BIBLIOGRAPHIC DATA SHEET	1. CONTROL NUMBER PN-AAH-602	2. SUBJECT CLASSIFICATION (695) AF00-0180-G240

3. TITLE AND SUBTITLE (240)

Risk and allocative errors due to imperfect information; the impact of wheat technology in Tunisia

4. PERSONAL AUTHORS (100)

Nygaard, D. F.

5. CORPORATE AUTHORS (101)

Minn. Univ. Economic Development Ctr.

6. DOCUMENT DATE (110)	7. NUMBER OF PAGES (120)	8. ARC NUMBER (170)
1979	145p.	TS633.11.N994

9. REFERENCE ORGANIZATION (130)

Minn.

10. SUPPLEMENTARY NOTES (500)

(Thesis (Ph.D.) - University of Minnesota)

11. ABSTRACT (950)

12. DESCRIPTORS (920)

Tunisia
Agricultural Production
Allocations
Productivity allocations
Technology adoption
Wheat
Production function
Agric ultural technology
Risk
High yield
Cost analysis
Productivity

13. PROJECT NUMBER (150)

931023600

14. CONTRACT NO.(140)

AID/ta-BMA-5

15. CONTRACT TYPE (140)

16. TYPE OF DOCUMENT (160)

54

AID 590-7 (10-79)

PN-AAH-602

TS
633.11
N994

RISK AND ALLOCATIVE ERRORS DUE TO IMPERFECT INFORMATION: THE IMPACT OF WHEAT TECHNOLOGY IN TUNISIA

by

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Ph.D Thesis
Department of Agricultural and Applied Economics
December, 1979

RISK AND ALLOCATIVE ERRORS DUE TO IMPERFECT INFORMATION: THE IMPACT ON WHEAT TECHNOLOGY IN TUNISIA

A THESIS
SUBMITTED TO THE FACULTY OF THE GRADUATE SCHOOL
OF THE UNIVERSITY OF MINNESOTA

by

DAVID FERGUS NYGAARD

IN PARTIAL FULFILLMENT OF THE REQUIREMENTS
FOR THE DEGREE OF
DOCTOR OF PHILOSOPHY

December, 1979

ACKNOWLEDGEMENTS

There were many persons whose assistance was of great help to me during the course of this research project. Although they are not all mentioned here, their support was still very much appreciated. Those mentioned below deserve a special thank you.

Dr. Terry Roe's contribution was most important, and he deserves to be acknowledged at the outset. As major professor, he was involved from the beginning and gave consistent support throughout. His guidance made the process more stimulating and interesting and resulted in an improved final product. The contribution of other committee members was also important. Dr. Harald Jensen's guidance after my return from Tunisia was greatly appreciated, particularly at the writing stage. Dr. Vernon Eidman helped me through a number of theoretical trouble spots. Drs. Oswald Brownlee and Norman Simler provided useful contributions to the analysis.

In Tunisia, I would have made little progress without the support of Dr. Ali Ben Zaid. INAT (Institut National Agronomique de Tunisie) provided me with an excellent working environment. I thank Dr. Kamel Belkhodja, Director, and Mr. Muncel Ben Said for the opportunity to work there. Mr. Habib Zidani, who assisted me in the data collection, was a sensitive and competent interviewer. Mr. Chabile Bedowi and Mr. Boubakker Thabet of the Bureau de Plan gave needed assistance. Dr. Werner Kiene of the Ford Foundation was a pleasant source of advice and continual encouragement.

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USAID (United States Agency for International Development) funded the research. These funds were administered by the Economic Development Center at the University of Minnesota. I thank these two organizations for this support.

Any credit for completing this research and, indeed, achieving this degree must be given to my wife, Mary. She contributed greatly to the whole process in many crucial and special ways. I hope that she and our daughters, Tanya and Kara, will also share in the resulting benefits.

Finally, this thesis is dedicated to my father, whose pride knows no bounds. I hope some of it is deserved.

