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SUBJECTIVE PRODUCTION FUNCTION PARAMETERS AND RISK: Wheat Production in Tunisia

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ABSTRACT

SUBJECTIVE PRODUCTION FUNCTION PARAMETERS AND RISK:
Wheat Production in Tunisia, by

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It is maintained that, at the time of seed bed preparation for the production of durum wheat, Tunisian farmers form subjective estimates of the parameters of the underlying production function. If their estimates are not accurate resources are not optimally allocated. If farmers behave as though their estimates are not known with certainty, they face risk. Based on a survey of 125 Tunisian farmers, the parameters of the underlying production function and farmers' subjective estimates of these parameters are estimated. The level of farmers risk aversion is also estimated. The results suggest that, at seed bed preparation, Tunisian farmers overestimated the yield they would obtain at harvest, but that the cause of this over-estimation was unusually low rainfall. Otherwise, farmers appeared to correctly perceive the true parameters. Years of experience are found to affect farmers subjective estimates. The results also suggest that about 80 percent of the farmers in the sample are risk averse and discount the market price for durum wheat of 7.1 dinars by sample average of 1.2 dinars per quintal. The method used in the study is unique and appears to be a reasonable approach to measure and identify the cause of allocative errors, risk and the value of information to farmers which results in more accurate subjective estimates of the parameters of the true underlying technology.

SUBJECTIVE PRODUCTION FUNCTION PARAMETERS AND RISK: Wheat Production in Tunisia

by

Terry Roe and David Nygaard*

I. INTRODUCTION

This paper focuses on the problem of decision making when the parameters of the underlying technology are either unknown or are not known with certainty by producers. This problem is considered within the context of Tunisian durum wheat production in Northern Tunisia where farmers' ability to accurately perceive the input-output characteristics of both old and new varieties is important to increasing allocative efficiency, decreasing subject risk and encouraging the adoption of high yielding varieties under uncertain climatic conditions.

In this paper it is maintained that producers allocate resources based on, among other factors, their subjective estimates of the parameters of the underlying technology. If their estimates are not accurate,and/or if producers behave as though their estimates have some subjective distribution about the true parameters of the technology, then subjective risk and allocative errors can occur. This gives rise to the value of information and experimentation yielding improved estimates of the unknown parameters.

Previous contributions in this area have, generally speaking, tended to either focus on the worker and allocative effect of cognitive variables [see for instance the contributions of Fane (1975), Khaldi (1975) and more recently

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Wu(1977) and Hoffman (1977)] or the effect on resource allocation of risk and uncertainty. The former contributions have clearly established the importance of education to increasing the allocative and worker components of economic efficiency. These efforts have relied on cost minimization or, in the case of Wu and Hoffman, profit maximization frameworks. Contributions in the area of risk and uncertainty include those of Moscardi and de Janvry (1977), Woglin (1975), Binswanger (1978) and Office and Halter (1964). These studies have generally found producers to be risk averse where the source of the uncertainty is weather and/or prices. An exception is the work of Hiebert (1974). He shows that as a risk averse decision maker obtains more information on a technology, he is likely to use more of it.

A conceptual framework is developed which incorporates elements of both the above mentioned focuses and, in some respects, resembles the approach of Heibert. Upon briefly discussing the Tunisian survey data used in this study, the conceptual framework is presented. Then, based on 125 observations from the survey data, both the parameters of the true production function and producers' subjective estimates of these parameters are estimated. A comparison of the true and subjective parameters are shown to yield important insights into causes of allocative efficiency. Finally, producers' subjective estimates of the true parameters are used to estimate producers' risk preferences in a manner similar to that of Moscardi and de Janvry. The results suggest that the majority of producers are risk averse.

II. DATA

The data is based on a sample survey of 125 farmers in northern Tunisia during the 1976/77 crop year. Farmers in the sample averaged about 27 hectares planted to wheat and ranged in size (total hectares owned and operated) from two to 381 hectares. Each producer was interviewed twice during the crop year. The first interview occurred at the time of seed bed preparation when most of the variable inputs are allocated to wheat production. It was at this point that producers' subjective expectations were solicited. Producers were requested to provide, along with other objective and subjective information, the yield they expected to obtain at harvest, given the level of variable inputs they had and were in the presence of applying and assuming that normal weather conditions prevail during the growing season. Each farmer was interviewed again at harvest. Along with other data, information on yields actually realized was obtained.

