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WHEAT, ALLOCATIVE ERROR AND RISK: NORTHERN TUNISIA

PERSONAL AUTHORS - ROE, TERRY
NYGAARD, DAVID

CORPORATE AUTHORS - MINN. UNIV. ECONOMIC DEVELOPMENT CTR.

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ECONOMIC DEVELOPMENT CENTER
Department of Economics, Minneapolis
Department of Agricultural and Applied Economics, St. Paul

UNIVERSITY OF MINNESOTA

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by

**Terry Roe**

and

**David Nygaard**

Department of Agricultural and Applied Economics
University of Minnesota
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## I. INTRODUCTION

This report seeks to contribute to the understanding of the factors influencing the extent and efficiency of resource use in wheat production in Northern Tunisia. It builds upon the results of Gafsi (5), Gafsi and Roe (6) and otherwise contributes to the studies (2, 3, 7, and 20) sponsored by CYMMIT in other parts of the world. Previous approaches, e.g., Moscardi and de Janvry (13), Wolgin (21), and Binswanger (1) have focused on the influence of farmers' risk attitudes and the importance of these attitudes on their resource allocation behavior. Other contributions have focused on the efficiency of resource allocation and factors (such as cognitive variables and access to information) influencing allocative efficiency. These include the contributions of Fane (4), Khaldi (11), Wu (22), and Hoffman (9). The methodological contribution of the study lies in integrating, in a single theoretical framework, the effects of both risk and farmers' knowledge of production characteristics on the overall efficiency of resource use.

Essentially, the findings from Gafsi's study and the later elaboration and extension of these findings by Gafsi and Roe are:

1. During the 1972/73 crop year, high-yielding durum wheat varieties were found to be technically neutral in input productivity. They appeared to produce a yield increase of about 16% over the ordinary varieties with the same level of input use.
2. The high-yielding soft wheat varieties were found to be inferior to the old soft wheat varieties at low levels of fertilization and seedbed preparation, but at higher levels of input use, they clearly outyielded the old soft wheat varieties. Evidence also suggested that the new soft wheat varieties were more susceptible to weather and rainfall conditions than were the old varieties.
3. Similarities among the factors influencing farmers' adoption of both the high-yielding soft and durum wheat varieties appeared to include (a) household taste or palatability preferences for the ordinary varieties and (b) whether farmers owned and operated hilly-rocky land or valley land.
4. Dissimilarities in the factors influencing farmers' adoption of the high-yielding durum and soft wheats were that: (a) farmers required more experience at using purchased inputs and required more time to experiment with the new soft wheat varieties before they would adopt them, (b) the use of mechanical traction in seedbed preparation was associated with the use of high-yielding soft wheats but the use of mechanical traction was not a prerequisite for the adoption of high-yielding durum wheat varieties, and that (c) access to high-yielding durum wheat seeds and the availability of credit significantly influenced farmers' adoption of the durum wheats but did not influence their adoption of the high-yielding soft wheats.

While these studies provide essential insights, several important questions remain unanswered. Some of these are: How economically efficient are Tunisian farmers in allocating chemical, labor and capital inputs to the production of ordinary and high-yielding varieties of wheat? What factors explain or account for input-output efficiency differences among farmers? More specifically, do farmers' risk attitudes affect their allocation of inputs and, hence, the input efficiency of wheat production, or for that matter, the area planted to new wheat varieties? If so, what farm and farmer characteristics are most important in explaining farmers' risk attitudes? This study provides insights to these questions for the case of ordinary high-yielding varieties of durum wheat. The specific objectives of study are:

1. to obtain insights into farmers' knowledge of the production surfaces of both high and ordinary-yielding varieties of durum wheat;
2. to explain how farmers' knowledge affects the resource allocation errors they make in producing durum wheat;
3. to ascertain farmers' risk attitudes and whether they perceive the high-yielding varieties to be riskier to produce than ordinary varieties; and
4. to assess whether risk attitudes affect resource use and to obtain insights into the factors associated with these attitudes.

Results from the study stress the importance of farm level programs designed to increase farmers' knowledge of the production surfaces of the high and ordinary yielding varieties and knowledge of the yield variability caused by weather conditions. The results suggest that ordinary varieties play an important risk-diversification role for some farmers, and hence, policies should not be designed to discriminate against their use. The results also suggest that additional research and consideration be given to crop insurance as a means of decreasing the risk of unfavorable rainfall conditions. The results also provide important insights to plant breeders.

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*Professor, Department of Agricultural and Applied Economics, University of Minnesota and Agricultural Economist, ICARDA, Aleppo Syria, respectively. The assistance and support of Ali Ben Zaied Salem, Professor of Economie Rurale, INAT, Tunis, Tunisia is acknowledged. The funding for this research was provided by the Economic and Sector Planning Branch of the Development Support Bureau, USAID.

The study is based on a sample survey of 125 farmers in Northern Tunisia. The survey was administered during the 1976/77 crop year. The nature of the sample and important aspects of Tunisian wheat production are discussed in section II.

The methodological procedure involves the fitting of two different sets of durum wheat production functions to the survey data. One set of functions attempts to capture the true physical correspondence between the yields farmers obtained at harvest and the levels of fertilizer, machinery services and land planted to high and ordinary yielding durum wheat varieties. The second set of functions attempts to capture the physical correspondence between yields that, at the time of seedbed preparation, farmers *expected* to obtain at harvest. A maintained hypothesis is that a comparison of the estimated true relationships with farmers' expectations as to what these true relationships are, serves to reveal farmers' knowledge of the true relationship and explain the errors they committed in resource allocation for durum wheat.

Based on these functions, the magnitude of allocative errors is estimated and the factors associated with these errors are evaluated. This analysis is presented in section III. In section IV, estimates of farmers' risk preferences are derived and the effects of risk on yields and area planted to high-yielding varieties is evaluated. Section IV concludes with an evaluation of factors associated with farmers' risk preferences. Summary and implications of this study are presented in the final section of the paper. The conceptual framework and a discussion of alternative measures of allocative efficiency is presented in Appendix A.

## II. SETTING

This section focuses on the Tunisian wheat sector and provides a background to support the analysis and results presented in the following sections. This section is organized into three parts. The first outlines some general characteristics of the Tunisian wheat sector and emphasizes those that apply to this research. The second section describes the sampling technique and the interview procedure. Then, essential production characteristics observed in the 1976/77 survey are discussed and contrasted with the 1972/73 survey.

### A. Background

The agricultural sector accounted for an annual average of 19.5 percent (245.5 million dinars) of the real gross domestic product for the 1975/1978 period. The major agricultural subsectors are cereals, livestock and tree and vegetable crops. Based on data reported in the Budget Economique for the year 1975-1978, the average annual share of the value of total agricultural production is cereals 21%; livestock and livestock products 38%; tree crops 23%; vegetable crops 14%; and other crops, including industrial crops, 4%. The agricultural sector grew at an impressive annual rate averaging, by World Bank estimates, 5.5% for the 1973-76 period. Due in part to favorable weather conditions during this period, the annual growth in cereals production was about 4.8%. However, less favorable weather conditions during the 1976-77 crop year has resulted in lower growth rates. For the years 1976/77-77/78, growth in cereals production declined to less than 2% per year (Table 1).

Table 1. *Total Area and Production of Cereals, 1976 to 1979*

| | 1975-76 | | 1976-77 | | 1977-78 | | 1978-79 | |
|---|---|---|---|---|---|---|---|---|
| | Area (000 ha) | Prod. (000 M.T.) | Area (000 ha) | Prod. (000 M.T.) | Area (000 ha) | Prod. (000 M.T.) | Area (000 ha) | Prod.$^{est}$ (000 M.T.) |
| Cereals | | | | | | | | |
| Hard Wheat | 995.0 | 700 | 1079.4 | 480 | 1030 | 570 | 920 | 643.5 |
| OV | 805.6 | n.a. | 891.5 | 344 | 730 | n.a. | 640 | 335.5 |
| HV | 189.4 | n.a. | 187.9 | 136 | 300 | n.a. | 280 | 308.0 |
| Soft Wheat | 219.0 | 180.0 | 104.0 | 90 | 101 | 150 | 145 | 152.5 |
| OYV | 182.7 | n.a. | 59.0 | 35 | 33 | n.a. | 75 | 47.5 |
| HYV | 36.3 | n.a. | 45.0 | 55 | 68 | n.a. | 70 | 105.5 |
| Barley | 575.6 | 270 | 310.6 | 100 | 497 | 180 | 535 | 204.5 |

Source: Budget Economique, Agriculture et Peche, 1977, 1978, 1979 Ministere de l'agriculture and, Budget Economique, 1977 and 1978, Ministere du Plan. OV and HV denotes ordinary yielding varieties and high-yielding varieties, respectively.

The northern portion of the country produces approximately 84% of the hard wheat and 82% of the soft wheat produced in the country. This production is produced on about 60% of the total land planted to wheats, only 10% of which is planted to soft wheat varieties. Nearly 64% of the total number of farms in Northern Tunisia are less than 9.9 hectares while only 6% of the farms are larger than 50 hectares (Table 2). In spite of the large numbers of small farms, the use of purchased inputs, e.g., fertilizer and mechanical traction, is quite extensive (Table 3). Nearly 34% of the farms ranging from 1 to 4.9 hectares reported using mechanical traction. Mechanical traction on these farms is most often obtained by renting tractors from local large farmers or from the government sector. This traction is often used for the first deep plowing operation and animal traction is used thereafter. The 1975 survey revealed that virtually all farms over 50 hectares use both mechanical traction and chemical fertilizers.

High-yielding varieties of soft wheat were introduced in about 1968 while high-yielding varieties of hard wheats were introduced in 1972. Based on data for the 1972/73 crop year, the new durum wheat varieties appeared to be about 16% more technically efficient than old durum varieties and technically neutral in input productivity (6). This appears not to be the case for soft wheat varieties. Based on the 1972/73 data, the new soft wheat varieties appeared to be inferior to the old soft wheat varieties at low levels of fertilizer use but out yield the old varieties at higher levels of fertilizer use. The hectares planted to high-yielding soft wheat varieties declined from a high of 70,000 hectares in 1973 to 36,300 hectares in 1976 and then increased to about 70,000 hectares in 1979 (15).

While small farmers appear progressive in the use of modern inputs, they are generally less progressive in the use of new high-yielding varieties. Approximately half of the area planted to soft wheat since 1977 has been in high-yielding varieties (HV) and over 87% of the area planted to these high-yielding varieties are grown on farms larger than 100 hectares. Relative to new high-yielding soft wheat varieties, high-yielding hard wheat varieties have been both more rapidly and evenly adopted by large and small farms. The area planted to high-yielding hard wheats increased from 3,500 hectares in 1972 to over 280,000 hectares in 1979. Yet, these high-yielding varieties only account for about 44% of the area planted to hard wheats. While the adoption of these varieties has varied less by farm size than in the case of soft wheat, only 2.3% of the area planted to the new durum varieties was on farms less than 10 hectares in 1975. Farms between 100 and 200 hectares planted roughly 43% of their land area in high-yielding hard wheats while farms 200 hectares and larger planted more than half of their land area to high-yielding varieties (Table 2).

Table 2. *Land Allocated to Cereals Production, by Farm Size in Northern Tunisia, 1975*

| Size of Farm | Proportion of All Farms | Dist. of area in Ordinary Yielding: Hard Wheat (%) | Dist. of area in Ordinary Yielding: Soft Wheat (%) | Distribution of area in High Yielding: Hard Wheat (%) | Distribution of area in High Yielding: Soft Wheat (%) | Area Distribution of: Barley (%) | Area Distribution of: Oats (%) |
|---|---|---|---|---|---|---|---|
| 0– .9 | 3.2 | 48.3 | 8.6 | 0 | 0 | 43.1 | 0 |
| 1– 1.9 | 11.7 | 49.3 | 4.3 | .9 | .9 | 40.0 | 4.6 |
| 2– 4.9 | 25.2 | 64.0 | 2.0 | 2.7 | 0 | 30.1 | 1.2 |
| 5– 9.9 | 23.5 | 60.4 | 3.7 | 3.5 | .4 | 30.5 | 1.4 |
| 10– 19.9 | 18.4 | 64.3 | 3.1 | 5.8 | .3 | 25.6 | 0.8 |
| 20– 49.9 | 11.9 | 65.3 | 1.2 | 9.9 | .3 | 22.2 | 1.0 |
| 50– 99.0 | 2.6 | 47.4 | 6.1 | 18.2 | 0 | 27.3 | .8 |
| 100–199.9 | 1.8 | 39.7 | 1.6 | 26.3 | 7.6 | 18.0 | 6.7 |
| 200–499.9 | .9 | 30.8 | 2.0 | 43.2 | 6.0 | 14.6 | 3.3 |
| >500 | .7 | 5.9 | 7.3 | 55.4 | 20.5 | 9.6 | 1.2 |
| Percent of Total Area Planted to Wheat by all Farms | | 45.6 | 3.5 | 22.4 | 5.2 | 21.2 | 7.2 |

Source: Conjoncture Agricole, Direction du Plan et des Analyses Economiques et de l'Evaluation des Projets, Ministere de l'Agriculture, 1976.

The Fifth Development Plan 1977-1981 calls for a rate of growth in the agricultural sector of 6.6% and an increase in the wheat sector of 5.2% (16, p. 7). Much of this increase is projected to come from the adoption of high-yielding varieties. The Fifth Plan projects a doubling of the area now planted to HV's. It would appear, based on previous experience, that these adoption rates and growth rates will be difficult to achieve unless the constraints to adoption and higher yield attainment are identified and alleviated.

## B. The Data Collection Process

In cooperation with the Institut National Agronomique de Tunisie [INAT] the data for this research were collected in Tunisia during the 1976/77 wheat season. The area from which the sample was taken amounted to a subsample of the farmers interviewed in Gafsi's study. The original population had been organized into governmental units, "mecheikhats." The lists were stratified by mecheikhat, and a random sample was chosen from each one. For the subsample procedure, the producers in each mecheikhat were listed by farm size. A subsample was drawn from these lists in a manner to assure the maintenance of the farm-size distribution of the original sample. One hundred and twenty-five farmers were selected by this procedure and of the 125 farmers interviewed, only a few substitutions were made. In four cases, the farmer listed was not producing wheat that year, and in three cases the farmer could not be located. On these occasions, the producer listed on either side of the original choice was chosen by a flip of a coin.

Each producer was interviewed twice during the growing season. The first visit occurred at the time of seedbed prepa-

Table 3. *Proportion of Farmers Using Fertilizer and Mechanical Traction by Farm Size in Northern Tunisia, 1975.*

| | Percent Using Tractors | Percent Using Chemical Fertilizer |
|---|---|---|
| 0– .9 | 7.2 | 22.9 |
| 1– 1.9 | 32.4 | 53.3 |
| 2– 4.9 | 34.0 | 47.7 |
| 5– 9.9 | 59.5 | 69.8 |
| 10– 19.9 | 69.4 | 74.3 |
| 20– 49.9 | 79.5 | 71.4 |
| 50– 99.9 | 93.5 | 95.0 |
| 100–199.9 | 100.0 | 100.0 |
| 200–499.9 | 100.0 | 100.0 |
| >500 | 100.0 | 100.0 |

Source: Conjoncture Agricole, Direction du Plan et des Analyses Economiques et de l'Evaluation des Projets, Ministere de l'Agriculture, 1976.

ration and planting. At planting, the farmer had made input decisions regarding land use, phosphate use, land preparation, seed choice, and one application of nitrogen. Depending mainly on rainfall in January and February, the producer may make a second and third application of nitrogen at the tillering and flowering stages, respectively. Weeding or chemical herbicide and harvesting costs are determined at a later stage in the production process.

