Technology and Uncertainty: Evidence from Egypt

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Abstract: An important question in the agricultural development literature is the relation between technology and production uncertainty. In this paper, a flexible, moment-based approach to production analysis is used to measure the technological determinants of production risk of Egyptian summer field crops. The inputs associated with modern technology—fertilizer and mechanical power—are risk reducing, meaning that risk need not be a limiting factor in technology adoption. More studies of stochastic technology in diverse environments are needed to establish empirical regularities in the relation of technology to production uncertainty.

Introduction

The agricultural development literature has long referred to production risk as a potentially important influence on producer behaviour and thus a determinant of technology adoption and productivity (Roumasset, Boussard, and Singh, 1979). Despite much theoretical research on the behavioural implications of production risk, only recently have production economists attempted to measure the determinants of production risk. Consequently, empirical regularities of the sort that have been established with respect to conventional "mean" production functions have yet to be established for production risk relationships. For example, it has been hypothesized that risk attributes of modern technology (or farmers' perceptions of them) may differ from those of traditional technology (e.g., Feder, 1982). That may be especially true when human capital, infrastructure, and institutional development constrain the transmission of technical information to farmers. That line of reasoning implies that risk averse farmers may underinvest in new technology. On the other hand, if relatively low cost technical information were available, or if the technology were to help farmers counter uncertainties such as weather and pests, modern technology could be less risky than the traditional technology.

One explanation for the dearth of information about production risk and its determinants is the lack of accurate farm level production data for the measurement of factors determining production risk; another explanation is the lack of statistical methods to quantify the relevant relationships. Until the mid-1970s, risk research relied on the application of the "method of moments" to pooled cross section and time series data from yield experiments (Day, 1965; Anderson, 1973; and Roumasset, 1976). That approach is not applicable with a single cross section of survey data and is difficult to use even with a number of cross section observations (Anderson, 1974).

More recently, econometric production models have been utilized in the production risk measurement problem. Just and Pope (1978) proposed a heteroscedastic error model that provides a flexible mean-variance representation of a stochastic production function. That model has been applied to Day's experimental data by Just and Pope (1979), to Australian data by Anderson and Griffiths (1982), to Paraguayan data by Nikiphoroff (1981), and to Egyptian data by Odhiambo (1983). The present author developed a general flexible representation of the probability distribution of output (based on the distribution's moments) and an associated econometric methodology (Antle, 1983). That methodology has been applied to California dairy production data (Antle and Goodger, 1984) and to Paraguayan data (Nikiphoroff, 1981).

In this paper, the flexible, moment-based approach is used to model and measure the determinants of farmers' net returns from production activities in a multiproduct framework. Previous studies modelled production risk in a single product framework. The present approach is proposed as a feasible, flexible methodology for the measurement and testing of production risk relationships using production survey data and as appropriate to the multiproduct technologies typically found in developing agricultures. The present approach is illustrated with results from Egyptian field crop production. Egypt provides an example where new mechanical and fertilizer technologies have been widely diffused.

The Decision Model

Farmers are assumed to be economically rational in the sense that one objective of their production input decisions is to maximize the economic returns to those resources. For simplicity of exposition, the farmer's preference function is assumed to be separable in net returns from other variables. Thus, for production decisions, the objective function is:

$$max\ EU[\pi;\omega] = \int U[\pi;\omega]f(\pi \mid x,z)d\pi = u[x,z;\omega]\ ,$$

where:
$U[\pi;\omega]$ is the farmer's utility function,
$\omega \equiv$ utility function parameters,
$\pi \equiv$ net returns to crop production,
$x \equiv$ vector of variable inputs,
$z \equiv$ vector of fixed factors, and
$f(\pi \mid x,z) \equiv$ probability distribution of net returns.

Observe that the risk attributes of the multiproduct technology are embodied in the net returns distribution $f(\pi \mid x,z)$, which is conditioned on inputs and fixed factors. Since the elements of net returns are defined as finite real numbers, the distribution of net returns is uniquely determined by its moments, or approximated in terms of the first m moments (Kendall and Stuart, 1977). Defining the mean of net returns as:

$$\mu_1[x,z] = \int \pi f(\pi \mid x,z,)d\pi\ ,$$

and the ith moment of net returns as the function:

$$(1)\ \ \mu_i[x,z] = \int (\pi-\mu_1)^i f(\pi \mid x,z)d\pi,\ \ i > 1\ ,$$

an approximation to $EU[\pi]$ is:

$$V[\mu_1,\ \mu_2\ ...,\ \mu_m]\ .$$

To draw inferences about the risk attributes of the technology, therefore, the moment functions (1) must be estimated, and the properties of $V[.]$ must be established. In the application below, a three-moment model is used. In this case, assuming risk aversion and downside risk aversion on the part of farmers implies:

