

Economists in their seemingly obligatory jargonistic way conceptualise their view of the world through a series of more or less conventional relationships. For production economists, a natural starting point is the technological relationship which is often described as a production function,

$$Y = f(t,X,Z), \tag{1}$$

where
Y represents output of a firm,
f is the production function that captures the productive technology and thus links inputs to outputs,
t denotes genetic traits of animals involved in the productive processes,
X denotes the controllable inputs, and
Z the uncontrollable or stochastic factors of production.

A representation of this type is general but still very simplistic. In particular, all the variables should, more comprehensively, be designated with subscripts that denote time and, especially given the genetic emphasis in the equation, the generation of the animals involved in production. The functional relationship is also driven by other variables that are not mentioned explicitly. One important set of activities that is concealed in the present expression is investment in research on the processes involved. Again, in the context of livestock improvement, this would also involve aspects of biotechnology and techniques for cervical insemination that will surely be important in influencing the rate of change of genetic aspects of the relationship. The sensitivity of the value of LIPs to the cost of A.I. is illustrated, for instance, by Klein and Kehrberg (1981).

The controllable inputs can be classified in various ways. In the present context, one important classification would be the marginal risk effects of different inputs (Griffiths and Anderson 1982). These could fall into three broad categories in terms of the marginal relationships between input X and output Y. These are risk increasing inputs (e.g., stocking rate and perhaps twinning), risk reducing inputs (e.g., vaccines, drought fodder reserves, water improvements), and other inputs that do not influence the riskiness of Y.

The vector Z of stochastic inputs includes such things as climatic effects such as droughts, other natural phenomena such as diseases, and other technological features that are more or less out of the direct control of decision makers running rural enterprise whose productive possibilities are more or less captured in equation (1).

The distinction between variables in t,X,Z is not always very clear. There are grey areas between what is a controllable 'input' and a genetic trait. Consider tick resistance in cattle, for instance. It is possible to think about breeding for greater resistance within a given herd, in which case the variable would be one of the t variables, or purchasing Bos indicus stock as another input, in which case this attribute would be captured more in X. Similarly, control over some inputs is sometimes limited (e.g., forage supply and feed conversion efficiency) in which case the variable might tend to be classified more in Z than in X.

From the perspective of livestock improvement, the production function inevitably features many uncertainties. These include the uncertain performance of given genotypes, the uncertainty surrounding the many parameters that go into a geneticist's conceptualisation of a breeding challenge such as just what values are taken by parameters such as heritabilities and correlations, and the intrinsic uncertainty in the Mendelian roulette itself. In short, equation (1) is riddled with uncertainties and the fact that these are not always recognised explicitly is probably more explicable by difficulties involved in doing so, rather than the lack of importance of such uncertainties in reality.

The production function itself is devoid of economic content and such matters can be brought into play in a second equation which would usually be termed a profit equation:

$$(2) \qquad G = p_y(t)Y - \Sigma p_i X_i,$$

where G denotes profit,

$p_y(t)$ is the unit price of output written in this way to emphasise the possibility that it may well also be determined by genetic traits, and

p_i are input prices.

Uncertainty may enter nearly every component of the profit function. Output prices are notoriously variable and unpredictable and are thus quite risky for most products of animal or other origin. They are often subject to the vagaries of international trade and, even when they are not traded internationally, they are subject to disturbances that arise through changes in consumers' incomes and tastes and thus demands for different products. Thatcher and Napier (1976), for instance, have illustrated the sensitivity of the net value of a sheep improvement program to the international price of wool.

Quality differentials can play a major role in determining price levels and these, in turn, can be critically influenced by genetic factors. This is overtly the case for superior livestock sold for breeding purposes but is also the case for animal products as diverse as wool of varying fibre diameter and meat of varying degrees of fat saturation (Hamilton 1984).

The input prices p are sometimes either completely known or highly predictable and thus do not manifest much degree of risk. This is not always the case, however, as a moment's reflection on the generally unknown real cost of farm credit and drought fodder, for instance, will reveal.

The profit function has seemingly been the main point of departure for geneticists who have endeavoured to account for the economic consequences of their work (Brascamp et al. 1985; Van Vleck et al. 1987). The profit function has been taken as a logical starting point from which to derive 'economic weights' that enter selection indexes. As far as can be observed, such empirical work has always been implicitly based on the assumption that there is no uncertainty in any of the prices involved and various authors talk of using 'good' estimates of long-run price levels to abstract from any short-term variation in the market for the commodity in question (Miller and Pearson 1979).