The primary purpose of the first visit was to gather information relating to the producer's expectations. A number of questions were posed whose responses would indicate yields farmers expected to obtain at harvest under various conditions. Questions during the first visit were also posed which permitted a quantitative measure of farmers degree of belief in their yield expectations. From November to February, the weather for the current growing season was considered to be normal. There was a fair degree of moisture in the ground at planting and a normal amount of rainfall in December and January.

The second interview occurred after harvest. It was designed to gather information on yields realized and input applications that occurred after the first interview. In a few cases, an effort was made to clarify confusing or contradictory information collected in the first interview.

The two-visit procedure had other benefits. The first visit allowed one to develop the confidence of the farmers and reduce the number of questions since more information could be collected in the second visit. At the time of the first visit, producers were better able to recall fertilizer allocation levels, machine use for land preparation, and various input procurement problems. Furthermore, the two-visit format allowed the gathering of data regarding income and consumption in two stages which minimized somewhat the hesitancy of revealing personal information.

### C. Characteristics of Farms Sampled

The 125 farmers in the survey produced wheat on a total of 288 parcels. High-yielding durum wheat was planted on 128 parcels, 100 parcels were planted to ordinary durum wheat varieties and 60 parcels were planted to soft wheat varieties. Approximately 57% of the parcels were located on flat land while the remaining parcels were located on hilly land. Farms were evenly divided between zones normally receiving rainfall in excess of an annual average of 450 mm of rainfall and zones receiving less than this average. However, weather conditions during the 1976/77 growing season were atypical. No additional rainfall occurred after seedbed preparation, i.e., after the first farm survey was obtained. This result has important implications to the results obtained in this study and, inadvertently, gives support to the methodology employed.

The affects of low rainfall are suggested in Table 4. First, contrast the use of fertilizer for the two periods. With the exception of nitrogen, fertilizer use is of approximately the same magnitude as in 1972/73. Because of the drought, farmers did not make a second application of nitrogen at the tillering stage of the high-yielding durum wheat varieties. Now, contrast the yields obtained in 1972/73 with those obtained in 1976/77. The lower yields in 1976/77 suggest the effect of weather conditions. The unexpected effect of weather is reflected by comparing the yields that, at seedbed preparation time, farmers reported they expected to obtain with yields actually realized at harvest. Average yields obtained for high-yielding durum wheats is only 57% of the average yield farmers expected to obtain, while the average yield obtained in the case of ordinary varieties is about 64% of the yield farmers expected to obtain.

It seems reasonable that farmers are well aware of the difficulty of predicting yields, and aware that as they are less able to predict yields, they are more likely to commit larger errors in the allocation of inputs. Furthermore, farmers having a relatively greater difficulty in predicting yields of the high-yielding varieties are more likely to continue growing the ordinary varieties since these errors translate into higher production costs. In this case, farmers' knowledge and access to information affects his ability to profitably produce high-yielding varieties. Hence, knowledge and information deficiencies can be an impediment to the adoption of high-yielding varieties.

In the next section we focus on farmers' knowledge of the production surfaces of both the high and ordinary yielding varieties. These insights provide a basis for estimating the errors farmers make in the allocation of fertilizer and machinery services to the production of durum wheat. They also provide a basis for identifying the factors associated with these errors.

Table 4. *Average Durum Yields Obtained at Harvest, Yields Expected at the Time of Seedbed Preparation, and Fertilizer Use, 1972/73 and 1976/77.**

| | Yield in Quintals per Ha. | | | Elemental Nitrogen Kg/Ha | | Elemental Phosphorus Kg/Ha | |
|---|---|---|---|---|---|---|---|
| | Observed 1972/73 | Observed 1976/77 | Expected 1976/77 | 1972/73 | 1976/77 | 1972/73 | 1976/77 |
| High Yielding Varieties | 13.7 | 7.51 | 13.20 | 28.7 | 19.2 | 29.1 | 27.9 |
| Ordinary Varieties | 12.7 | 5.44 | 8.49 | 14.9 | 14.7 | 17.2 | 21.20 |

*Averages for the 1972/73 crop year are based on a sample of 375 farms. Averages for the 1976/77 crop year are based on a sample of 125 farms in the same geographic area as the 1972/73 study. Both the 1972/73 and the 1976/77 averages compare favorably with the corresponding government estimates reported in the *Budget Economique,* Ministere du Plan, Republicque Tunisienne for the years 1973 and 1977.

## III. REALIZED AND PERCEIVED YIELD RESPONSE TO INPUT CHOICES

This section is divided into three parts. The specification of the durum wheat production functions that are hypothesized to explain the yields farmers obtained at harvest and the functions that are hypothesized to explain the yields that, at the time of seedbed preparation, farmers expected to obtain at harvest are presented in the first part. The results from fitting these functions to the survey data and a comparison of the results with those obtained by Gafsi and Roe are discussed in the second part. An analysis of the allocative errors committed by farmers and the factors associated with these errors concludes this section.

### A. "Realized" and "Subjective" Production Function Specification[1]

The physical correspondence determining the production (Y) of durum wheat that farmers realized at harvest is specified as

$$(1)\quad Y^T_{HV} = B_1\, Ph_1^{\beta_1} N_1^{\beta_2} M_1^{\beta_3} L_1^{\beta_4} e^{\beta_6 D_2 + \beta_7 D_3} \epsilon_1 = f(X_1; \beta)\epsilon_1$$

$$(2)\quad Y^T_{OV} = B_2\, Ph_2^{\lambda_1} N_2^{\lambda_2} M_2^{\lambda_3} L_2^{\lambda_4} e^{\lambda_6 D_2 + \lambda_7 D_3} \epsilon_2 = f(X_2; \lambda)\epsilon_2$$

where

- $Y^T_{HV}$, $Y^T_{OV}$ = Quintals of high and ordinary yielding varieties of durum wheat *havested*, respectively,
- $P_h$ = Kg of elemental phosphorus
- $N$ = Kg of elemental nitrogen
- $M$ = Expenditure on field operations performed. These include four: (1) deep plowing, (2) discing, (3) planting, and (4) harvesting. The value is expressed in Tunisian dinars and based on rental rates as determined in the interview or the opportunity cost, i.e., rental value, if owned.
- $L$ = Hectares of land in parcel
- $D_2$ = Dummy variable for soil, D = 1 for good soil, zero otherwise.
- $D_3$ = Dummy variable for zone, D = 1 if low rainfall zone (El Kef) and zero if high rainfall zone (Jendouba).

Parameters are B, $\beta$ and $\lambda$ and $\epsilon$ is a stochastic term. These equations are referred to as the realized or true production functions.

We also maintain that the structure underlying farmers' forecasts of production is a structure which gives rise to estimates of the parameters in equations (1) and (2). Our approach, therefore, is to assume that each producer formulates a subjective density on the parameters of (1) and (2). Previous research (9, 4, 11) has found that the more education and access to information an individual farmer has, the more capable he is at choosing economically efficient input levels. Pursuing this reasoning further implies that farmers ability to more accurately forecast production implies a forecast of input productivity which depends on cognitive factors such as their education, farming experience and access to information. In analytical terms, this implies that the subjective density each farmer is assumed to formulate on the parameters of (1) and (2) is dependent on cognitive and information variables.

Therefore, the underlying structure which explains a farmers' production forecast of a particular variety can be hypothesized to depend on input choice, years of education, years of experience with the variety, number of extension agent visits, etc.) Several alternative analytical specifications of this type were fit to the data. The specification which appeared to best fit the data is the following:

$$(3)\quad Y^P_{HV} = A_1\, Ph_1^{\beta_1^*} N_1^{\beta_2^*} M_1^{\beta_3^*} L_1^{\beta_4^*} Ex_1^{\beta_5^*} e^{\beta_7^* D_2 + \beta_8^* D_3} \nu_1 = f(X_1, Ex_1; \beta^*)\, \nu_1$$

$$(4)\quad Y^P_{OV} = A_2\, Ph_2^{\lambda_1^*} N_2^{\lambda_2^*} M_2^{\lambda_3^*} L_2^{\lambda_4^*} Ex_2^{\lambda_5^*} e^{\lambda_7^* D_2 + \lambda_8^* D_3} \nu_2 = f(X_2, Ex_2; \lambda^*)\, \nu_2$$

where the above variables are

- $Y^P_{HV}$, $Y^P_{OV}$ = Quintals of high and ordinary yielding varieties of durum wheat the farmer *expected* to obtain at harvest, respectively.
- $P_h, N, M, L, D_2, D_3$ = as defined above.
- $Ex$ = Inverse of farmers years of experience with this variety.

The farmers' subjective parameters are denoted by $A^*$, $\beta^*$ and $\lambda^*$ where $\nu$ is a stochastic term.

This formulation permits farmers to make the subjective estimates $A^*$, $\beta^*$, $\lambda^*$, $\nu$ which are estimates of the true parameter B, $\beta$, $\lambda$ and $\epsilon$ of (1.0) and (2.0). Each farmer is assumed to behave as though his estimates $A^*$, $\beta^*$, $\lambda^*$, $\nu$ are in reality the true parameters of (1.0) and (2.0) when, in fact, these estimates may unknowingly differ from the true parameters (B, $\beta$, $\lambda$ and $\epsilon$). Hence, since the parameters of (1.0) and (2.0) are either unknown or not known with certainty by the producer, his choice of inputs depends on his forecast of input productivity given by (3.0) and (4.0). If the parameters of (1.0) and (2.0) differ from (3.0) and (4.0) then the farmer can make allocative errors, i.e., allocate his inputs in a manner that does not result in a least cost combination of inputs for the yield ($Y^T_{HV}$, $Y^T_{OV}$) he realizes at harvest.

As pointed out above, several alternative specifications incorporating knowledge and information variables were attempted. The inverse of years of experience with producing high-yielding varieties (variables Ex) appeared to provide the best statistical fit to the data. This variable is used as a proxy variable for farmers' knowledge of the production characteristics of the wheat they produce. In terms of (3) and (4), as the farmers' experience with growing high-yielding varieties increase, the hypothesis is that $A_1 Ex^{\beta_5}$ and $A_2 Ex^{\lambda_5}$ will approach the value of $B_1$ and $B_2$ of the true production functions (1) and (2) respectively.

In the next section, we report the results from fitting both the "realized" production functions (1) and (2) and the behavioral functions (3) and (4) to the survey data.

[1] See Appendix A for conceptual details.

## B. Production Function Results

The results from estimating the parameters of equations (1) and (2) by the method of ordinary least squares (OLS) appear in Table 5. Overall, equations (1) and (2) appear to fit the data reasonably well. The coefficients are of reasonable magnitudes and the independent variables appear to explain about 77 and 79 percent respectively, of the variation in the quantity of high-yielding ($Y^T_{HV}$) and ordinary yielding ($Y^T_{OV}$) durum wheat *obtained* by farmers at harvest.

The equations were tested for homoscedasticity. The hypothesis that the error term is homoscedastic cannot be rejected. Interdependence of the independent variables and the omission of variables (such as rainfall) can bias the estimates reported in Table 5. However, the dummy variables ($D_i$) should account for weather, zone and soil type differences. Thus, the extent of bias should not be sufficient to negate the results obtained.

Table 5. *Parameter Estimates of (1) and (2) for the 1976/77 Crop Year, Northern Tunisia*

| Variables | Equation (1) HV True ($\beta_i$) | | Equation (2) OV True ($\lambda_i$) | |
|---|---|---|---|---|
| B = constant term | .5425 | (2.1)[a] | .7595 | (4.6)[a] |
| $D_2$ = soil | .3712 | (3.1) | .3959 | (2.9) |
| $D_3$ = zone | −.3887 | (3.3) | −.2987 | (2.3) |
| Ph = phosphate | .1525 | (3.2) | .1031 | (2.4) |
| N = nitrogen | .0163 | (0.4) | −.0134 | (0.3) |
| M = machinery | .3375 | (4.0) | .1856 | (3.0) |
| L = land | .3718 | (3.0) | .7874 | (7.6) |
| $R^2$ | 77 | | 79 | |
| SSE | 42.42 | | 28.02 | |
| $\Sigma\beta_i;\Sigma\lambda_i$ | .8781 | | 1.063 | |
| n | 127 | | 98 | |
| F | 72.5 | | 61.06 | |

[a]t statistics are in parentheses. All coefficients are significant at the 99 pecent level except the nitrogen coefficients.

A Chow test was administered to test whether there is a structural difference between the parameters of the HV's and the OV's. The results of the test suggested that taken together, $\beta_1 \neq \lambda_1$, for i = 1, . . ., 4. Nevertheless, on an individual basis, statistical tests suggest that neither the phosphate (Ph) nor the nitrogen (N) coefficients are significantly different between varieties at the .95 percent level of confidence.

A comparison of the two production functions in Table 5 suggest that, for the 1976/77 crop year, the high-yielding varieties of durum wheat were more responsive to the quantity of mechanical inputs than were the ordinary varieties. This conclusion is suggested by a comparison of the machinery coefficients (.3375 and .1856). This implies that for weather conditions prevailing during 1976/77, the high-yielding varieties were perhaps more sensitive to the timeliness of field operations and/or more sensitive to the quality of seedbed preparation than were the ordinary varieties.

The rather large coefficient on land (.7874) planted to ordinary varieties is puzzling. It suggests that ordinary varieties are more sensitive than high-yielding varieties to the quantity of land input. This result may reflect a statistical bias from an omitted variable such as soil moisture. Furthermore, parcels planted to ordinary varieties tend to be smaller than parcels planted to high-yielding varieties (Table 2). As parcel size increases, yield may increase due to more intensive management that farmers devote to larger more important parcels of land. A comparison of the constant terms (.5425 and .7595) suggests that for low levels of input use the ordinary varieties can out yield the high-yielding varieties.

As mentioned previously, the 1976/77 crop year in Tunisia was a poor year for growing wheat due to a deficiency of rainfall. The geographic area from which the sample data was obtained received a uniform rainfall distribution during this period. Hence, it is not possible to account directly for the effects of rainfall in the estimated equations. Nevertheless, insights into the effects of weather can be obtained by comparing the results reported in Table 5 with those obtained by Gafsi and Roe (6, p. 128). Results from estimating the production function parameters for high and ordinary yielding varieties of durum wheat grown in the same area during the 1972/73 crop year appear in Table 6. It is important to note that weather conditions for the 1972/73 crop year were quite favorable (see Table 4).

A comparison of Tables 5 and 6 suggests that the production function coefficients tend to vary somewhat from year to year. The "t" test suggests that the coefficient of the soil variables ($D_2$) are significantly different, as are the constant term. This comparison suggests that for weather conditions prevailing in 1972/73, the high-yielding varieties on average out performed the ordinary varieties for all levels of input use observed in the data. Other comparable coefficients are those on fertilizer. In 1972/73, nitrogen had a significant effect on yield whereas in a low rainfall year its effect could not be detected from the data. The "t" test suggests, however, that phosphate had a more pronounced effect in 1976/77 than its effect in 1972/73. Overall, the comparison suggests that the high-yielding varieties are more sensitive to weather conditions and hence, may be somewhat more riskier to produce.