$$\partial V/\partial\mu_2 < 0\ \text{ and}$$

$$\partial V/\partial\mu_3 > 0\ .$$

Econometric Estimation of the Moment Functions

The moment functions (1) are specified as linear-in-parameters flexible function forms:

$$\mu_i = X\gamma_i\ ,$$

where X is a vector of known functions of the variable inputs x and the fixed factors z.
Defining:

$$\pi_1 \equiv \pi\ \text{and}$$

$$\pi_i \equiv (\pi-\mu_1)^i\ ,\ \text{then:}$$

$$(2)\ \ \pi_i = \mu_i + \epsilon_i = X\gamma_i + \epsilon_i\ ,$$

where:

$E(\epsilon_t) = 0$.

That is, a random variable π_t can always be written as its expectation μ_t plus a random variable ϵ_t with expectation zero. The econometric problem is to obtain estimates of the γ_t with desirable properties. The solution to this problem is found in Antle (1983), where it is shown that a feasible generalized least squares estimator of γ_t can be obtained that is consistent and asymptotically normally distributed. Thus, by viewing the moment model (2) as a regression model, all conventional large sample test procedures can be utilized to draw inferences about the risk characteristics of the technology.

Production Risk in Egyptian Summer Field Crops

The above moment-based methodology was applied to data from Egyptian summer field crop production. The data are described in detail in Antle and Aitah (1985) and represent the 1981 maize, cotton, and rice production of 267 farms surveyed in 12 villages in the Nile Delta. Those are the three major summer field crops in much of the Delta Region. The net returns from those crops were calculated by subtracting from gross revenue the value of labour (family and hired), fertilizers (nitrogen and phosphate), animal power, and mechanical power (tractors and irrigation pumps). The moment functions (1) were specified as quadratic functions of the quantities of labour (in hours per season), animal power (in hours per season), mechanical power (in hours per season), fertilizer (in kg), and land. Regional dummy variables were included to account for location effects on production risk.

Table 1 summarizes the findings from GLS estimation of the second and third moment functions. The table contains the elasticities of the moments with respect to the inputs (calculated at the sample means of the data) and their standard errors. Assuming that Egyptian farmers are risk averse and downside risk averse, any input that reduces the second moment and increases the third moment of net returns is clearly a risk reducing input. Similarly, an input that increases variance and reduces the third moment is clearly risk increasing. However, other combinations of effects on the second and third moments cannot be interpreted as risk reducing or increasing without parameterizing the utility function.

A striking implication of Table 1 is that the modern inputs—fertilizer and mechanical power—are risk reducing. Mechanical power has a statistically significant negative effect on the second moment (variance) and a statistically significant positive effect on the third moment (skewness). Fertilizer has a significant negative effect on variance and a negative effect on skewness, but the latter is insignificant. Thus, in the case of Egyptian summer field crop production, modern technology is not associated with increased production risk. Table 1 also suggests that the traditional inputs (land and labour) are more likely to be risk increasing (only the positive variance effects of those inputs are statistically significant).

The coefficients of the regional dummy variables in the moment functions (not reported here) showed statistically significant different risk characteristics for the six regions represented in the data. Those differences represent soil, water, and other systematic technological differences in the regions not explicitly accounted for in the other variables.

Table 1—Elasticities of Second and Third Moments of Net Returns with Respect to Inputs

Moment	Fertilizer	Hired Labour	Land	Animal Power	Mechanical Power
Second	-0.2183	1.3325	0.6718	-0.2425	-0.3392
	(0.1947)	(0.3080)	(0.3215)	(0.1301)	(0.1089)
Third	-1.2360	1.5231	2.9645	-1.0199	2.4363
	(1.5178)	(1.9936)	(2.2569)	(0.9963)	(0.7631)

[Note: Standard errors in parentheses.]

Conclusions

The flexible, moment-based approach to production analysis was adapted to measure the determinants of net returns risk in Egyptian summer field crop production. The findings showed that the inputs associated with modern technology—fertilizer and mechanical power—were risk reducing, giving evidence that modern technology need not be risk increasing and, thus, that production risk need not be a constraint to technology adoption. Similar conclusions were reached by Roumasset (1976) in his study of Philippine rice production, but the evidence was mixed in the studies by Nikiphoroff (1981) and Odhiambo (1983). Thus, the accumulation of more empirical evidence on the risk attributes of modern technology in diverse environments is needed before one can determine whether any generally valid empirical regularities or "stylized facts" about technology and uncertainty exist.

Note

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