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CHAPTER I

INTRODUCTION

Agricultural producers in many developing countries have been exposed during the past decade to pressures to increase their productivity. Recognizing (1) the importance of agriculture for general economic development, (2) the potential for increased productivity in both the traditional and modern agricultural sectors, and (3) the increasing demand for food explains, in part, why these pressures developed. The early successes of the "green revolution," which increased production in some of these countries, has encouraged development efforts with high expected returns.

However, as efforts to spread new seed varieties and production techniques continued, the growth rate of productivity decreased and adoption rates declined. Even the superiority of the new technology is called into question as (1) marginally poorer land is brought under the umbrella of development plans, (2) more producers with small farms become potential adopters, (3) infrastructure constraints become binding as one moves away from modern centers, and (4) managerial skills of potential adopters become weaker. The apparent complexity of the adoption process and variable resource use has become evident, and it is recognized that a host of determinants affect this process.

The Tunisian experience provides a good example of this complexity. Mexican high-yielding wheat varieties were introduced into Tunisia

in 1968. Adoption by the state-owned farms and large private farms occurred rather quickly. These farms are located on some of the best agricultural land in the country, are operated by informed managers or entrepreneurs, are large and highly mechanized, are well-serviced by roads, and have access to local and national capital markets.

The percentage of total wheat area planted to high-yielding varieties (HYV's) in 1971, three years after new varieties were introduced into Tunisia, was 10.7 percent.[1] A large portion of this area was state-farm land. In 1976, nine years after introduction, this percentage had only increased to 14.7 percent.[2] Compare this with adoption rates of over 50 percent in India, Nepal, and Pakistan.[3] Added to this is the fact that wheat production in general only increased at a rate of 0.5 percent during the fourth development plan from 1972-1976.[4]

Why has the rate of adoption been so low in Tunisia after an initially successful introductory phase? What are the constraining factors to increasing this adoption rate and wheat yields in general? What tools are available to governments to alleviate the constraints, and what are realistic adoption and production goals?

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[1] Salem Gafsi. "Green Revolution: The Tunisian Experience." Unpublished Ph.D. thesis, University of Minnesota. August, 1975. P. 3.

[2] République Tunisienne, Ministere de l'Agriculture, Direction du Plan. "Budget Economique 1977." P. 3.

[3] United States Department of Agriculture, Economics Research Service. Development and Spread of High-Yielding Varieties of Wheat and Rice in the Less Developed Countries. Foreign Agricultural Economic Report No. 95. July, 1974. P. 72.

[4] Republique Tunisienne, Ministere de l'Agriculture. Preparation du Veme Plan: Retrospective et Projection Preliminaire. Janviere, 1976. P. 3.

Answers to these questions have been attempted; some constraints to adoption and productivity growth in Tunisia have been identified and, in some cases, eased. However, adoption and growth rates are still low. The relationship and importance of the many variables involved are not completely understood. This study is an effort to clarify some of these relationships that are characteristic of wheat production in Tunisia.

Gains can be made in any production process or technique if it is currently being done inefficiently. However, several previous studies, most notably Schultz's (64), conclude that farmers in developing countries using traditional methods are rather efficient in their use of available inputs.[1] Thus, the brunt of increased productivity must come largely from new inputs or techniques. Ruttan (61), in the first of his seven generalizations about the green revolution, notes that "the new wheat and rice varieties were adopted at exceptionally rapid rates in those areas where they were technically and economically superior to local varieties."[2] Winkelmann (72) coordinated for CIMMYT seven adoption studies of new wheat and maize varieties. These studies generally found farmers to be profit-motivated and risk-averse. Agroclimatic characteristics were the factors most consistent in explaining adoption practices. Statements on the consistency of a number of socio-economic factors across the seven studies cannot be made. Gafsi's study on Tunisia, one of CIMMYT's seven, is obviously most relevant to this study. He found

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[1]Hopper (31), Massel (45,), and Yotopoulos (77) are other examples.

[2]Vernon W. Ruttan. "The Green Revolution: Seven Generalizations." International Development Review. 13 (April, 1977): p. 16.

topography, credit use, and price differentials across varieties as partially explanatory factors of adoption in northern Tunisia.