Table 6. *Cobb-Douglas Production Function Estimates of Durum Wheat Produced During the 1972/73 Crop Year, Northern Tunisia*

| Variables[a] | 1972/73 | |
|---|---|---|
| Dependent: Quintals per ha. | | |
| A = constant term | 1.323 | (.069)[b] |
| $D_1$ = HYV | .164 | (.047) |
| $D_2$ = soil | .235 | (.041) |
| $D_4$ = type of traction | .170 | (.050) |
| $D_5$ = weeding | .105 | (.053) |
| Ph = phosphate | .064 | (.013) |
| N = nitrogen | .061 | (.014) |
| LP = number land preparations | .461 | (.069) |
| $R^2$ | 57 | |
| n | 436 | |

Source: Gafsi and Roe, p. 128.

[a]All variables are equivalent to those of table 5 with the following exceptions; all variables are expressed in per hectare terms, $D_1$ = 1 if the variety is high-yielding durum wheat and zero if ordinary yielding durum wheat, $D_4$ = 1 if mechanical traction and zero otherwise and variable (LP) is the number of equipment passes over the land during the growing season.

[b]Standard error values (as opposed to t values) are presented in parentheses. All variables are significant at the 95% level of confidence.

This comparison also highlights the precariousness of drawing implications on input productivity beyond a single year of cross-section data. While the conclusions drawn from our results have been strengthened and conditioned by the 1972/73 results, additional time series observations are needed to obtain insights into both the functional form of the wheat production-input correspondence and into the nature of input productivity. Until this research is undertaken, our conclusions remain suggestive.

The next step is to report the results from estimating the subjective (or behavioral) production functions. Recall that our maintained hypothesis is that farmers behave (i.e., make their input choices) based on their "best" guess (estimate) of the parameters of the "true" production functions (1) and (2). Hence, if the subjective production function parameters differ from those reported in Table 5, farmers are likely to make errors in their input choices. Given the unfavorable weather conditions that prevailed after seedbed preparation in 1976/77 this result is expected.

Before we report these results, it should be pointed out that initial attempts to fit (3.0) and (4.0) to the data suggested, based on the Chow test, that the slope parameters $\beta_i^\circ$ and $\lambda_i^\circ$ for i = 1, . . . , 5 were not significantly different. Hence, equations (3.0) and (4.0) were combined and the following combined model was fit to the data:

$$(6)\quad Y^P = A\, Ph^{\beta_1^\circ} N^{\beta_2^\circ} M^{\beta_3^\circ} L^{\beta_4^\circ} Ex^{\beta_5^\circ} e^{\beta_6^\circ D_1 + \beta_7^\circ D_2 + \beta_8^\circ D_3}$$
$$\nu^\circ = f(X, Ex; \beta^\circ)\, \nu^\circ$$

and where the dummy variable $D_1 = 1$ if $(Y^P_{HV})$ is the dependent variable and zero otherwise.

The results from fitting (6) to the data appear in Table 7. The reader is referred to Appendix A for a brief discussion of the problems in estimating the parameters of (6). Regressions I and II differ in that the experience variable (Ex) is omitted from Regression II. Regression III differs from Regression IV for the same reason. Regressions III and IV are in terms of yield per hectare. A number of other dummy shifters were fit to the data to determine whether they might be associated with farmers' yield estimates. These include dummy variables for rented land vs. owned land and a dummy variable indicating crop rotation. Since none of these variables entered the production function with significant values and since their addition or deletion did not change the values of the remaining coefficients, they were dropped from the final estimate.

Table 7. *Perceived Production Function Estimates, Equation (6), for the 1976/77 Crop Year, Northern Tunisia*

| | Alternative Formulations of Equation (6) | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | **Regression I** | | **Regression II** | | **Regression III** | | **Regression IV** | |
| Dep. Var. = *Expected* Production | | | | | | | | |
| A = constant term | 1.3882 | (17.3) | 1.3412 | (17.2) | 1.3990 | (17.5) | 1.3509 | (17.2) |
| $D_1$ = HYV | .3604 | (6.2) | .2908 | (5.7) | .3812 | (6.6) | .3100 | (6.2) |
| $D_2$ = soil | .2966 | (5.7) | .2849 | (5.4) | .3031 | (5.6) | .2913 | (5.6) |
| $D_3$ = zone | .1577 | (3.2) | .1345 | (2.8) | .1753 | (3.6) | .1525 | (3.2) |
| Ex = experience | −.2054 | (2.3) | | | −.2150 | (2.4) | | |
| Ph = phosphate | .0406 | (2.3) | .0413 | (2.3) | .0423 | (2.3) | .0420 | (2.4) |
| N = nitrogen | .0645 | (3.7) | .0658 | (3.7) | .0674 | (3.9) | .0690 | (3.9) |
| M = machinery | .1063 | (3.7) | .1099 | (3.8) | .1130 | (4.0) | .1175 | (4.1) |
| L = land | .8301 | (18.6) | .8279 | (18.4) | | | | |
| $R^2$ | 93.2 | | 93 | | 51.5 | | 50.5 | |
| SSE | 26.19 | | 26.84 | | 26.55 | | 27.26 | |
| $\Sigma_1^4 \beta_i$ | 1.0414 | | 1.0449 | | | | | |
| n | 228 | | 228 | | 228 | | 228 | |
| F | 388.44 | | 434.37 | | 35.51 | | 39.55 | |

t values in parentheses. All coefficients significant at the 99-level.

Each of the estimated equations reported in Table 7 were tested for homoscedasticity. In each case, the hypothesis that the error terms are homoscedastic cannot be rejected. Also, the hypothesis that the coefficients of the independent variables sum to one cannot be rejected. Overall, the estimated coefficients are of plausible magnitudes and the equations fit the data reasonably well. Hence, the statistical results lend confidence to our maintained hypothesis that (6) is indeed a plausible model to explain farmers' yield forecasts, in spite of the questions raised in Appendix A regarding the difficulties of estimating subjective coefficients.

An important implication of the statistical results which permitted an aggregation of equation (3) and (4) into (6) is that, at the time of seedbed preparation in 1976, farmers perceived or acted as though there was no difference between the varieties in their responsiveness to the inputs they control, namely, phosphorous and nitrogen fertilizer and machinery-labor inputs. This has important implications which are discussed below. The dummy variable ($D_1$) suggests that, at the time of seedbed preparation, farmers expected the high-yielding varieties to out yield the ordinary varieties by at least 30%. The coefficients on the soil dummy ($D_2$) implies that farmers expect that wheat planted on good soil will also increase its yield in the vicinity of 30%. The negative sign on the experience variable (EX = 1/years of experience with high-yielding varieties) suggests that as farmers gain more experience with the variety they expect to obtain higher yields but the rate at which they expect these yields to increase, decreases with each additional year of experience.

Next, we turn attention to the coefficients on fertilizer, machinery and land. However, implications are best drawn from these results by first comparing them to the "true" production function coefficients reported in Table 5. A comparison of the phosphate coefficients suggests that at the time of seedbed preparation in 1976 farmers underestimated the productivity of phosphate fertilizer. Comparison of the coefficients on nitrogen fertilizer suggests that they overestimated the productivity of nitrogen fertilizer; a comparison of the machinery coefficient suggests that they also underestimated the productivity of machinery. The relatively large coefficient on land is puzzling except that it is of similar approximate magnitude to the coefficients reported in Table 5.

If our maintained hypothesis is valid, and, if farmers choose that combination of inputs which result in the lowest possible cost for the production of a given amount of wheat (or in our case, their forecast production), the differences in the coefficient between Table 5 and Table 7 suggest errors in farmers' estimates of resource productivity. The differences in the coefficients also imply that, for the 1976/77 crop year, farmers made errors in the allocation of these inputs. But, if 1976/77 had been a normal year, would they have made mistakes? Partial insights into this question can be obtained by first comparing the 1972/73 fertilizer coefficients reported in Table 6 with the 1976/77 coefficients of Table 7. The "t" test suggests that these coefficients are not significantly different. This implies that had 1976/77 been a "normal" year, their 1976/77 perceptions of the productivity of phosphorus and nitrogen fertilizer would in fact *not have* been a source of error.[2]

Now that a comparison between the input variables have been made, the next step is to compare the constant term and dummy variables. First, notice that Gafsi and Roe's estimates of the true production function (Table 6) also permit the combining of high-yielding and ordinary yielding equations into a single equation, just as was the case with the perceived production functions (3) and (4) into (6). Thus, for a normal year, farmers are perhaps correct in visualizing that there is no individual input productivity difference between the high and ordinary yielding varieties except for a yield difference.

A comparison of the constant terms obtained by Gafsi and Roe (1.323) with those of the subjective functions (1.3882, . . ., 1.3509) also supports the contention that *had 1976/77* been a normal year, this term also would not have been a source of error. When the constant terms of Table 7 are compared to the constant term of the "true" 1976/77 crop year production function in Table 5 (i.e., .5426 and .7595) the implication is that farmers expected substantially higher yields than they obtained. Next, compare the coefficient associated with ($D_1$) in Tables 6 and 7. While Gafsi and Roe found that high-yielding varieties in 1972/73 increased yield by 16.4%, farmers in 1976/77 expected a yield difference of nearly 30 percent; hence a possible source of error. However, the coefficients on the soil variable for 1972/73 is nearly identical to the perceived effect of soils in 1976/77.

In the next section we attempt to measure the magnitude of allocative error and attempt to determine if variables other than farmers' misperceptions of the true underlying production function contribute to the error in resource allocation.

### C. Measures of Allocative Error.

Several alternative measures exist for measuring allocated error. These are discussed in Appendix A. Because of our interest in farmers' perceptions, our measure compares farmers' perceived costs with the least possible cost of producing at production levels realized at harvest. Thus, our approach is to derive a "perceived" unit (average) cost function based on the subjective parameter estimates reported in Table 7. This equation has the form:

$$(7)\ \frac{C^P}{Y^P} = \gamma\,[\beta_1^{\circ\,\beta_1^\circ}\,\beta_2^{\circ\,\beta_2^\circ}\,\beta_3^{\circ\,\beta_3^\circ}]^{-\frac{1}{\gamma}}\,\bar{A}^{-\frac{1}{\gamma}}\,P_1^{\frac{\beta_1^\circ}{\gamma}}\,P_2^{\frac{\beta_2^\circ}{\gamma}}\,P_3^{\frac{\beta_3^\circ}{\gamma}}\,Y^{P\,\frac{1}{\gamma}-1}$$

where $C^P$ = total perceived cost per parcel and $Y^P$ = the production farmers expected to obtain at harvest. Hence, $C^P/Y^P$ is the cost per quintal of wheat farmers expected to realize at harvest.[3] The coefficients $\gamma$ and $\bar{A}$ are defined as follows:

$$\gamma = \beta_1^\circ + \beta_2^\circ + \beta_3^\circ,$$
$$\tilde{A} = A^\circ \cdot e^{\beta_6^\circ D_1 + \beta_7^\circ D_2 + \beta_8 D_3} \cdot E(\nu^\circ)$$

variables $P_1$ and $P_2$ are the respective prices of phosphorus and nitrogen fertilizer, while $P_3$ is the weighted average price of machinery and labor services (variable M). The coefficients $\beta^\circ$ are taken from Table 7.This function gives the least cost rule for producing an expected level of output $Y^P$ by allocating fertilizer and machinery in a least cost manner.

The next step is to obtain the "true" unit cost functions. $C^T/Y^T_{HV}$ and $C^T/Y^T_{OV}$. These functions give the least cost rule for producing a quintal of durum when the farmer has perfect knowledge of the true production functions (1) and (2) respectively. Its form is identical to (7) except the coefficients of (1) and (2) replace the coefficient $A^\circ$, $\beta^\circ$ in (7) for the respective high and ordinary yielding varieties.

The results from computing the perceived and "true" unit (average) costs per quintal ($C^P/Y^P$, $C^T/Y^T_{HV}$, $C^T/Y^T_{OV}$) for each parcel and farmer in the study appears in Appendix Table B.1. The results are summarized in Table 8. The results suggest that at the time of seedbed preparation, farmers expected the average per quintal cost of fertilizer and machinery allocated to the production of HV of durum wheat to be in the vicinity of 2.72 dinars. The corresponding expected cost for ordinary varieties (OV) was perceived to be in the vicinity of 3.28 dinars.

Since farmers expected the high-yielding varieties to out yield the ordinary varieties by about 30 percent (Table 7) as a group, farmers tended to allocate more fertilizer and machinery inputs to the production of high-yielding varieties than to the production of the ordinary varieties (also, see columns 5 and 7 of Table 4). However, due in part to unfavorable weather, they overestimated the yield of HV's by 76% and the yields of OV's by 56%.

Thus, as a group, farmers growing the high-yielding varieties (in 1976/77) tended to make relatively larger allocative

[2]Note that we cannot compare the 72/73–76/77 coefficients of the machinery variable because they are not equivalently defined.

[3]This functional form is derived from the form of Cobb-Douglas production function.

Table 8. *Estimated Fertilizer and Machinery Costs of Producing Durum Wheat, 1976/77, Northern Tunisia*

| Varieties | Perceived Average Cost Per Quintal $C^P/Y^P$ Dinars/Quintal | Least Average Cost Per Quintal $C^T/Y^T$ Dinars/Quintal |
|---|---|---|
| HV | 2.72 | 6.18 |
| OV | 3.28 | 5.64 |

Source: Appendix Table B.1.

errors than farmers growing the ordinary varieties.[4] The implication of these errors to returns over the cost of fertilizer and machinery services suggests that some farmers actually incurred a financial loss. The Office of Cereals price for durum wheat was 7.1 dinars per quintal in 1977. A comparison of this price with the cost estimates in Appendix Table B.1 suggests that a financial loss occurred on approximately 18% of the 288 parcels. Thirty-five of the parcels on which a loss occurred were planted to high-yielding varieties. The remaining parcels (18) were planted to ordinary varieties. Since many farmers had more than a single parcel, this implies that about 32% of the 125 farms in the sample experienced a financial loss on at least one of the parcels they planted to wheat.

The next step is to attempt to identify factors explaining the differences in allocative errors among farmers. Our approach is to define a new variable (E) as the ratio of $E = (C^P/Y^P)/(C^T/Y^T)$ and regress the logarithm of this variable on cognitive and information variables and selected farm level variables. Values of E are generally fractions. They are reported in Appendix Table B.1.

A value of E equal to one is consistent with the farmer correctly estimating average production costs attributable to fertilizer and machinery. It is possible, of course, that for an individual farmer average costs obtained from the two functions are equal by chance, and at the same time, for a farmer's expected yield to differ from the yield he actually obtained at harvest (see Appendix A).

The functional form and variables selected are:

$$(8)\ \ln E = A + \alpha_1 X + \alpha_2 S + \alpha_3 D + \alpha_4 C + \alpha_5 Z + \nu$$

where X = years of experience with growing high-yielding varieties

S = size of parcel, in hectares

D = distance from the Office of Cereals, in kilometers

C = Constraints dummy, = 1 if farmers reported no difficulty in obtaining fertilizers or seeds, and zero otherwise.

Z = zone dummy.