Finally, for purposes of interpreting the empirical results, it is important to point out that during the 1976/77 crop year, rainfall after the time of seed bed preparation was far below normal for the entire northern portion of the country. Based on estimates from the Tunisian Ministry of Agriculture, durum wheat yields in northern Tunisia averaged 13.8 quintals per hectare for the 1975/76 crop year, but only 9.1 quintals for the 1976/77 crop year. The average actual yields obtained based on the survey data is 9.388 quintals per hectare. But farmers expectations were based on normal weather conditions. The sample average of their expected yields is 13.195 quintals per hectare, which exceeds the yields obtained by 3.807 quintals per hectare.

III. CONCEPTUAL FRAMEWORK

We assume the physical correspondence determining the production of a single output Y (durum wheat) for all producers in any given crop year as

$$(1.0) \qquad Y = f(X,m)\varepsilon$$

where X is a vector of k* control and q-k* noncontrol inputs, m is a nonstochastic vector of parameters and ε is a disturbance term. It is assumed that $\partial Y/\partial X > 0$

and $\partial^2 Y/\partial^2 X < 0$ for $k = 1, \ldots, k^*$. With some exception, (e.g., Hiebert, 1974), it is generally assumed that producers have at least perfect knowledge of m in (1.0). However, this may not be the case in general, especially for new varieties and techniques.

Our approach is to assume that a producer formulates a subjective density on the parameters m of (1.0) which permits the specification of the following subjective (or behavioral) production function.

(2.0) $$Y_n = f(X, m_n)\nu_n$$

where m_n and ν_n are the n-th producers' subjective estimate of the parameters in (1.0) and Y_n is subjective output of durum wheat. It is also assumed that $\partial Y_n/\partial X > 0$ and $\partial^2 Y_n/\partial^2 X < 0$. This formulation permits a subjective estimate of the parameters of (1.0) for each of n producers, but restricts them to the same general functional form (f). Each producer is assumed to behave as though his estimates m_n, ν_n, are the true parameters of (1.0), when in fact the estimates may unknowingly differ from the true parameters in (1.0). In this paper, we report on the results from fitting both (1.0) and (2.0) to data on Tunisian wheat production.

Since (1.0) is unknown to the producer, his choice of input levels depends on (2.0). If the parameters of (2.0) differ from (1.0), if the level of the q-k* uncontrollable variables differ from their expected level and/or the producer is not risk neutral, then allocative errors in the k* control inputs can occur. Because we wish to concentrate on the effect of uncertain parameters relative to decisions which only consider ε as random, in this section of the paper we assume that all uncontrollable variables q-k* are known with certainty at the time the n-th producer chooses the level

(X_n^o) of the k* control inputs. Throughout the paper, we assume that product (P) and input prices P_k, k=1, ..., k* are known with certainty.

Each producer is assumed to be a mean-variance expected utility maximizer with expected utility of gains and losses $E[U_n]$ to the n-th producer given by

$$(3.0) \qquad E[U_n] = U(E[\pi_n], V[\pi_n])$$

where $V[\pi_n]$ denotes variance of profit and expected profit $E[\pi_n]$ is[1/]

$$E[\pi_n] = PE[Y_n] - \Sigma_k^{k*} P_k X_{kn}$$

Expected utility (3.0) is maximized when the q-k* input levels X_n^o are chosen such that

$$(4.0) \qquad \Phi \partial V[\pi_n]/\partial X_{kn} = P\partial E[f(X, m_n)\nu_n]/\partial X_{kn} - P_k$$

where it has been shown by others that

$$(4.1) \qquad \Phi \equiv \{- \frac{\partial E[U_n]}{\partial V[\pi_n]} / \frac{\partial E[U_n]}{\partial E[\pi_n]} \gtreqless 0\} \begin{array}{l}\text{risk averse}\\ \text{risk neutral}\\ \text{risk preferred}\end{array}$$

If the producer behaves as though the parameters of (1.0) are <u>not</u> known with certainty, the subjective parameters m_n, ν_n are independent, there is no serial correlation in ν_n, and the subjective density on m depends only on past observations and a prior density, then the subjective variance of Y depends and the subjective variance of the parameters m_n and ν_n. In this case, the subjective variance $V[\pi_n]$ is of the form:

$$(5.0) \qquad V[\pi_n] = P^2(E[f(X,m_n)]^2 V[(\nu_n)] + E[\nu_n]^2 V[f(X,m_n)] + V[f(X,m_n)]V[\nu_n])$$

1/ The specification of (3.0) can be viewed as a second order Taylor series approximation of a constant risk aversion utility function. If Y_n is log normal, then π_n follows a log normal distribution. Levy (p. 610) shows that mean variance analysis applied to a log normal distribution is a sufficient decision rule. A both necessary and sufficient decision rule for all non-decreasing concave utility function is $E[\pi_n]$, variance log π_n (Levy, p. 611). In this case, $V[\log \pi_n]$ is substituted for $V[\pi_n]$ in (3.0) and the analysis remains essentially unchanged.