In order to expand on Gafsi's results, one needs to better understand the adoption and productivity problems of the wheat subsector and needs to obtain insights into the decision-making process for Tunisian wheat producers. Such a process requires a decision be made given incomplete information and imperfect knowledge of the true state of nature--a state whose outcomes can at best be foreseen as having only a probability of occurring. An early decision is required on inputs such as fertilizer application, seedbed preparation, variety choice, and seeding rate six to nine months before the production is realized and the yields known. One of the problems confronted in this study is to understand what and how possible adjustments in resource allocations, including seed choice, are made by the producer due to the imperfect information that he has when these input decisions must be made.

Risky outcomes, risk attitudes provoked by these outcomes, the formulation of perceptions of a production process, errors caused by incorrect perceptions, knowledge gained over time, and adjustments taken in response to this new knowledge may be important determinants of input choices and realized outcomes. These determinants give rise to the value of education, information, and/or related variables which influence managerial ability.

Consequently, the objectives of this thesis are as follows:

1. To gain insights into the decision-making process regarding the nature of the producers' expectations of input-output relationships and to show how these expectations influence

input decisions including seed choice.

2. Assess and explain the difference between these expectations and the input-output relationship actually obtained and relate this error to productivity issues in Tunisia.

These objectives can be achieved by answering the following questions:

1. What is the producer's perception of the production relationship at the time he makes his input decisions?
2. Do risk and uncertainty play a role in resource allocation and new technological adoption? If so, how?
3. What are the true production parameters, and do these differ from the perceived parameters?
4. What is the likely impact of the producer's misperceptions of the true production parameters on wheat production in Tunisia, including the impact on adoption rates of HYV's?
5. Which farm and farmer characteristics are most important in explaining behavior patterns such as risk aversion, allocative errors, and adoption hesitancy in Tunisian wheat production?

From a sample of 125 durum wheat producers in nothern Tunisia during the 1976/77 wheat season, data were collected and analyzed to permit one to achieve the objective mentioned above. The following approach is taken: First, a utility maximization decision rule based on producer perceptions is constructed to test the hypotheses that

1. decision makers perceive the potential outcomes from wheat production in Tunisia as being described by a probability

distribution;

2. they are risk averse, and

3. these risk preferences are determined by characteristics of the producer and his farm.

If their utility function is nonlinear, and if its attribute is normally distributed, they maximize profits subject to an adjustment made due to a random variance in profit. A risk-averse producer confronted with a risky prospect will underutilize inputs and might be less likely to adopt high-yielding varieties. To test these hypotheses, a perceived production function is estimated, a risk parameter is derived, and a functional relationship is established to explain its variability. Finally, the parameter is tested as an explanatory variable of adoption rates.

Input decisions are made on expected or perceived parameters of the decision variables. The second objective of this research involves a comparison of these perceptions with the true parameters. This is done by deriving normative, perceived, and true total cost curves. The difference between perceptions and reality is a measure of allocative error. Then a functional relationship between this error and experience, other measures of managerial ability, and some farm characteristics is estimated. Thus, the hypotheses relative to the efficiency of technology use are as follows:

1. Tunisian producers make allocative errors due to misperceptions of the production process.

2. These errors indicate that costly resource allocation errors are made.

3. These errors are negatively correlated with the number of years experience a farmer has with the variety as well as correlated with other producer and farm characteristics.

The usefulness of the results to Tunisian planners and policymakers concerned with wheat production includes the following: gaining information on the importance of risk and uncertainty, obtaining insights into the nature of allocative errors in the resource allocation process at the farm level, understanding the likely impact of the error on durum wheat production and the adoption of HYV's, identifying constraints to durum wheat productivity and constraints to adoption which might be alleviated by existing policy instruments, and finally, recognizing a more realistic potential of wheat production in Tunisia.

The thesis is organized as follows: The conceptual framework is the focus of the next chapter where the contributions of others are discussed. The impact of risk and uncertainty is developed, and the relationship between the perceived and true states of nature is determined. The sampling procedure, the questionnaire, and the interview process employed in Tunisia are explained in Chapter III. The Tunisian wheat sector is also described. The estimating equations which follow from the theoretical framework are specified in Chapter IV. The hypotheses which can be derived from the conceptual framework are tested, and the empirical findings presented. The usefulness of these results to Tunisian policymakers is also outlined. Chapter V concludes the thesis with a summary and suggestions for further research.