$A, \alpha_i$ = coefficients and $\nu \sim IN(0, \sigma^2)$

[4] Reviewers of this report questioned the use of "allocative error" in this regard since farmers could not have known future weather conditions. At the time of seedbed preparation, they made the best decisions given the information available to them.

Several alternative functional forms were fit to the data. Equation (8) was selected because it appeared to provide the best statistical fit. Rationale for including the experience variable is self-explanatory. Parcel size is included because it is reasoned that in the case of larger sized parcel farmers may tend to be more conscientious with their input choices. Distance to the Office of Cereals is selected as a proxy variable to reflect access to information. The greater the distance, the less likely are farmers to have access to extension agents. The constraint dummy (C) is included to account for farmers' difficulty in acquiring inputs.

The independent variables in (8) appear to explain about 57 percent of the variation in the dependent variable (Table 9). Variables associated with positive coefficients imply that small or nominal increases in their value are consistent with decreases in allocative errors. The positive coefficient associated with years of experience in growing high-yielding varieties suggests that farmers with this type of experience tend to allocate fertilizer and machinery to the production of durum wheat more efficiently than other farmers. The negative coefficient on parcel size (S) suggests that for the 1976/77 crop year, farmers with larger parcels tended to commit larger allocative errors. In the case of a normal year, this would be a counter-intuitive result. Signs associated with constraint dummy (C) and zone (Z) imply that difficulty in acquiring fertilizer and machinery services contributes to errors and that during the 1976/77 crop year farmers in the normally high rainfall zone tended to commit larger errors than farmers in the normally low rainfall zone.

Table 9. *Allocative Errors as a Function of Socio-economic Variables*

| | dependent variables | $\ln(AC^P/AC^T)$ | |
|---|---|---|---|
| A | = constant term | −.5329 | (11.3)** |
| X | = experience, years | .0372 | (5.3)** |
| S | = size of parcel, Ha. | −.0115 | (7.3)** |
| D | = distance from parcel to Office des Cereales. Km. | −.0159 | (1.2) |
| C | = constraint dummy = 1 if difficulty in obtaining inputs, = 0 otherwise | −.0711 | (1.6) |
| Z | = zone dummy | −.3849 | (10.8)** |
| $R^2$ | | .57 | |
| SSE | | 13.52 | |
| n | | 225 | |
| F | | 60.48 | |

**Significant at the 99-percent level. t values are in parentheses.

These results, by themselves, tend to be suggestive rather than conclusive. However, together with the results reported in Tables 5 to 7 they strongly suggest that farmers commit allocative errors and face risk and uncertainty. The next step is to quantify farmers' risk preferences. This is discussed in the next section where quantitative estimates of farmers' reaction to risk and uncertainty are obtained and implications to farmers' choice of inputs are discussed.

## IV. ANALYSIS OF RISK

This section also has three parts. First, a brief statement of the theory underlying our empirical estimates of farmers' aversion to risk is presented. Since a thorough presentation of the theoretical framework can be found in Nygaard (14), Roe (17) and Roe and Nygaard (18) and in Appendix A, only those elements of the theory essential for the continuity of this section are presented. The remaining two sections report the empirical results from fitting the conceptual framework to the survey data.

### A. Theoretical Framework

Each producer is assumed to be a mean-variance expected utility maximizer with expected utility E[U] of gains and losses ($\Pi_n$) incurred in the production of durum wheat to each producer given by

$$(9) \quad E[U_n] = U(E[\Pi_n], V[\Pi_n])$$

where $V[\Pi_n]$ denotes variance of gains and losses. Expected "profit" $E[\Pi_n]$ is

$$E[\Pi_n] = PE[Y_n^P] - \Sigma_{k=1}^{k^*} P_k X_{kn}$$

where P is the price of durum wheat in dinars per quintal, $P_k$, is respectively, the price of phosphorus and nitrogen fertilizer and machinery services. The inputs of fertilizer and machinery are denoted by $X_{kn}$, k = 1, 2, 3.

It should be emphasized that ($Y_n^P$) is the production any farmer expected, at the time of seedbed preparation, to realize at harvest. Hence, $E[\Pi_n]$ is the expected return over the cost of fertilizer and machinery services they also expected, at the time of seedbed preparation, to realize at harvest. This point is emphasized because the equations essential to our analysis are the "perceived" production functions (3) and (4) whose parameter estimates appear in Table 7.

Dropping the subscript n, expected utility is maximized when producers choose input levels $X_k$ such that:

$$(10) \quad \Phi \partial V[\Pi]/\partial X_k = P\partial E[f(X, Ex; \beta^{\circ})\,\nu^{\circ}]/\partial X_k - P_k$$

where it has been shown by others that

$$(11) \quad \Phi = \left\{- \frac{\partial E[\Pi]}{\partial V[\Pi]} \Big/ \frac{\partial E[U]}{\partial E[\Pi]}\right\} \begin{matrix} > \\ = 0 \\ < \end{matrix} \begin{matrix} \text{risk averse} \\ \text{risk neutral} \\ \text{risk preferred} \end{matrix}$$

Hence, if a producer is risk averse, and if $\partial V[\Pi]/\partial X$ is positive[6] then the producer *does not* allocate inputs to the point where the expected return from the last unit of the resource is just equal to its price, i.e., $P\partial E[f(X, Ex; \beta^{\circ})\nu^{\circ}]/\partial X_k = P_k$. That is, he is reluctant to obtain all possible net returns from his inputs because of the chance or risk that some unexpected event (such as unfavorable weather) could occur and result in lower than expected yields and, hence, an economic loss.

The objective of this section, therefore, is to determine if farmers, in fact, behave in this manner. If so, to what extent, and what are the economic effects of this behavior? Finally we attempt to determine the farm and household factors that are associated with this behavior.

### B. Estimates of Farmers' Risk Preferences

The risk preference of each farmer in the sample is obtained by estimating the values of ($\Phi \partial V[\Pi]/\partial X_k$) and $\Phi$ in condition (10) and (11). The input selected for $X_k$ in order to compute these values was the amount of phosphate fertilizer the farmer applied at the time of seedbed preparation. Other inputs could have been chosen or, for that matter, all inputs could have been chosen and used to compute these values.

Phosphate was chosen for three reasons: (1) Phosphate and land are the only inputs that were completely committed to the production process at the time of first interview; (2) It was, relative to other inputs, easier to establish whether farmers faced constraints in the acquisition of phosphorus fertilizer; (3) The accuracy of estimating risk preferences from (10) requires good price data. The most accurate price data for the four inputs are on phosphate and nitrogen. Land rental rates are very difficult to determine for each farmer. While machinery rental rates are available, they are not as representative as phosphate fertilizer prices.

The final step is to explain why 15 farmers were removed from the sample and not included in the analysis. Fifteen producers indicated that they could not obtain phosphorus fertilizer and, if they could have, they would have allocated it to durum wheat production. In this case, equation (9) requires modifications implying the computation of a shadow price to fertilizer. Instead, these fifteen farmers were simply removed from the risk analysis.

Based on equation (10) and the estimates from regression I, Table 7, the values of ($\Phi \partial V[\Pi]/\partial X_1$) appear in column three of appendix Table B.2. These values must be interpreted with caution. Since the computation depends on the assumptions underlying (9) and since the estimates of (6.0) contain a stochastic element ($\nu^{\circ}$), a particular value of ($\Phi \partial V[\Pi/\partial X_1$) for an individual farmer cannot be given the strict interpretation implied by condition (10). Of more importance are the descriptive statistics of these values which appear in columns one through three, Table 10, and the number of values which imply risk averseness.

The results suggest that approximately 75% of the farmers in the sample are risk averse. The mean values reported in Table 10 suggest the extent to which they are risk averse. These results clearly suggest that, as a group, farmers apply a subjective discount due to risk. This can be interpreted as a discount to the price of durum wheat.[7] The average magnitude of the discount for all farmers appears to fall somewhere in the vicinity of 1.16 to 1.85 dinars per quintal.

The descriptive statistics of the estimates reported in Appendix Table B.2 suggest that the distribution about the mean might be slightly skewed to the left. The kurtosis of a normal distribution is approximately three. Hence, the values reported in Table 10 suggest that the distribution about the mean is somewhat "flat" relative to the normal distribution.

The effect of risk on yields can be only roughly approximated. Nevertheless this approximation is useful since it provides some insights into the magnitudinal effects of risk on resource allocation and production. The approximated effect of risk on yields is obtained by computing the percentage change in yields if risk could be eliminated entirely—a very unlikely possibility in reality.

[5]Notice that $f(X, Ex; \beta^{\circ})\nu^{\circ}$ is defined by equation (6).

[6]Contrary to Just and Pope's analysis for the Cobb-Douglas case, the term $\partial V[\Pi]/\partial X_k$ can be either positive or negative (18, p. 5).

[7]This interpretation is correct if $V(\Pi) = P^2 f(X, EX^{\circ}; \beta^{\circ})^2 V(\nu^{\circ})$. Otherwise, these results should be interpreted as either a subjective discount of the expected marginal value product of $X_1$, i.e., $P\partial E[f(X, EX^{\circ}; \beta^{\circ})\nu^{\circ}]/\partial X_1$, or subjective increase in the price ($P_1$). In any case, the interpretation of the mean values as a subjective discount is consistent with (10). This is discussed in more detail by Roe (17).

Table 10. *Summary of Risk Aversion Estimates of Tunisian Durum Wheat Producers, 1976/77 Northern Tunisia*

| | $\Phi\ \partial V[\Pi_\eta]/\partial X_1$[a] | | | Roe and Nygaard[c] $\Phi\ \partial V[\Pi_\eta]/\partial X$ |
|---|---|---|---|---|
| | **Average Entire Sample** | **Only Positive Values (risk averse)[b]** | **Only Neg. Values (risk pref.)[b]** | |
| Mean | 1.851 | 3.456 | −2.903 | 1.164 |
| Standard Deviation | 3.661 | 2.374 | 2.475 | 2.42 |
| Skewness | −.523 | .326 | −.864 | .268 |
| Kurtosis | .121 | −1.149 | −.194 | 2.379 |

[a]Source: Appendix Table B.2.
[b]This is based on the assumption that $\partial V[\Pi_\eta]/\partial X_1$ is positive.
[c]Source: Both phosphate, notrogen and the cost of machinery services were used to compute these values. See Roe and Nygaard (18, P. 11).

The results of these calculations appear in Table 11. Essential assumptions underlying the calculations are that, (a) farmers maximize the expected utility of returns over the cost of fertilizer and machinery services, (b) input acquisition and use constraints are not binding and, (c) farmers behave as though their estimates ($\beta^{\circ}$) are the true parameters of equations (3) and (4).

Table 11. *Approximation of the Percentage Increase in Yields of Durum Wheat from the Complete Elimination of Risk*

| | Range of Yield Increase, In Percent[b] | |
|---|---|---|
| | *(Minimum)* | *(Maximum)* |
| Favorable weather[a] | | |
| HV and OV | 9.6 | 15.3 |
| Unfavorable weather | | |
| HV | 8.0 | 12.8 |
| OV | 4.7 | 7.5 |

[a]Estimates for "favorable weather" are based on parameter estimates reported in Table 6 while estimates for an "unfavorable" weather are based on parameter estimates reported in Table 5.
[b]The first column assumes an average risk aversion level of 1.164 dinars while the second column assumes a risk aversion level of 1.851 dinars per quintal.

The results suggest that the effect on yield of eliminating risk entirely might range from a low of 4.7% yield increase for ordinary varieties when unfavorable weather conditions prevail to a yield increase for high-yielding varieties of 15% when favorable conditions prevail. Thus, the effects of risk on the level of resource use and, hence, yields is significant. However, due to the strong conditions and assumptions underlying these results, no additional conclusions should be drawn from them.

While these results establish fairly strongly that as a group farmers behave in a risk averse manner the result can be strengthened and extended if the risk aversion parameter $\Phi$ in condition (11) can be estimated. This is the next step.

The estimate $\Phi$ for each farmer is based on equation (10) and on the subjective yield variance information obtained from the survey. The reader is referred to Appendix A for a discussion of this estimation procedure. The results appear in Table B.2.

Table 12. *Effect of Risk on Area Planted to HYV's, 1976/77 Northern Tunisia*

$$\ln R = A + \delta_1 \Phi + \delta_2 Fs + \delta_3 Ext + \delta_4 Ed + \delta_5 D + \delta_6 Z + \nu$$

| | Regression I $\ln\left(\frac{\text{Ha. HV's durum wheat}}{\text{Total Ha. durum wheat}}\right)$ | | Regression II $\ln\left(\frac{\text{Ha. HV's}}{\text{Total Ha. wheat}}\right)$ | |
|---|---|---|---|---|
| R = dependent variable | | | | |
| A = constant term | −2.356 | (4.09)** | −2.4399 | (4.33)** |
| $\Phi$ = risk parameter | −27.5069 | (2.07)* | −27.1688 | (2.09)* |
| Fs = farm size (Ha.) | .0049 | (1.61) | .0046 | (1.54) |
| Ext = number of extension agent contacts | .0385 | (0.85) | .0305 | (0.72) |
| Ed = education, years | .0015 | (0.04) | .0010 | (0.02) |
| D = topography = 1 if hilly, zero otherwise | −1.1396 | (2.39)** | −1.2370 | (2.64)** |
| Z = zone, = 1 if high rainfall, zero otherwise | −1.1446 | (1.14) | −.3458 | (0.90) |
| $R^2$ | .27 | | .27 | |
| SSE | 201.56 | | 194.11 | |
| f | 4.36 | | 4.43 | |
| n | 78 | | 78 | |

*Significant at the 97.5 percent level. **Significant at the 99 percent level.
Zone = dummy variable which is the same as in production function estimates. t values are in parenthesis.

The mean (arithmetic) of $\hat{\Phi}$ overall farmers is (.00825). The mean of $\hat{\Phi}$ for those farmers that are risk averse is .01387 while the mean of $\Phi$ for those that appear to be risk preferring is (–.09396). Seventy-three percent of the values $\Phi$ are of a positive sign, thus suggesting risk averseness. Of the remaining 29, the results suggest that 8 are risk-preferers, but with small negative values. The average of the subjective standard deviation of expected yields over all farms was computed from column 5 Appendix Table 2 for each variety. The average of the standard deviation of the high-yielding varieties is 5.654 quintals while for ordinary varieties the average is 4.70 quintals per hectare. This is the most direct evidence that farmers view the high-yielding varieties to be somewhat more risky than the ordinary varieties.

These results suggest that risk can be a deterrent to the area planted to high-yielding varieties. In order to obtain insights into the magnitudinal effect of risk on the area planted to high-yielding varieties, a regression analysis was performed. Two similar equations were estimated, results of which appear in Table 12. In the case of the regression I, the dependent variable is defined as the hectares planted to high-yielding varieties of durum wheat divided by the total area planted to durum wheat. In the case of regression II, the dependent variable is in terms of the area planted to HV's of both soft and hard wheat, divided by the total area planted to wheat.

The analysis was performed only for those 78 producers in the sample who, based on the estimates of $\hat{\Phi}$, were found to be risk averse. The equations do not fit the data very well, since the independent variables only explain about 27% of the variation in the dependent variable. Nevertheless, the signs of the coefficients of each independent variable conform with expectations. Years of education have very little explanatory power, which was also found to be the case in (6). While the zone dummy has some explanatory power, it is not highly significant. Topography and farm size also appear to be associated with the area planted to high-yielding varieties.