An analogous and usually risky subtlety in valuing traits that has seldom been accounted for in estimating economic values in breeding is the phenomenon of supply responsiveness by producers. As a valuable (say, productivity-increasing) trait becomes available, producers typically respond by increasing their individual quantities of product supplied to a market and this, in aggregate, usually has the effect of depressing price and thus reducing marginally the economic gains from the genetic improvement (Brennan 1988, p.83). Economic weights in a profit function should thus depend on industry output levels and technological change in general. A similar point is made (but not dealt with empirically) by Ladd and Gibson (1978, p.239) in the context of pig breeding.

The next relationship that must be introduced in order to conceptualise risk in a comprehensive manner is a function that captures the risk and other preferences of decision makers involved. This can be written most straightforwardly as a preference function for an individual producer. Such a function is usually called a utility function, U(G), where U is, in general, a nonlinear function defined over an argument such as profit or perhaps wealth (Anderson et al. 977).

A relationship such as U is a device for capturing the non-neutral attitudes to risk held by producers. Typically, producers are averse to risk to some degree. Such aversion seems to be a fact of life. It can be captured by measures defined in terms of the first two derivatives of U, namely a coefficient of absolute risk aversion, $r = -U''/U'$, and a unit-free coefficient of relative risk aversion, $R = rW$, where the primes denote derivatives, W represents the wealth of the decision maker and according to theory, r diminishes with W.

To make the producers' preference function operational, one additional idea from modern decision theory is required, namely what can most rationally serve as an objective function for a producer who is not neutral towards risk. This is the Bernoullian idea of maximising expected utility: max $E[U]$, where $E[\,]$ denotes the expected value operator, and the expectations are taken with respect to the producer's subjective probability distribution for any uncertain quantities involved in the arguments of the utility function (Anderson et al. 1977). Animal geneticists (e.g., Hazel 1943, Harris 1970) who have used profit functions as the basis for economic and selection indexes have thus implicitly assumed that producers are essentially risk-neutral. This may not have led them too far astray in their work because the expected partial derivatives from the profit function are merely inflated by the product of the marginal utility at the mean level of profit (Just and Pope 1978),

$$(3)\qquad \partial E[U]/\partial t = E[U'(G)\partial G/\partial t].$$

Since it is the relative rather than the absolute value of the economic weights that is most important in the application of selection indexes, little is lost by excluding the marginal utility effect in the computation of such weights.

MEASURING RISK IN LIPs

Moment-based statistics have their limitations in describing probability distributions if the family of the distribution is in any way out of the ordinary. Normal distributions are, of course, described completely by the first two moments and, in this special case, the moments indeed tell all. In more general cases, however, such is not the case and the only way to describe risk adequately and comprehensively is by means of complete probability distributions. For many analytical purposes, the most convenient way of describing a distribution is by means of its cumulative distribution function (CDF). Risk analyses at a high level of generality, which means the analyses that are done if there is some doubt about the function U, are based on comparisons of CDFs of uncertain quantities. The procedures here are usually described as stochastic efficiency analyses and often enable considerable progress to identifying distributions that would not be of interest to quite large classes of decision makers and thus enable the identification of efficient sets of prospects that are of interest (Anderson 1974).

In incorporating explicit attention to risk in LIP work, it would thus in principle be necessary to specify appropriately stochastic versions of equation (1) and also to specify all the probability distributions involved in the random variables in equation (2). This is, in fact, a most demanding task and one to which econometricians have hardly yet done justice. In recent years, there has been considerable attention to estimating stochastic production relationships but most of this has been focused on only the first two moments of the distribution of Y (Just and Pope 1978, Griffiths and Anderson 1982). Even here the methods involve multi-stage nonlinear estimation and, needless to say, there are considerable demands upon data for such enriched estimations. If there is uncertainty about some of the mean effects linking t,X,Z and Y, there is bound to be considerably more uncertainty about the effects of these variables on the higher moments of Y. Empirically, at least, it is easy to understand why animal geneticists have not given a great deal of attention to risk effects in the economic dimensions of their work.