If the agent behaves as though m is known with certainty (even though $m_n \lesseqqgtr m$) then $V[f(X,m_n)]$ equals zero and (5.0) reduces to the form considered by Pope and Just (1977). Otherwise, it is possible for the right hand side of (4.0) to be negative.

Suppose the subjective parameters in (2.0) can be estimated. Then it is possible to estimate the risk discount factor $\Phi \partial V[\pi_n]/\partial X_{kn}$ for each producer from (4.0). The procedure and results for estimating both (1.0) and (2.0) and the risk discount are presented below.

IV. STATISTICAL FRAMEWORK AND EMPIRICAL RESULTS

Based on (6.2), observations Y_n^θ and X_n^o should permit OLS estimation of the parameters of the "true" function (1.0) since ε is only related to ν_n in the case of perfect knowledge of (1.0). The functional form selected for (1.0) is:

$$(1.1) \qquad Y_n^\theta = me^{\delta_1 D_1 + \delta_2 D_2} \prod_{k}^{k*=4} X_{kn}^{o\,m_k} \varepsilon_n, \quad \varepsilon \sim ILN[e^{\frac{1}{2}\sigma},\ e^{\sigma}\ (e^{\sigma} - 1)]$$

where Y_n^θ denotes quintals of durum wheat harvested, D_1 equals 1 if "good soil" in agronomists opinion and zero otherwise, D_2 equals 1 if normally high rainfall zone and zero otherwise, X_1^o denotes kilograms of elemental phosphate, X_2^o denotes kilograms of elemental nitrogen, X^o denotes monetary value in dinars of labor and mechanical inputs (these include deep plowing, disking, planting and harvesting), X_4^o denotes hectares of land planted to durum wheat, and σ is variance of log Y_n^θ. Two problems arise in estimating the parameters of the subjective function (2.0); (a) obtaining observations on the subjective value of the dependent variable (Y_n^o) and (b) estimation of the subjective parameters m_{kn}, ν_n which can, in principle, vary with each producer.

Subjective observations (Y_n^o) were obtained directly from producers at the time of seed bed preparation and seeding as pointed out above. Since the studies cited above found that information and cognitive related variables e.g., experience and education, affect producers allocative efficiency, to resolve (b), it is reasoned that these variables affect producers prior subjective estimates of the parameters m. The functional form selected for (2.0) is

$$(2.1) \qquad Y_n^o = m_o e^{\beta_1 D_1 + \beta_2 D_2 + \alpha_1 Z_1 + \alpha_2 Z_2} \prod_k^{k*=4} X_{kn}^{o\; m_{ok} + m_{k1} Z_1 + m_{k2} Z_2} \nu_n$$

$$\nu_n \sim \text{ILN}(e^{\frac{1}{2}\psi},\ e^{\psi}(e^{\psi} - 1))$$

where: Y_n^o denotes farmers expected production of durum wheat, in quintals, $D_1, D_2, X_1^o, X_2^o, X_3^o, X_4^o$; as defined in (1.1) above, Z_1 denotes education of farmer, in years of schooling, Z_2 denotes the inverse of years of farmers experience with the variety, and ψ is variance of log Y_n^o. This specification unfortunately restricts farmers with equivalent years of schooling and experience to similar prior parameter densities. Perhaps more unsettling assumptions are that each producer's estimate of the variance is ψ and that X_n and ν_n are independent when (4.0) suggests otherwise. However, in practice it is unlikely that producers fine tune their resource allocation decisions to the point where (4.0) holds exactly, but rather, only approximately with some independent, random deviation. In this case, a construction along the lines of Zellner <u>et. al</u>. (1966) can be used to demonstrate the independence of X_n and ν_n. For this reason and purposes of simplicity, (2.1) is fit to data by the method of OLS.

The results from fitting (1.1) to Tunisian farm survey data appear in the first column of Table 1. The coefficients (m_{kj}) corresponding to the effect of education and experience on farmers' perceptions of the productivity of the input variables were not significantly different from zero. Consequently the ($m_{kj}Z_j$) components of (2.1) were purged. The results from fitting (2.1) to the data with these components purged from the input variables appear in the second column of Table 1. Both functions appear to fit the data reasonably well. The Goldfeld-Quant test for homoscedasticity cannot be rejected either in the case of (1.1) or (2.1).

With three exceptions, the coefficients of the subjective function are of similar relative magnitude to those of (1.1) and, based on the t-test, both are approximately homogeneous of degree one. Two exceptions are the constant term (m_o) and the coefficient (δ_{01}) of the zone variables which are larger in the subjective function. This is consistent with the observation that, because of unusually low rainfall during the growing season of the 1976/77 crop year, producers' yield expectations at planting exceeded the yields realized at harvest. The third exception is the coefficient of nitrogen fertilizer.