Of key interest is the coefficient of the risk parameter, $\hat{\Phi}$. This coefficient has the expected sign and is significant at the 97.5% level. Together with the results obtained previously, these results lend additional support to the conclusion that risk affects the area planted to high-yielding varieties. Based on regression I of Table 12 and the mean values of (ln R) and $\hat{\Phi}$ the results suggest that a one percent decrease in the subjective variance of the high-yielding durum wheat varieties will result in an increase in the area planted to these varieties by about 1.45%. However, this result must be interpreted with caution because of the possible statistical biases inherent in the coefficients of the risk variable.

### C. Factors Associated with Farmers' Attitudes Towards Risk

Since our results suggest that risk aversion is an important factor limiting the area planted to HV's and causing the under utilization of resources, then knowledge of the human, farm and household characteristics associated with farmers' risk attitudes should be useful to extension agents and others. These insights should permit extension agents and others to focus their efforts to increase the area in high-yielding varieties, and encourage the efficient use of resources by concentrating on those characteristics affecting farmers' attitudes towards risk. To obtain these insights, we regressed the estimated risk aversion coefficient $\hat{\Phi}$ of each farmer who was found to be risk averse on, (1) years of education (Ed); (2) farmers' age (Ag); (3) farm size in hectares (Fs); (4) percentage of consumption that is produced on the farm (Cn); (5) land owned as a percentage of land farmed (Ow), and (6) a dummy variable for producers whose only income is from farming. The functional form of the equation and the results appear in Table 13.

Table 13. *Factors Associated With Farmers' Attitudes Towards Risk, 1976/77 Northern Tunisia*

$$\ln \hat{\Phi} = A + \alpha_1 Ed + \alpha_2 A_g + \alpha_3 F_s + \alpha_4 OW + \alpha_5 T + \alpha_6 I + \alpha_7 \left(\frac{1}{Cn}\right) + v^a$$

| **Dependent variable** | **ln $\hat{\Phi}$** | **t values** |
|---|---|---|
| A = constant | –6.0724 | (7.3)** |
| Ed = education in years | –.0218 | (0.7) |
| Ag = age | .0279 | (2.4)** |
| Fr = farm size in Ha. | –.0112 | (5.3)** |
| Ow = land ownership, % | .3967 | (0.7) |
| T = topography, = 1 hilly, zero otherwise | 1.2183 | (3.9)** |
| I = income source, = 1 if no off farm income, zero otherwise | .5246 | (1.5) |
| Cn = consumption, % | .0105 | (0.9) |
| $R^2$ | .51 | |
| SSE | 90.76 | |
| f | 10.69 | |
| n | 78 | |

**Significant at the 99-percent level.

[a]Given the method used to estimate $\hat{\Phi}$, these results should also be interpreted with some caution since farmers' subjective estimate of the variance $V(Y^P)$ may also be associated with one or more of the exogenous variables.

Overall, the equation fits the data reasonably well considering that the dependent variable, $\hat{\Phi}$, is estimated from another set of equations containing stochastic terms. Furthermore, the results appear consistent with intuition. Beginning with the coefficients that are statistically significant from zero, the results suggest that older farmers are more risk averse than younger farmers, all else constant. The negative coefficient on farm size suggests that farmers with larger endowments of cultivatable land are less risk averse than are farmers of small farms. If farm size is assumed to be a proxy for wealth, then, as wealth increases farmers' aversion to risk decreases. These results are also consistent with the findings of others, notably, Moscardi (12). They are also consistent with the information on farm size and area planted to high-yielding variety presented in Table 2.

The sign of the coefficient associated with topography (T) also is intuitively consistent. Apart from land quality farms located on hillsides in Northern Tunisia are generally more isolated from roads and distribution centers than are farms located on flat valley land. Hence, the negative coefficient of the topography variable suggests that isolated farmers are more risk averse than are farmers with easier access to sources of information.

Of the remaining four variables that are not statistically significant from zero, three have an intuitively consistent sign; they are: years of education (Ed), source of income (I) and household consumption (Cn). Off farm sources of income tend to be associated with less risk averse attitudes. As the percent of food consumption that is home produced increases, i.e., household needs become more important, farmers tend to be slightly more risk averse. Also, better educated farmers appear to be slightly less risk averse. Clearly, these results must be interpreted with much more caution than the former results. They are also deserving of further investigation.

## V. SUMMARY AND POLICY IMPLICATIONS

The general objective of this paper is to contribute to the understanding of the factors influencing the extent and efficiency of resource use in wheat production in Northern Tunisia. Risk, uncertainty and allocative error are frequently mentioned as constraints to productivity growth and adoption of new techniques and practices. Yet, their roles have not been well-established empirically. Our results suggest that insights into these relationships have been obtained. The extent to which our theoretical devices reflect the decision making process and the extent to which these devices fit the survey data determine the viability of this conclusion. Since this area of inquiry is complex, additional research is required to confirm and extend our results.

This study is based on a sample survey of 125 farmers in Northern Tunisia which was administered during the 1976/77 crop year. The methodology used in the study is unique relative to other studies. Two different sets of durum wheat production functions were fit to the survey data. One set of functions attempted to capture the true physical correspondence between the yields farmers obtained at harvest and the levels of fertilizer, machinery services and land planted to high and ordinary yielding durum wheat varieties. The second set of functions attempted to capture the physical correspondence between yields that, at the time of seedbed preparation, farmers expected to obtain. It was maintained that a comparison of the true functions with farmers' beliefs about the functions would help explain the errors they committed in the allocation of resources to the production of durum wheat. Estimates of the physical relationship between yield and inputs from an earlier study were also used for comparison.

Based on these functions, the magnitude of allocative errors were estimated and the factors associated with these errors were determined. Estimates of farmers' risk preferences were derived and the effects of risk on yields and area planted to high-yielding varieties were studied. Finally a search was made for factors associated with farmers' risk preferences.

The important findings from the study can be summarized as follows:

1. In the case of unfavorable conditions, the high-yielding varieties of durum wheat only out-yielded the ordinary varieties at high levels of input use. This finding is a qualification of Gafsi and Roe's results where, in the case of favorable weather conditions the high yielding varieties of durum wheat were found to out yield ordinary varieties for all levels of input use.
2. The results also suggest that yields of the high-yielding durum wheat varieties are more sensitive than yields of the ordinary varieties in low rainfall years. The yields of high-yielding varieties appear more responsive to machinery services than do the yields of ordinary varieties. Weather conditions appear to affect yield response to fertilizer for both ordinary and high-yielding varieties.
3. At the time of seedbed preparation, farmers significantly overestimated the yields they would obtain in 1976/77. This overestimate appeared to be caused by unexpected weather conditions. However, as a group, farmers tended to overestimate the yields of high-yielding varieties to a greater extent than they did the yields of ordinary varieties.
4. Farmers appear to be quite knowledgeable of the true physical correspondence between inputs (fertilizer, machinery) and yields for both high and ordinary yielding varieties when good to normal weather conditions prevail.
5. Years of experience in growing high-yielding varieties were found to affect farmers' yield estimates and their ideas about the productivity of the resources they allocated to producing durum wheat. This effect decreased with time such that the first year experience was more important than the last. Years of formal education did not appear to affect their yield estimates.
6. For the 1976/77 crop year, farmers generally made substantial errors in the allocation of fertilizer and machinery to the production of durum wheat. These mistakes occurred because farmers allocated inputs based on the assumption that weather conditions during the 1976/77 crop year would be at least normal, when in fact, weather conditions turned out to be unfavorable.
7. The analysis of allocative errors suggested that the errors in the allocation of inputs to the production of high-yielding durum wheats exceeded the errors farmers made in allocating inputs to the production of ordinary varieties.
8. As farmers' experience in growing high-yielding varieties increase, their input allocation errors tended to decrease.

9. Because of abnormal weather, many farmers, whose allocative errors were relatively large, actually earned returns below their costs.
10. The analysis of farmers' risk preferences suggests that the majority of farmers are risk averse, and hence, in a normal year they tend to under-utilize fertilizer and machinery services in wheat production. Since 1976/77 was an atypical year, this behavior actually prevented larger allocative errors on the part of some farmers.
11. The overall effect of farmers' risk averse behavior is to discount the price of durum wheat by approximately 16 to 20 percent. In the absence of risk, yield increases would be significant, perhaps in the range of 5 to 15 percent.
12. The analysis also suggests that farmers view high-yielding varieties to be "riskier" to produce than ordinary varieties.
13. Farmers' risk attitudes are also a deterrent to increasing the area planted to high-yielding varieties. Farmers appear to plant both high and ordinary yielding varieties in order to reduce the risk they face. The analysis suggested that a one percent decrease in the income variability faced by farmers in growing high-yielding varieties might lead to an increase in the area planted to these varieties by about 1.4 percent.
14. Several human, farm and household factors were found to be associated with farmers' risk preferences. Risk aversion was found to be positively correlated with farmers' age and valley land. Risk aversion was negatively correlated with farm size. Education, home consumption, land ownership and an off-farm income source were not significant variables in explaining farmers' risk aversion.

These results stress the importance of farm level programs that are designed to increase farmers' knowledge of the yields they can expect to obtain from various combinations and levels of fertilizer and machinery services. These programs must also embody information on the yield variability farmers can expect from favorable and unfavorable weather conditions. Extension programs designed to provide production information will be more useful to the extent they take into consideration each farmer's endowments of resources, outside sources of income, age, experience and household consumption demands on farm produced food. Extension programs will also be more successful when they empathize with farmers' decision making problems, the farmers' present state of knowledge and beliefs regarding the production possibilities of both high and ordinary yielding varieties under good and unfavorable weather conditions. Information regarding the nature of yield response should articulate the effect on yields of various input levels that include the input levels actually employed by the farmer.

Given the production characteristics of the new varieties, production of ordinary varieties should not be discouraged as they play an important and useful role in risk diversification. This is more important for farmers whose farm size and other resource endowments are meager, who are advanced in age and where household demands on farm produced food tend to be substantial. This is not to imply that farmers in this category be discouraged from producing high-yielding varieties or not be given access to the type of programs discussed above. On the contrary, these programs can also assist these farmers in the more efficient allocation of resources to the production of both high and ordinary yielding varieties. However, Tunisian policymakers should perhaps not pursue policies whose objectives are to replace the entire area planted to ordinary varieties unless some crop insurance scheme can be implemented which reduces the risk faced by farmers. Furthermore, policies to relax constraints to the acquisition of fertilizer and machinery services should be encouraged, since this will lead to more efficient resource use.

As indicated above, variance in returns over the input costs of fertilizer and machinery services is important to risk averse farmers. This suggests that additional research and thought should be given to crop insurance programs designed to reduce risk due to low rainfall. This type of a program can be socially profitable because both yields of high and ordinary yielding varieties and the area planted to high-yielding varieties can be expected to increase if such programs are implemented. However, crop insurance programs can become socially unprofitable if the gains to farmers are lost to the costs of administering or if the programs become a form of farm subsidy.

As in the case of programs designed to increase farmers' knowledge, programs designed to reduce risk should also take into consideration the important environmental circumstances of each farmer. Furthermore, farmers whose farm size is small and located in hilly areas and who have little formal education and experience with growing high-yielding varieties, and who have no outside sources of income and face high household food demands on farm produced foods, can benefit most from programs to reduce risk. While other more favorably endowed farmers can also benefit, their opportunities for risk diversification, access to information and markets allows them to lower the risk they face. Hence, their marginal benefit from, for instance, a crop insurance program, will likely be less than the marginal benefit to less endowed farmers.

Further study and consideration should also be given to price policy. Presently, the price farmers receive for wheat at harvest is, for all practical purposes, known at the time of seedbed preparation. An alternative policy might be to guarantee farmers a minimum price at the time of seedbed preparation. But, if weather is unfavorable and wheat production declines accordingly, then the price at harvest should be allowed to increase to account for lower than expected supplies. This type of policy should tend to reduce risk because the yield decreasing effects of unfavorable weather will be partially offset by higher prices.

The results also provide important insights to plant breeders. They suggest that important tradeoffs exist between wheat variety attributes such as high yields, yield variability and the similarity between new varieties and the old familiar varieties. The more similar the new and old varieties—except for a higher yield that is proportional to input use—the more efficient are farmers likely to be in producing the new variety and the more quickly are they likely to adopt the variety. Ideally, these new higher yielding varieties should also be less sensitive to factors outside of the farmers' control.

This issue has another dimension as well. If yields of a new variety are sensitive to, for instance, insects and weeds for which chemicals might be needed for control, then chemicals become a control variable at the disposal of the farmer. While the chemicals permit better control, they also permit the farmer to commit allocative errors and, hence, raise production costs. Thus, unless farmers reasonably understand the nature of the production response associated with the new input, they can be expected to be reluctant and hesitant to growing the new variety. Again the less endowed farmers are likely to lag in this process.

The analysis also suggests that the risk farmers face and the allocative errors they commit could be reduced if chemical and/or mechanical technology could be developed to allow farmers the opportunity of allocating at least some of their inputs later in the growing season. Farmers are now forced to make most of their major resource commitment in the early stages of the growing season when expected yields are difficult to predict. It would be more desirable if they could delay certain input allocations until weather conditions and expected yields are somewhat more predictable.

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# APPENDIX A: Conceptual Framework

## A.I INTRODUCTION

The conceptual framework underlying the empirical analysis is presented in this section. The section is divided into two parts. The nature of the Producers' decision making problem is presented in the first part where it is maintained that Producers allocate resources based on, among other factors, their subjective estimates of the parameters of the underlying technology. It is shown that if their estimates are not accurate, and/or if they behave as though their estimates have some subjective distribution about the true parameters of the technology, then subjective risk and allocative errors can occur. In the second part alternative measures of allocative error are presented for two special cases of risk behavior.

## A.II PRODUCER BEHAVIOR

Let

$$(A.1)\quad Y = f(X; m)\epsilon,\ \epsilon \sim ILN(e^{1/2\sigma^2}, e^{\sigma^2}(e^{\sigma^2}-1))$$

denote the true physical correspondence between a single output Y and a K element vector of $k^*$ choice and $K-k^*$ nonchoice inputs where m is a vector of parameters and $\epsilon$ is a disturbance term. We assume that a producer formulates a subjective density on the parameters of (A.1) which permits the specification of the following subjective (or behavioral) production function.

$$(A.2)\quad Y_n = f(X; m_n)\nu_n,\ \nu_n \sim ILN(e^{1/2\psi_n^2}, e^{\psi_n^2}(e^{\psi_n^2}-1))$$

The n-th Producers subjective estimate of the parameters of (A.1) are $m_n$ and $\psi_n$. These parameters may in turn depend on cognitive, experience and information variables. For our purposes here, both (A.1) and (A.2) are assumed to be homogenous, concave and monotonic in the $k^*$ control variables.