DEALING WITH RISK

The most straightforward way of addressing risk would be to deal explicitly with selecting for traits that are risk-reducing. Essentially, this means extending the concept of economic values for weights beyond those that would normally be included in a profit function. Some of the effects would not normally get very explicit treatment in a riskless or deterministic profit function as seems to be standard practice. A further implication of such work that is designed to moderate the effects of risk and thus make the breeding work more useful to risk-averse agents would relate to the strategy for selecting superior animals in appropriate environments. If it is desired to breed a more drought-tolerant animal, this will not likely be achieved by making selections under very favourable, possibly even continually hand-fed nutritional regimes. There has been much more work done in plant breeding than in animal breeding of this type (Anderson and Hazell 1989; Brennan 1988). Plant breeders perhaps more readily accept the costs of selecting in adverse environments for such attributes.

A general result that comes out of the economics of dealing with risk-averse individuals is that, ceteris paribus, they will prefer relatively diversified portfolios of assets. Taking this to the level of animal breeding strategies, this means that they will derive some risk-reducing benefits from such strategies as having more lines than would otherwise be optimal in their animal genetic portfolio and will probably also run more diversified enterprises in terms of species as well as of lines. The cautious behaviour induced by risk aversion may also lead people to adopt conservative strategies with regard to genetic resources, which might explain the seeming irrationality of some people clinging to traditional lines of animals and being very cautious about stocking new, presumably superior, materials, even if they could seemingly afford to purchase the phenotypic expressions of such novel genes for their own exploitation.

The conjunction of AI technology and the centralisation of sire selection associated with BLUP and related methods enlarges to new levels of potential significance risks that have always prevailed in LIPs, albeit probably at inconsequential levels at traditional intensities of selection. These are the 'risks' or 'costs' of the wrong decision. Good decisions are those that make good use of information available at the time of decision. In an uncertain world, however, there is no guarantee that the outcomes will be 'good' and if, indeed, a very widely used sire proves to have been an unfortunate choice, the impact of the once-good (even best) decision may be large and negative.

Normatively speaking, there is not too much that can be done about this class of risk. Research directed at improving the precision and uniformity of breeding values may lessen such risks generally, but this has its own costs that, a priori, are not necessarily covered by the risk-reducing benefits. Similarly, more extensive progeny testing to refine genetic information must be approached tentatively in a cost (including costs of delayed use of sires) benefit (including benefits from making decisions that are better on average) sense. All such work on valuing

information in the context of risky decision making falls logically into the framework of decision analysis (Anderson et al. 1977; Byerlee and Anderson 1988), which is not to say that such analysis itself is straightforward and costless.
The above consequences of private risk aversion also potentially carry over to public animal breeding programs. The 'good news' here, however, is that these tend to be very modest in their influence, given the diversified nature of most animal breeding in an economy (Anderson 1983). It is hard to imagine a particular animal breeding exercise having an impact on a very significant fraction of, say, the Gross National Product. The social accounting of risk aversion is much influenced by the size of the enterprise relative to the national economy and, because of this typically small effect in animal breeding work, animal geneticists working in the public domain can, for all intents and purposes, neglect social risk aversion as a friction in their work.

CONCLUSION

What then is the appropriate stance for LIP workers in their accounting for risk? It seems that risk indeed represents considerable trouble to deal with and the advantages of dealing with it are probably rather minor. It can reasonably be hypothesised that the optimal attention to risk amongst animal breeders generally is approximately zero, as is implicitly the case in most work in the field (e.g., Thatcher and Napier 1976; Ladd and Gibson, 1978; Melton et al. 1979; Thompson 1980; Cunningham 1982).

One situation where this may not be true is in cases where there are multiplicative interactions between uncertain variables in a profit function. This could well be the case, for instance, where product prices and productivity are both uncertain and are both under the influence of genetic manipulation. The expected values of the partial derivatives that might serve as economic weights would thus need to be appropriately assessed to allow for the fact that the mean of a product of random variables is not the product of their means, unless they are stochastically independent. It may thus be worth doing some risk accounting to get improved values of the expected values that should enter a deterministic selection index.

More generally, consideration of the issue from first principles suggests that risk will not figure importantly in genetic selection work. Its effects are probably of orders of magnitude less than the mean effects that are the subject of attention in conventional analyses.

It thus seems that, while raising interesting methodological and even some potential empirical issues, it is probably premature to invest much in the way of resources dealing with risk in LIPs.

It would, however, be of advantage to have some detailed case studies to back up this judgement from the foregoing rather peripheral and theoretical consideration of the matter. Such work does not seem to be vigorously in hand at this stage and so observers such as the present one must be patient if they are to be either perspicacious or profound.

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