If the subjective function accurately reflects production conditions in a normal year, i.e., farmers prior knowledge of the coefficients of the true function in a normal year are accurate, then a comparison of the two functions suggest that good soil (δ_1) appeared to contribute slightly more to yield than farmers expected, as did the resources allocated to seed bed preparation (m_3), while nitrogen (m_2) apparently had no significant affect on yields in this particular year, contrary to farmers expectations (m_{02}).

The only cognitive related variable that appeared to affect farmers' prior knowledge of the parameters of (1.1) is years of experience. The results suggest that as a farmers' years of experience with this variety increase, their expectation of its productivity in a normal year also increases in an input neutral manner. The result that education and experience do not significantly affect the input parameters (m_{k1}, m_{k2}) of the subjective function is, in retrospect, not surprising. The variety of durum wheat upon which the results in Table 1 are based has been used by farmers in the sample for an average of 4.6 years. However, Gafsi and Roe (1979) found that among old and new varieties of durum wheat, differences in production functions only appeared to occur in the constant term; their slope coefficients being approximately equal. In this case, farmers may be sufficiently knowledgeable of the parameters of (1.1) in a normal year so that additional years of experience have either no or very little affect on changing their estimates of the slope coefficient (m_k) in (1.1).

It should be clear that if farmers make resource allocation decisions based on their subjective beliefs (2.1) when in fact (1.1) obtains, allocative errors occur. The measurement of these errors based on the above theoretical framework and their relationship to other firm-household characteristics is the subject of a forthcoming paper.

The next step is to estimate the risk discount ($\Phi \partial V[\pi_n]/\partial X_{kn}$) by deriving the expected marginal value product from (2.1) at the level of observed input use (X^o_{kn}) and prices for each farmer, substituting this value into condition (4.0) and solving the resulting system of equations. However, land was not included in this system because of the problem of estimating land price for each producer. A summary of the results appears in table 2.

Based on 125 observations and three inputs for each producer the mean value of the risk discount obtained is 1.164 dinars (Table 2), and implies risk averseness. In other words, because of risk, producers discounted the market price of 7.129 dinars per quintal by a sample average of 1.164 dinars at the time of seed bed preparation. About 79 percent of the estimates were positive, suggesting risk averseness. Measures of skewness and kurtosis suggest that the distribution of the risk discount estimates are slightly skewed to the left of the mean and, relative to the normal distribution, slightly "flat" about the mean.

V. CONCLUSIONS

This paper focused on the problem of resource allocation when the parameters of the underlying technology are not known with certainty. This problem becomes more acute if the parameters of the underlying technology vary in some complex manner, in the case of wheat, with yearly weather, soil moisture, disease and other soil-atmospheric conditions affecting plant growth. We maintain that producers make decisions on the basis of their subjective estimates of the "true" production function parameters, so both the "true" and subjective parameters are estimated using data from a sample of 125 Tunisian wheat producers for the crop year 1976/77. Based on the subjective parameter estimates and the assumption of an E-V indifference system, a risk discount was estimated for each producer. The results appear reasonable, consistent and provide insights to sources of allocative error. Perhaps more important, the method developed appears to be a reasonable approach to the measurement of allocative error, risk, the value of information and the identification of information and cognitive variables affecting farmers expectations of the parameters of the underlying technology.

Table 1. Results from Fitting (1.1) and (2.1) to Farm Level Data

Coefficients; Variables	True Production Function (1.1)		Subjective Production Function (2.1)	
	Coefficient	t Statistic	Coefficient	t Statistic
m, m_0; constant term	.7595	(4.8)	1.3882	(17.3)
δ_1, δ_1; soil	.3959	(2.9)	.3604	(6.2)
δ_2, δ_2; zone	-.2987	(2.3)	.2966	(5.7)
α_1; education			.0032	(0.1)
α_2; 1/yrs. experience			-.2054	(2.3)
m_1, m_{01}; phosphate	.1031	(2.4)	.0406	(2.3)
m_2, m_{02}; nitrogen	-.0134	(0.3)	.0645	(3.7)
m_3, m_{03}; mach.-labor	.1856	(3.0)	.1063	(3.7)
m_4, m_{04}; land	.7874	(7.6)	.8301	(18.6)
R^2	79.0		93.2	

Table 2. Summary of Risk Discount Estimates for 125 Tunisian Durum Wheat Producers

	Mean (dinars)	Percent of Estimates indicating Risk Averseness	Variance	Skewness (<.5)	Kurtosis (<3.)
Risk Discount $\Phi \partial V[\pi_n]/\partial X_{kn}$	1.164	79.3	5.894	.268	2.379

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