The Producer is assumed to be a mean variance expected utility maximizer with expected utility of gains and losses $E[U_n]$ give by[1]

$$(A.3)\quad E[U_n] = U(E[\Pi_n], V[\Pi_n])$$

where $V[\Pi_n]$ denotes variance of profit. Expected profit $E[\Pi_n]$ is

$$E[\Pi_n] = PE[f(X;m_n)\nu_n] - \sum_{k}^{k^*} P_k X_{kn}$$

Prices of output (P) and inputs ($P_k$) are assumed known. Given, subjectively or otherwise, the values of the $K-k^*$ nonchoice variables, expected utility is maximized when the $k^*$ input levels $X_k^o$ are chosen such that

$$(B.4)\quad \Phi_n \partial V[\Pi_n]/\partial X_k = P\partial E[f(X, m_n)\nu_n]/\partial X_{kn} - P_k$$

where it has been shown by others that

$$(B.4.1)\quad \Phi_n = \{-\frac{\partial E[U_n]}{\partial V[\Pi_n]} / \frac{\partial E[U_n]}{\partial E[\Pi_n]} \begin{matrix} > \\ = \\ < \end{matrix} 0\} \begin{matrix} \text{risk averse} \\ \text{risk neutral} \\ \text{risk preferred} \end{matrix}$$

Notice that the choice $X_{kn}^o$ yields an expected output from (A.2) which we denote as $E[Y_n^o]$. Substituting the choice $X_{kn}^o$ into (A.1) also yields an estimate of output to be realized at harvest, which we denote as $E[Y_n^u]$.

Depending on the mathematical form of (f) the parameters of (A.1) should not be extraordinarily difficult to fit to data since $\epsilon$ is only related to $\nu$ in the case of perfect knowledge of (A.1). The subjective parameters of (A.2), which correspond to equations (3) and (4) in the text, are extraordinarily difficult to estimate from cross section data for namely three reasons.

First, the observations $Y_n^o$ are subjective and not measurable in the sense of $Y_n^u$ which is observed at harvest. The structuring of questions to obtain a producer's statement of $Y_n^o$ in a manner consistent with the definition of (A.2) is somewhat precarious.[2] Second, each agents' subjective estimate of the parameters of (A.1) are likely to vary, i.e., the subjective parameters are stochastic. In the case of this study, this problem may be lessened somewhat because of the small geographic area over which the data was obtained, the fact that most producers have produced wheat for many years and by the incorporation of cognitive and information variables in the statistical model of (A.2). Third, $\nu_n$ appears in (A.4) suggesting interdependence between the choice $X_{kn}^o$ and $\nu_n$. However, producers may not fine tune their resource allocation decisions to the point where (A.4) holds exactly, but rather, only approximately with some independent random deviation. In this case, a construction along the lines of Zellner, *et al.* can be used to demonstrate the independence of $X_{kn}^o$ and $\nu_n$.

If the subjective parameters of (A.2) can be estimated and if at least one of the $k^*$ choices $X_k^o$ are not constraining, then the risk discount factor $\Phi_n \partial V[\Pi_n]/\partial X_{kn}$ can be estimated from (A.4). An estimate of $\Phi_n$ depends on the form of $V[\Pi_n]$, which in turn can be shown to depend on whether the agent *acts as through* the parameters and variables upon which his subjective estimates are conditioned are in fact true exact estimates. For instance, given levels of the $K-k^*$ nonchoice variables, if the producer behaves as through the parameters of (A.1) are *not* known with certainty, the subjective parameters $m_n$, $\nu_n$ are independent, there is no serial correlation in $\nu_n$, and the

[1]The specification of (A.3) can be viewed as a second order Taylor series approximation of a constant risk aversion utility function. If $Y_n$ is log normal, then $\Pi_n$ follows a log normal distribution. Levy shows that mean variance analysis applied to a log normal distribution is a sufficient decison rule. A necessary and sufficient decision rule for all nondecreasing concave utility function is $E[\Pi_n]$, variance log $\Pi_n$ (Levy, p. 611). In this case, $V[\log \Pi_n]$ is substituted for $V[\Pi_n]$ in (B.3) and the analysis remains essentially unchanged.

[2]Farmers were asked to condition their subjective estimate $Y_n^o$ on conditions they felt would effect yield during the 1976/77 growing season. Thus, among the problems are, for instance, whether the nonchoice variables upon which the subjective estimate is conditioned varies between farmers. Weather and soil moisture are surely among these factors. Henc whether the subjective estimates $Y_n^o$ are consistent with the assumptions underlying (A.2) is conjectural. Yet, our statistical results do not suggest otherwise.

subjective density on m depends only on past observations and a prior density, then the subjective variance of $Y_n$ depends on the subjective variance of the parameters $m_n$ and $\nu_n$. In this case, the subjective variance $V[\Pi_n]$ is of the form:

$$\text{(A.5)} \quad V[\Pi_n] = P^2(E[f(X,m_n)]^2 V[\nu_n] + E[\nu_n]^2 V[f(X,m_n)] + V[f(X,m_n)]V[\nu])$$

If, given the level of the nonchoice variables, the Producer behaves as though m is known with certainty, then $V[f(X; m_n)]$ equals zero and (A.5) reduces to the form considered by Pope and Just (1977). In this case,

$$\text{(A.6)} \quad \partial V[\Pi_n]/\partial X_{kn} = 2P^2 f(X; m_n)\, f_k'(X; m_n)\, V(\nu_n)$$

and from (A.4)

$$\text{(A.7)} \quad \Phi_n = (P\partial E[f(X;m_n)\nu_n]/\partial X_{kn} - P_k)/2P^2 f(X;m) f_k'(X,m_n) V(\nu_n)$$

The value of $V(\nu)$ can be estimated when (A.2) is fit to observations $(Y_n^0, X)$. This is not our approach, however. The questionnaire was designed to permit the estimation of $V(\nu_n)$ for each agent. Questions were asked to establish a confidence interval about the yield that, at seedbed preparation, producers expected to obtain. Then, based on the assumed distribution of $\nu_n$, a variance is calculated from these data for each producer. To distinguish this estimate from $V(\nu_n)$, we denote it as $V(\tilde{\nu}_n)$. This estimate should more closely reflect producers' subjective estimate of variance than $V(\nu_n)$ namely because (a) the nature of farmers' beliefs as to the certainty of the subjective estimate of m are not known and (b) it is not reasonable to expect each farmer to estimate $V(\nu_n)$ in a manner consistent with the calculus of ordinary least squares. Hence, given estimates of $m_n$, $V(\tilde{\nu}_n)$ is substituted for $V(\nu_n)$ in (A.7). Then, given the estimates $m_n$, prices and input levels $X^0$ for each observation, (A.7) is used to estimate $\Phi_n$ for each farmer in the sample.[3]

## A.III MEASURES OF ALLOCATIVE EFFICIENCY

Alternative measures exist for estimating allocative efficiency of the producers choice $X_k^0$, only one of which is empirically used in this study. However, three such measures are presented below.

Let total variable cost ($T_n$) perceived at the time of seedbed preparation be defined as

$$\text{(A.8)} \quad T_n = g(P_1 \cdots P_{k^*}, E[Y_n], X_{k^*+1} \cdots X_K; m_n, E[\nu_n]) = \min_k \sum^{k^*} P_k X_{kn}$$

subject to

$$E[Y_n^0] = E[f(X_1 \cdots X_{k^*}, X_{k^*+1} \cdots X_K; m_n)\nu_n]$$

where, for simplicity, the level of the $K\text{-}k^*$ nonchoice inputs are assumed known with certainty. Total variable cost (T) based on perfect knowledge of (A.1) is defined as:

$$\text{(A.9)} \quad T = g(P_1 \cdots P_{k^*}, E[Y], X_{k^*+1} \cdots X_K; m, E[\epsilon]) = \min_k \sum^{k} P_k X_k$$

subject to

$$E[Y^*] = E[f(X_1 \cdots X_{k^*}, X_{k^*+1}, \cdots X_K; m)\epsilon]$$

Consider the case of either a risk neutral agent or an agent whose beliefs are depicted by (A.6). If $m_n \neq m$, $E(\nu_n) \neq E(\epsilon)$, then almost surely, for $E[Y_n] = E[Y]$

$$X_{kn}^0 = \frac{\partial T_n}{\partial P_k} \neq \frac{\partial T}{\partial P_k} = X_k^*, \; k = 1 \cdots k^*.$$

In other words, if an agents' subjective estimates of the parameters of (A.1) are not exact, then, for a given level of expected output, his choice $X_{kn}^0$ is likely to differ from the cost minimizing level of inputs $X_k^*$, $k = 1 \cdots k^*$. Clearly, $T_n \lesseqgtr T$ depending on the agents' subjective estimate of the parameters of (A.1). However, if $T_n = T$ for a level of output where $E[Y_n] = E[Y]$, then the choice $X_k^0$ results in least cost. In this case, a measure such as the ratio $T_n/T$, can be used to obtain insights into the efficiency of resource allocation when either $\Phi_n = 0$ or the the agent perceives risk in the sense of (A.6). If the $K\text{-}k^*$ noncontrol variables are not known at the time of seedbed preparation and if their values obtained during the growing season differ from the value forecast when the choice $X_{kn}^0$ is made, then $T_n \neq T$ is likely even though the parameters of (A.1) are known with certainty. However, if (A.1) and (A.2) are homogeneous, perfect knowledge of the parameters of (A.1) nevertheless result in a choice $X_{kn}^0$ consistent with a least cost combination of inputs.

A second more direct measure of resource allocation efficiency within this framework is to compare the total cost realized at harvest with least costs based on perfect knowledge of (A.1), i.e., equation (A.9). The total cost realized ($T_n^0$) at harvest can be expressed as a function of the parameters of both (A.1) and (A.2). Intuitively, the realized total cost function contains the parameters of both (A.1) and (A.2) because the choice $X_{kn}^0$ is based on (A.2) while an estimate of realized yield $E[Y_n^0]$ is the result of substituting $X_{kn}^0$ into (A.1).

More specifically, consider the case where $K = 3$, $k^* = 2$ and where the functional form of (A.1) and (A.2) is Cobb-Douglas. The realized total cost function is obtained by deriving the equations for the perceived least cost combination of inputs based on (A.2) and substituting these equations into the true production function (A.1). Then, making use of the accounting equation $\sum_{k=1}^{k=2} P_k X_k$, the following is obtained

$$\text{(A.10)} \quad T_n^0 = (m_{n1} + m_{n2})(A m_{n1}^{m_1} m_{n2}^{m_2})^{-1/r} E[Y_n^0]^{1/r} (P_1^{m_1} P_2^{m_2})^{1/r}$$

[3]The difficulty of soliciting farmers' response to obtain a confidence interval to their subjective yield estimate is recognized and should be taken into consideration when interpreting the results. Although surprisingly, farmers did not generally appear to find it difficult or confusing to provide a lower and upper yield estimate to their subjective yield estimate. Questions were not asked to obtain insights into the nature of their subjective distribution of yields. Instead, the form of the distribution of yields is assumed.

where

$$A = m_0 X_3^{m_3} E[\epsilon]$$

$r = (m_1 + m_2)$

$m_i$, i = 0,1,2,3 denotes the efficiency and input parameters respectively of (A.1),

$m_{ni}$, i = 1, 2 denotes the input parameters of (A.2).

This equation is observable in the since that the variables $\{T^0_n, X_3, E[Y^0_n], P_1, P_2\}$ are observable. Notice that (A.10) is of identical form to a cost function derived from an underlying Cobb Douglas production function. The positioning of the subjective parameters ($m_{nk}$) do not appear as a power to any of the right-hand size variables. If $m_{nk} = m_k$ for all K; then (A.10) is identical to (A.9).

Given the concavity and homogeneity assumptions imposed on (A.1) and (A.2), it can be shown that for the general case the realized cost function can be stated as:

(A.11) $T^0_n = g(P_1 \cdot\cdot P_{k^*}, E[Y^0_n], X_{k^*+1} \cdot\cdot X_K; m_n, m, E[\epsilon])$.

Since (A.9) is, by definition, least cost for any positive level E[Y],

(A.12) $\Delta T_n {}_{E[Y] = E[Y^0_n]} = T^0_n - T \geq 0.$

Thus, a second measure of allocative efficiency is the comparison of (A.9) and (A.11). This measure is appropriate for either the case where the agent is risk neutral ($\Phi_n = 0$) or when behavior is consistent with (A.6).

Another measure of allocative efficiency can be derived for the case where $\Phi_n$ is zero, i.e., the agent is risk neutral. In this case, let the indirect profit function obtained from maximizing expected profit subject to (A.1) be denoted as:

(A.13) $E[\Pi^*] = H(P, P_1 \cdot\cdot P_{k^*}, X_{k^*+1} \cdot\cdot X_K; m, E[\epsilon])$.

Similarly, let the indirect profit function derived from the maximization of expected profit subject to (A.2) be denoted as

$$E[\Pi^o_n] = H(P, P_1 \cdot\cdot P_{k^*}, X_{k^*+1} \cdot\cdot X_K; m_n, E[\nu_n]).$$

The level of the choice variables are given by $X^o_{kn} = -\partial E[\Pi^o_n]/\partial P_k$, $k = 1 \cdot\cdot k^*$. The choice $X^o_{kn}$, when substituted into (A.1) yields the expected realized profit

$$E[\Pi^0_n] = P\, E[f(X^o_{1n} \cdot\cdot X^o_{kn}, X_{k^*+1} \cdot\cdot X_K; m)\epsilon] - \Sigma^{k}_{kn} P_k X^o_{kn}.$$

It follows that

(A.14) $\Delta \Pi_n = E[\Pi^*] - E[\Pi^0_n] \geq 0$

since (A.13) is the conjugate of (A.1) while $X^o_k$ is only a feasible solution to the maximization of expected profit subject to (A.1). Condition (A.14) can be used as a measure of allocative efficiency or as the maximum value of information yielding perfect knowledge of (A.1). Figure 1 depicts an example of the relationship between $E[\Pi^*_n]$, $E[\Pi^o_n]$ and $E[\Pi^0_n]$ in input space.

Clearly, condition (A.14) measures allocative efficiency in terms of both the least cost combination and level of choice variables. However, since the behavioral assumptions of the expected profit maximization model are more stringent than those of the cost minimization model, it would appear that, for many applications, efficiency measures suggest by (A.12) are perhaps more appropriate.

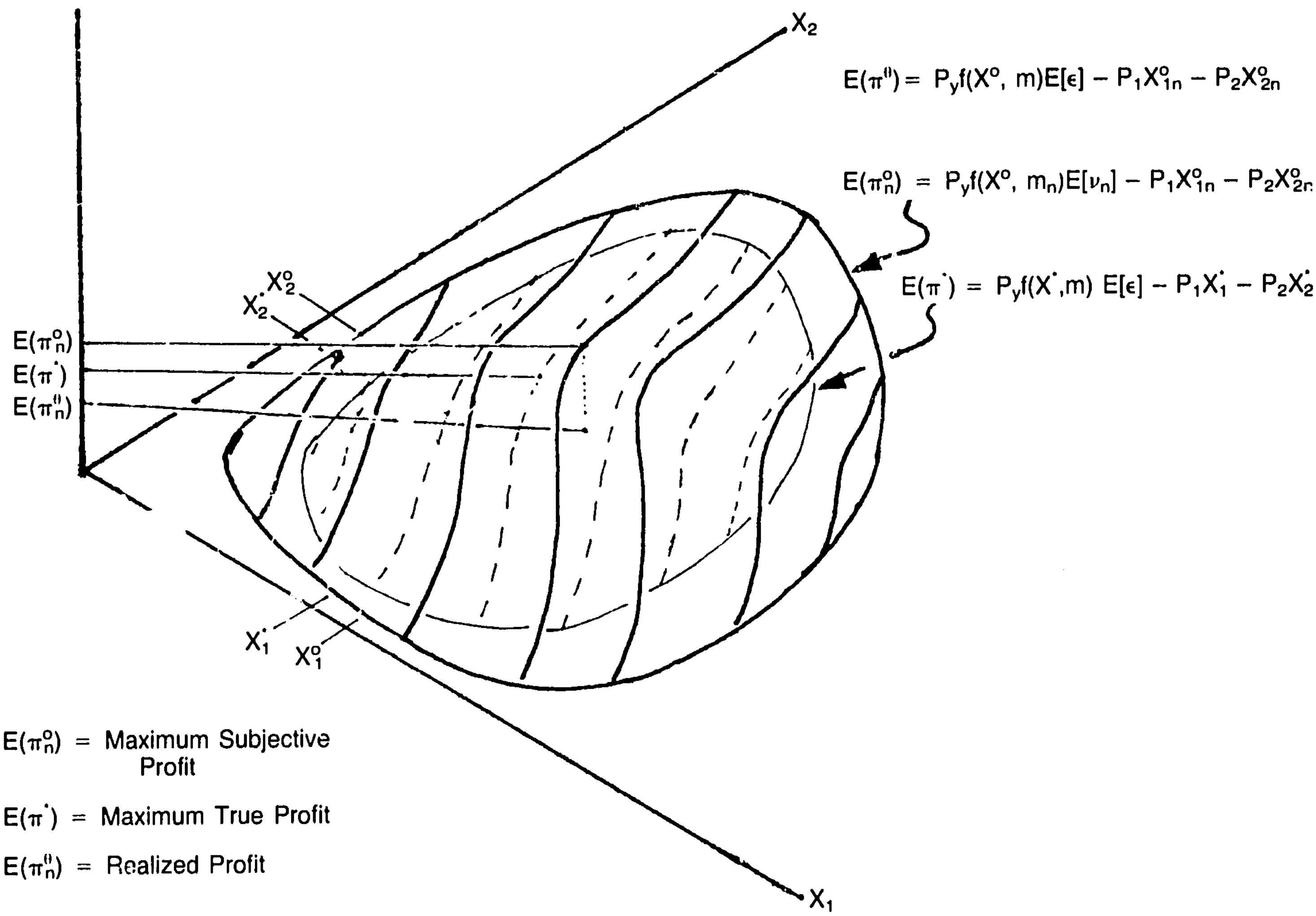


Figure A.1. Relationship between subjective $E(\pi^o_n)$, true $E(\pi^*)$ and realized $E(\pi^{\shortparallel}_n)$ profits for the case where $E(Y^o_n) \neq E(Y)$ for all $X^o_1$, $X^o_2$.

# APPENDIX B: Estimates of Allocative Error and Risk

Table B.1. *Perceived ($AC^P$) and Least Cost ($AC^T$) per Quintal of Durum Wheat, 1976/77 Northern Tunisia.*

| Farmer | HV Dummy | $Ac^P$ | $AC^T$ | $Ac^P/AC^T$ | Farmer | HV Dummy | $Ac^P$ | $AC^T$ | $Ac^P/AC^T$ |
|---|---|---|---|---|---|---|---|---|---|
| 1 | 1 | 4.02 | 4.16 | .97 | 36 | 0 | 4.53 | 10.37 | .44 |
| 1 | 1 | 5.24 | 9.45 | .55 | 36 | 0 | 3.63 | 7.70 | .47 |
| 2 | 1 | 1.56 | 6.57 | .24 | 37 | 0 | 3.55 | 7.59 | .47 |
| 2 | 0 | 2.04 | 4.69 | .44 | 38 | 0 | 1.81 | 3.75 | .48 |
| 3 | 1 | 2.71 | 7.05 | .38 | 38 | 1 | 1.31 | 4.72 | .28 |
| 3 | 0 | 3.55 | 6.35 | .56 | 39 | 1 | 2.56 | 11.09 | .23 |
| 4 | 1 | 3.87 | 8.91 | .43 | 39 | 1 | 1.94 | 7.59 | .26 |
| 5 | 1 | 3.81 | 8.55 | .45 | 40 | 1 | 1.50 | 5.13 | .29 |
| 5 | 1 | 4.01 | 6.68 | .60 | 40 | 0 | 1.91 | .376 | .51 |
| 6 | 1 | 2.82 | 5.51 | .51 | 40 | 0 | 2.49 | 5.48 | .45 |
| 7 | 0 | 2.97 | 5.43 | .55 | 41 | 0 | 2.16 | 4.73 | .46 |
| 7 | 0 | 2.51 | 4.53 | .55 | 41 | 1 | 2.21 | 5.84 | .38 |
| 8 | 0 | 3.48 | 7.28 | .48 | 42 | 1 | 1.52 | 5.26 | .29 |
| 9 | 1 | 3.40 | 8.27 | .41 | 43 | 0 | 1.53 | 3.06 | .50 |
| 9 | 1 | 4.40 | 13.15 | .33 | 44 | 1 | 1.81 | 7.16 | .25 |
| 9 | 0 | 5.60 | 10.84 | .52 | 45 | 1 | 1.77 | 8.29 | .21 |
| 10 | 0 | 2.60 | 5.10 | .51 | 45 | 1 | 1.34 | 5.65 | .24 |
| 10 | 1 | 2.03 | 6.59 | .31 | 45 | 0 | 1.80 | 3.60 | .50 |
| 10 | 1 | 2.03 | 6.80 | .30 | 45 | 0 | 1.85 | 3.81 | .48 |
| 11 | 1 | 2.12 | 4.96 | .43 | 45 | 1 | 1.39 | 5.55 | .25 |
| 11 | 1 | 2.15 | 5.11 | .42 | 46 | 1 | 1.47 | 3.29 | .45 |
| 12 | 1 | 2.17 | 7.14 | .30 | 46 | 0 | 2.46 | 6.28 | .39 |
| 13 | 1 | 2.33 | 6.85 | .34 | 47 | 0 | 6.00 | 12.94 | .46 |
| 14 | 0 | 3.82 | 7.01 | .55 | 48 | 1 | 1.76 | 8.62 | .20 |
| 14 | 0 | 4.00 | 7.67 | .52 | 48 | 1 | 1.81 | 7.71 | .23 |
| 15 | 0 | 1.57 | 3.76 | .42 | 49 | 0 | 2.28 | 5.12 | .45 |
| 15 | 1 | 1.16 | 5.20 | .22 | 49 | 1 | 1.74 | 7.98 | .22 |
| 16 | 0 | 3.41 | 7.08 | .48 | 50 | 1 | 3.53 | 8.14 | .43 |
| 16 | 1 | 2.43 | 7.03 | .35 | 51 | 1 | .275 | 8.06 | .34 |
| 17 | 1 | 1.99 | 6.48 | .31 | 52 | 1 | 2.44 | 6.34 | .38 |
| 18 | 0 | 3.24 | 1.74 | .54 | 52 | 0 | 3.43 | 6.24 | .55 |
| 18 | 1 | 2.72 | 2.44 | .90 | 53 | 0 | 1.94 | 4.20 | .46 |
| 18 | 1 | 2.85 | 2.63 | .92 | 53 | 1 | 1.45 | 7.40 | .20 |
| 19 | 1 | 2.67 | 10.90 | .24 | 54 | 1 | 2.05 | 4.74 | .43 |
| 19 | 1 | 2.01 | 7.02 | .29 | 54 | 1 | 2.17 | 2.20 | .98 |
| 20 | 0 | 3.57 | 8.59 | .42 | 55 | 1 | 5.45 | 15.85 | .34 |
| 21 | 1 | 2.57 | 8.13 | .32 | 56 | 1 | 1.67 | 8.93 | .19 |
| 22 | 1 | 3.39 | 5.10 | .66 | 56 | 1 | 1.64 | 9.16 | .18 |
| 23 | 0 | 3.45 | 8.03 | .43 | 57 | 1 | 2.48 | 5.29 | .47 |
| 24 | 1 | 2.67 | 7.11 | .38 | 58 | 1 | 4.25 | 7.02 | .61 |
| 24 | 0 | 3.38 | 8.10 | .42 | 58 | 1 | 4.16 | 7.29 | .57 |
| 25 | 0 | 3.60 | 9.26 | .39 | 59 | 0 | 2.62 | 3.68 | .71 |
| 26 | 1 | 2.40 | 6.13 | .39 | 60 | 0 | 4.85 | 6.46 | .75 |
| 27 | 1 | 3.45 | 9.31 | .37 | 61 | 1 | 3.11 | 5.51 | .56 |
| 27 | 1 | 4.76 | 9.22 | .52 | 62 | 1 | 4.40 | 6.58 | .67 |
| 28 | 1 | 4.27 | 13.09 | .33 | 63 | 1 | 3.23 | 5.19 | .62 |
| 29 | 1 | 2.57 | 8.41 | .31 | 64 | 0 | 1.88 | 2.48 | .76 |
| 29 | 1 | 2.60 | 8.41 | .31 | 64 | 0 | 1.81 | 2.68 | .68 |
| 29 | 1 | 2.58 | 8.76 | .30 | 66 | 1 | 3.97 | 5.85 | .68 |
| 30 | 1 | 2.10 | 5.11 | .41 | 67 | 1 | 2.46 | 5.04 | .49 |
| 31 | 1 | 2.44 | 6.17 | .40 | 67 | 1 | 2.40 | 5.28 | .45 |
| 32 | 1 | 2.81 | 13.83 | .20 | 67 | 0 | 3.31 | 4.04 | .82 |
| 32 | 1 | 2.95 | 11.16 | .26 | 68 | 1 | 4.05 | 7.08 | .57 |
| 33 | 0 | 2.32 | 5.35 | .43 | 69 | 1 | .402 | 4.74 | .85 |
| 33 | 1 | 1.69 | 8.19 | .21 | 69 | 1 | 4.93 | 8.57 | .58 |
| 34 | 0 | 3.55 | 9.11 | .39 | 70 | 0 | 7.22 | 8.58 | .84 |
| 35 | 0 | 1.53 | 3.56 | .43 | 71 | 1 | 2.97 | 4.35 | .68 |

| Farmer | HV Dummy | $Ac^P$ | $AC^T$ | $Ac^P/AC^T$ |
|---|---|---|---|---|
| 61 | 1 | 3.92 | 6.63 | .59 |
| 72 | 1 | 2.37 | 6.05 | .39 |
| 72 | 1 | 2.45 | 4.58 | .54 |
| 73 | 0 | 3.00 | 3.90 | .77 |
| 74 | 0 | 4.10 | 6.07 | .78 |
| 75 | 0 | 4.03 | 6.43 | .63 |
| 75 | 0 | 3.98 | 6.28 | .63 |
| 65 | 1 | 2.19 | 3.40 | .64 |
| 75 | 1 | 2.72 | 3.87 | .70 |
| 76 | 1 | 2.98 | 6.29 | .47 |
| 76 | 1 | 3.09 | 5.53 | .56 |
| 77 | 0 | 4.10 | 6.07 | .68 |
| 78 | 0 | 3.27 | 5.12 | .64 |
| 79 | 0 | 4.05 | 5.88 | .69 |
| 80 | 1 | 1.50 | 2.87 | .52 |
| 80 | 1 | 1.56 | 2.84 | .55 |
| 81 | 1 | 2.72 | 7.75 | .35 |
| 82 | 1 | 2.58 | 4.31 | .60 |
| 83 | 0 | 4.96 | 6.94 | .71 |
| 84 | 1 | 4.24 | 6.89 | .62 |
| 85 | 1 | 2.10 | 4.31 | .49 |
| 86 | 0 | 3.10 | 3.97 | .78 |
| 86 | 0 | 4.29 | 6.43 | .67 |
| 87 | 0 | 4.08 | 6.35 | .64 |
| 88 | 0 | 2.77 | 3.79 | .73 |
| 88 | 0 | 3.61 | 5.17 | .70 |
| 89 | 0 | 4.21 | 6.65 | .63 |
| 90 | 0 | 1.71 | 2.69 | .63 |
| 91 | 1 | 2.95 | 6.20 | .48 |
| 91 | 1 | 3.09 | 5.19 | .60 |
| 92 | 0 | 3.77 | 5.03 | .75 |
| 93 | 0 | 3.13 | 4.41 | .71 |
| 93 | 0 | 3.12 | 4.17 | .75 |
| 93 | 0 | 3.21 | 4.46 | .72 |
| 93 | 0 | 2.95 | 3.66 | .81 |
| 94 | 1 | 3.69 | 7.71 | .48 |
| 94 | 1 | 5.10 | 9.37 | .54 |
| 95 | 1 | 1.63 | 4.95 | .33 |
| 95 | 1 | 1.34 | 2.58 | .52 |
| 95 | 1 | 1.82 | 3.12 | .58 |
| 96 | 0 | 1.29 | 2.50 | .52 |
| 97 | 1 | 1.55 | 3.60 | .43 |
| 97 | 0 | 2.08 | 3.29 | .63 |
| 97 | 0 | 2.15 | 3.56 | .60 |
| 97 | 0 | 2.07 | 3.52 | .59 |
| 98 | 1 | 3.04 | 5.69 | .53 |
| 98 | 1 | 3.10 | 6.05 | .51 |
| 98 | 1 | 3.09 | 5.14 | .60 |
| 99 | 0 | 4.33 | 6.02 | .72 |
| 99 | 0 | 4.51 | 6.52 | .69 |
| 99 | 0 | 4.13 | 6.37 | .65 |
| 100 | 0 | 3.74 | 4.67 | .80 |
| 100 | 0 | 3.78 | 4.74 | .80 |
| 100 | 1 | 2.84 | 4.10 | .69 |
| 100 | 1 | 2.88 | 3.85 | .75 |
| 101 | 1 | 2.88 | 5.63 | .51 |
| 101 | 0 | 4.24 | 6.81 | .62 |
| 102 | 0 | 3.86 | 5.12 | .76 |
| 102 | 0 | 4.97 | 7.28 | .68 |
| 103 | 1 | 1.71 | 5.34 | .32 |
| 104 | 1 | 3.14 | 5.31 | .59 |
| 104 | 1 | 2.52 | 3.24 | .78 |
| 104 | 1 | 2.23 | 4.32 | .52 |
| 105 | 0 | 4.43 | 5.83 | .76 |
| 105 | 0 | 4.56 | 6.08 | .75 |
| 106 | 1 | 2.47 | 3.33 | .74 |
| 106 | 1 | 2.47 | 3.29 | .75 |
| 106 | 0 | 3.24 | 4.23 | .77 |
| 106 | 0 | 4.59 | 7.14 | .64 |
| 107 | 1 | 2.14 | 4.52 | .47 |
| 107 | 1 | 2.12 | 5.33 | .40 |
| 107 | 0 | 3.01 | 3.97 | .76 |
| 107 | 0 | 3.01 | 3.97 | .76 |
| 108 | 1 | 3.53 | 6.15 | .57 |
| 108 | 1 | 2.80 | 3.60 | .78 |
| 108 | 0 | 4.85 | 7.57 | .64 |
| 109 | 1 | 2.45 | 4.86 | .50 |
| 109 | 0 | 3.28 | 4.84 | .68 |
| 109 | 0 | 3.42 | 5.28 | .65 |
| 109 | 0 | 3.34 | 5.07 | .66 |
| 110 | 0 | 5.69 | 7.17 | .79 |
| 111 | 0 | 4.11 | 6.06 | .68 |
| 111 | 1 | 3.07 | 4.27 | .72 |
| 111 | 1 | 3.02 | 4.69 | .64 |
| 112 | 0 | 4.08 | 6.79 | .60 |
| 112 | 0 | 3.99 | 6.56 | .61 |
| 113 | 0 | 1.38 | 2.26 | .61 |
| 114 | 0 | 2.00 | 3.11 | .64 |
| 115 | 0 | 3.46 | 5.84 | .59 |
| 115 | 0 | 3.41 | 5.52 | .62 |
| 116 | 0 | 3.91 | 5.77 | .68 |
| 116 | 0 | 4.40 | 7.08 | 162 |
| 117 | 0 | 4.02 | 5.95 | .68 |
| 118 | 1 | 4.32 | 2.99 | .69 |
| 118 | 1 | 4.57 | 4.00 | .88 |
| 118 | 1 | 4.26 | 4.22 | .99 |
| 118 | 1 | 4.21 | 4.39 | .96 |
| 119 | 0 | 3.54 | 4.43 | .80 |
| 121 | 1 | 1.97 | 4.80 | .41 |
| 121 | 0 | 2.65 | 3.18 | .83 |
| 123 | 1 | 4.06 | 5.22 | .78 |
| 123 | 1 | 3.95 | 5.51 | .72 |
| 124 | 1 | 2.73 | 4.14 | .66 |
| 125 | 1 | 1.82 | 3.62 | .50 |
| 125 | 1 | 2.22 | 7.34 | .30 |
| 125 | 1 | 2.32 | 5.54 | .42 |

*Table B.2. Risk Preference and Subjective Yield Variance Estimates, 1976/77 Northern Tunisia*

| Farmer | HV Dummy | ΦK[a] | Φ | $V(Y)^{.5}$/ha | Farmer | HV Dummy | ΦK[a] | Φ | $V(Y)^{.5}$/ha |
|---|---|---|---|---|---|---|---|---|---|
| 1 | 1 | 3.023 | .004055 | 5.885 | 39 | 1 | 1.995 | .001264 | 5.074 |
| 1 | 1 | 4.057 | .003550 | 7.806 | 39 | 1 | .186 | .000063 | 7.026 |
| 2 | 1 | 1.848 | .002972 | 9.758 | 40 | 1 | 5.395 | .004350 | 10.929 |
| 2 | 0 | .738 | .001235 | 7.806 | 40 | 0 | 5.402 | .007326 | 5.855 |
| 3 | 1 | 4.069 | .008558 | 6.635 | 40 | 0 | 7.257 | .001944 | 5.074 |
| 3 | 0 | −3.789 | −.005741 | 5.464 | 41 | 0 | 3.244 | .001776 | 5.464 |
| 4 | 1 | 7.225 | .027046 | 6.635 | 41 | 1 | 7.203 | .013062 | 4.879 |
| 5 | 1 | 5.219 | .001413 | 8.977 | 42 | 1 | 7.290 | .003596 | 4.294 |
| 5 | 1 | 4.963 | .003112 | 7.026 | 43 | 0 | −.640 | −.000386 | 4.684 |
| 6 | 1 | 6.931 | .038576 | 3.513 | 44 | 1 | 7.870 | .003825 | 5.074 |
| 7 | 0 | 5.466 | .001818 | 7.806 | 45 | 1 | −.146 | −.000025 | 7.806 |
| 7 | 0 | 4.186 | .000787 | 7.416 | 45 | 1 | −.046 | −.000008 | 7.806 |
| 9 | 1 | 1.204 | .001592 | 5.074 | 45 | 0 | −1.090 | −.000226 | 5.855 |
| 9 | 1 | .962 | .000285 | 5.855 | 45 | 0 | −2.060 | −.001128 | 5.855 |
| 9 | 0 | 1.380 | .000129 | 7.026 | 45 | 1 | −.592 | −.000862 | 3.903 |
| 10 | 0 | 4.928 | .002395 | 7.806 | 46 | 1 | 7.141 | .035742 | 5.855 |
| 10 | 1 | 3.831 | [illegible] | 9.758 | 46 | 0 | 7.176 | .012234 | 6.635 |
| 10 | 1 | 4.202 | .002896 | 9.758 | 47 | 0 | 7.242 | .009085 | 5.855 |
| 11 | 1 | 2.692 | .005935 | 12.100 | 47 | 0 | 7.242 | .015024 | 6.245 |
| 11 | 1 | 2.009 | .008215 | 7.026 | 48 | 1 | 3.572 | .000112 | 11.710 |
| 12 | 1 | 3.709 | .010363 | 6.245 | 48 | 1 | 3.783 | .000850 | 7.805 |
| 13 | 1 | 4.677 | .001667 | 9.758 | 49 | 0 | −3.548 | −.001954 | 3.903 |
| 14 | 0 | −.040 | −.000054 | 7.026 | 49 | 1 | −2.010 | −.001205 | 5.464 |
| 14 | 0 | −3.968 | −.044909 | 2.342 | 50 | 1 | 3.521 | .002820 | 9.563 |
| 16 | 0 | 1.091 | .003765 | 4.294 | 52 | 1 | 1.489 | .000514 | 7.806 |
| 16 | 1 | 3.796 | .002354 | 8.587 | 52 | 0 | .236 | .000858 | 3.903 |
| 17 | 1 | 2.910 | .001757 | 7.026 | 53 | 0 | 4.828 | .000933 | 6.440 |
| 18 | 0 | 1.235 | .002839 | 3.513 | 53 | 1 | 4.194 | .000668 | 4.879 |
| 18 | 1 | 2.889 | .004509 | 4.294 | 54 | 1 | −2.285 | −.000112 | 13.661 |
| 18 | 1 | 2.889 | .013528 | 4.294 | 54 | 1 | −3.217 | −.001998 | 7.806 |
| 19 | 1 | .785 | .000178 | 6.245 | 54 | 1 | 2.414 | .002018 | 8.197 |
| 19 | 1 | 1.482 | .000423 | 5.074 | 54 | 0 | −2.035 | −.001041 | 6.635 |
| 20 | 0 | −1.487 | −.008043 | 2.342 | 55 | 1 | −4.325 | −.007252 | 2.342 |
| 21 | 1 | 2.876 | .003016 | 2.732 | 56 | 1 | −2.254 | −.000398 | 6.440 |
| 22 | 1 | 3.857 | .001408 | 6.245 | 56 | 1 | .862 | .000228 | 3.513 |
| 23 | 0 | 3.245 | .008395 | 4.684 | 57 | 1 | 7.119 | .011399 | 4.294 |
| 23 | 1 | 4.080 | .020970 | 5.464 | 58 | 1 | 2.634 | .003720 | 3.513 |
| 24 | 1 | 2.966 | .010698 | 4.879 | 58 | 1 | 1.902 | .000328 | 7.806 |
| 24 | 0 | 7.225 | .009283 | 5.464 | 59 | 0 | 4.159 | .003158 | 5.855 |
| 25 | 0 | −6.283 | −.009408 | 5.464 | 60 | 0 | 5.759 | .010266 | 10.148 |
| 26 | 1 | .738 | .005495 | 3.513 | 61 | 1 | 3.454 | .011670 | 3.513 |
| 27 | 1 | −6.839 | −.005869 | 3.903 | 62 | 1 | 3.052 | .001392 | 3.903 |
| 27 | 1 | −2.194 | −.005700 | 5.464 | 63 | 1 | 3.777 | .009940 | 6.440 |
| 28 | 1 | 4.483 | .004597 | 4.684 | 64 | 0 | −7.425 | −.015758 | 2.537 |
| 29 | 1 | 2.123 | .007450 | 3.123 | 64 | 0 | .258 | .000310 | 4.684 |
| 29 | 1 | 2.123 | .014595 | 2.342 | 66 | 1 | 3.903 | .003049 | 8.197 |
| 29 | 1 | .139 | .000394 | 3.513 | 67 | 1 | 1.733 | .000281 | 5.855 |
| 30 | 1 | 7.257 | .024534 | 4.684 | 67 | 1 | 7.290 | .001786 | 5.074 |
| 31 | 1 | 7.322 | .007694 | 12.490 | 68 | 1 | 7.154 | .031768 | 2.342 |
| 32 | 1 | 1.592 | .000085 | 10.148 | 69 | 1 | −3.479 | −.011723 | 5.074 |
| 32 | 1 | −.335 | −.000041 | 9.758 | 69 | 1 | 1.042 | .001083 | 8.197 |
| 33 | 0 | 7.029 | .003159 | 3.903 | 70 | 0 | 5.219 | .004237 | 5.269 |
| 33 | 1 | 6.765 | .002220 | 4.294 | 71 | 1 | 1.045 | .001916 | 7.806 |
| 33 | 0 | 6.946 | .001924 | 4.294 | 71 | 1 | .143 | .000680 | 3.903 |
| 34 | 0 | 3.436 | .012586 | 3.123 | 72 | 1 | .611 | .000088 | 12.881 |
| 34 | 0 | 4.007 | .020064 | 3.123 | 72 | 1 | .620 | .000253 | 7.806 |
| 35 | 0 | −7.25 | .009887 | 5.464 | 73 | 0 | 4.521 | .016300 | 1.952 |
| 38 | 0 | .328 | .000544 | 3.123 | 75 | 0 | 3.709 | .033149 | 2.732 |
| 38 | 1 | .756 | .000494 | 4.294 | 75 | 0 | 3.857 | .024286 | 3.123 |

| Farmer | HV Dummy | ΦK* | Φ | $V(Y)^{.5}$/ha |
|---|---|---|---|---|
| 75 | 1 | 3.631 | .014590 | 3.123 |
| 75 | 1 | 3.591 | .008078 | 4.489 |
| 77 | 0 | −.003 | −.000020 | 1.561 |
| 78 | 0 | 4.345 | .015870 | 1.756 |
| 79 | 0 | −.677 | −.003331 | 2.342 |
| 80 | 1 | 3.903 | .005234 | 5.855 |
| 80 | 1 | 1.043 | .000887 | 8.197 |
| 81 | 1 | 2.987 | .000111 | 9.758 |
| 82 | 1 | .592 | .000947 | 5.855 |
| 83 | 0 | −.003 | −.000007 | 1.952 |
| 84 | 1 | 2.484 | .000307 | 13.661 |
| 85 | 1 | −1.374 | −.004954 | 4.879 |
| 86 | 0 | 7.029 | .036128 | 2.732 |
| 86 | 0 | 6.768 | 1.34488 | 1.561 |
| 88 | 0 | −1.589 | −.008723 | 5.074 |
| 88 | 0 | −6.141 | −.020592 | 5.074 |
| 89 | 0 | .568 | .007095 | 2.342 |
| 90 | 0 | 2.281 | .018662 | 3.513 |
| 91 | 1 | 1.482 | .000267 | 7.026 |
| 91 | 1 | .662 | .000453 | 7.026 |
| 92 | 0 | 3.418 | .005209 | 4.684 |
| 93 | 0 | .294 | .003651 | 2.927 |
| 93 | 0 | .568 | .000657 | 7.806 |
| 93 | 0 | −.325 | .004389 | 3.903 |
| 93 | 0 | 6.497 | .008245 | 3.903 |
| 94 | 1 | 4.400 | .002298 | 3.903 |
| 94 | 1 | 3.803 | .007258 | 3.123 |
| 95 | 1 | −1.024 | −.000630 | 3.903 |
| 95 | 1 | 2.207 | .012301 | 5.074 |
| 95 | 1 | −9.625 | −.039429 | 2.342 |
| 96 | 0 | 7.077 | .091356 | 5.035 |
| 97 | 1 | −5.159 | −.016247 | 4.879 |
| 97 | 0 | −6.706 | −.026395 | 4.098 |
| 97 | 0 | 6.768 | .022415 | 1.952 |
| 97 | 0 | 7.029 | .019976 | 4.098 |
| 98 | 1 | 3.583 | .005637 | 4.879 |
| 98 | 1 | 2.077 | .005922 | 3.513 |
| 98 | 1 | 1.440 | .005074 | 3.318 |
| 99 | 0 | 1.867 | .003525 | 3.123 |
| 99 | 0 | −7.389 | −.074598 | 3.903 |
| 99 | 0 | 4.778 | .015508 | 4.684 |
| 100 | 0 | 6.856 | .029178 | 3.318 |

| Farmer | HV Dummy | ΦK* | Φ | $V(Y)^{.5}$/ha |
|---|---|---|---|---|
| 100 | 0 | 6.920 | .077453 | 1.756 |
| 100 | 1 | 4.650 | .027471 | 5.074 |
| 100 | 1 | 4.583 | .090183 | 2.537 |
| 104 | 1 | 1.550 | .003291 | 8.392 |
| 104 | 1 | .647 | .002937 | 10.539 |
| 104 | 1 | .257 | .000130 | 6.831 |
| 105 | 0 | −4.825 | −.022609 | 3.903 |
| 105 | 0 | −2.045 | −.025169 | 4.489 |
| 107 | 1 | .919 | .00329 | 5.464 |
| 107 | 1 | 1.234 | .000322 | 5.464 |
| 107 | 0 | 1.130 | .0005[illegible]0 | 6.635 |
| 108 | 1 | 7.176 | .006289 | 4.489 |
| 108 | 1 | 7.190 | .012354 | 5.855 |
| 108 | 0 | 7.141 | .024323 | 3.123 |
| 108 | 1 | 7.159 | .022761 | 3.903 |
| 109 | 1 | 1.121 | .002991 | 2.732 |
| 109 | 0 | 7.366 | .016396 | 1.756 |
| 109 | 0 | −4.965 | −.060260 | 1.366 |
| 109 | 0 | −1.926 | −.013355 | .976 |
| 110 | 0 | −2.631 | −.003101 | 3.708 |
| 110 | 0 | −1.455 | −.000894 | 4.098 |
| 111 | 0 | −3.217 | −.029008 | 1.952 |
| 111 | 1 | −.316 | −.001848 | 2.537 |
| 111 | 1 | −.316 | −.000831 | 3.318 |
| 113 | 0 | −3.831 | −.005048 | 3.708 |
| 114 | 0 | .3354 | .017544 | 1.561 |
| 116 | 0 | 2.688 | .003649 | 4.294 |
| 116 | 0 | −2.045 | −.033860 | 3.513 |
| 117 | 0 | −7.776 | −.074498 | 1.952 |
| 118 | 1 | .247 | .001010 | 3.318 |
| 118 | 1 | .497 | .006898 | 3.316 |
| 118 | 1 | .273 | .001193 | 3.708 |
| 118 | 1 | .287 | .001192 | 3.123 |
| 119 | 0 | −1.385 | −.001452 | 6.245 |
| 121 | 1 | −2.127 | −.000403 | 5.660 |
| 121 | 0 | −1.909 | −.000659 | 3.903 |
| 123 | 1 | 2.150 | .004450 | 8.782 |
| 123 | 1 | .672 | .001462 | 4.879 |
| 124 | 1 | 1.425 | .003988 | 5.855 |
| 125 | 1 | 1.463 | .002142 | 5.855 |
| 125 | 1 | .1174 | .000207 | 7.806 |
| 125 | 1 | 2.650 | .002810 | 5.855 |

*$K = \partial V(\Pi_n)/\partial X_{1n}$