CHAPTER II

THE THEORETICAL MODEL

This chapter proposes a framework that characterizes the decision-making process of Tunisian wheat farmers. The emphasis is on adjustments made by the decision maker to allow for uncertainty in production and lack of perfect information. A wealth of literature exists covering issues relevant to this study, yet the framework proposed here has many unique features. Consequently, much of the discussion revolves around adapting others' work to the problem when this is applicable and more rigorously and consistently weaving in the unique features to complete the model.

This chapter is divided into three sections. First, the problem, the approach, and a general formulation of the model is presented in a descriptive fashion. An effort is made to mention those studies clearly related to the topic, especially those most important in helping to conceptualize the decision-making process and guiding the direction and approach of this thesis. Also, an effort is made to clarify terminology.

The second edition is a more detailed treatment of the perceived production function and the role of risk and uncertainty in the decision-making process when derived from the theory of utility maximization. The model is formulated in this setting, and its hypothesized usefulness in understanding the wheat sector in Tunisia is discussed. The third section differentiates between perceived and true relationships. Again

the methodology relating to the Tunisian situation is explored.

A GENERAL FORMULATION

The problem is to develop a model of the decision-making process that explains producer behavior under uncertain physical conditions and in a dynamic economic setting. To do this, a model is specified that describes a process which

1. incorporates risk and uncertainty principles by using a utility maximization framework,
2. differentiates between a production relationship that the decision maker has in mind when input decisions are made, e.g., at seed bed preparation time, and that process which converts those inputs into products,
3. characterizes this difference as an allocative error, and
4. relates risk attitudes and allocative errors to adoption rates and experience that producers have had with a variety.

As a starting point, one can visualize, in a static context, a profit-maximizing entrepreneur who, subject to production function constraints, input-output price relationships, and fixed and/or noncontrollable resource endowments, meets the traditional neoclassical equilibrium conditions. These are (1) the value marginal product of any input is equal across uses, (2) the value marginal product of each input equals its price, and (3) the ratio of marginal products for two inputs equals the price ratio of those inputs. Sufficient conditions for reaching such an equilibrium are well-known as are the required assumptions of perfect knowledge and a single-goal (i.e., profit maximization) objective

function.

The modification of the neoclassical framework to characterize a situation where output and/or input variables are random and decision-maker's utility is influenced by this uncertainty is well-established in the literature. Examples include Magnusson (43), Pratt (52), and Arrow (4). This is particularly true in the agricultural economics' literature (Anderson, Dillon, and Hardaker [1], Roumasset [60], Scandizzo and Dillon [63], and Woglin [74]).

Consequently, a conventional wisdom has developed which is frequently seen in the literature which stresses the importance of risk and uncertainty and the effect on production decisions in the following way: First, production of most agricultural products is said to be stochastic and thus the economic return to the producer is variable. Seocnd, producers are assumed to maximize utility, are risk-aversive, and underutilize inputs relative to profit-maximizing optima;[1] i.e., they are allocatively inefficient. They are inefficient in the sense that additional resources will yield returns greater than their cost. While they may be efficiently maximizing their utility, a reduction in risk will increase their income and utility as well.

What evidence exists to support or refute this perspective? First, the riskiness of the potential outcomes must be determined. There is fairly wide acceptance of riskiness of agricultural production itself. De Janvry (14) considers the riskiness of using fertilizer on wheat and

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[1]Just and Pope (36) point out examples such as in the case of herbicide use, a risk-averse producer may overutilize inputs relative to profit-maximum criteria.

corn in Argentina. He illustrates the importance of understanding the level of risk attached to different amounts of fertilizer usage. Ryan and Perrin (62) found increased risk associated with fertilizer doses when they estimated a response function for potatoes in Peru. In contrast, it is worth noting that Roumasset found, when studying rice in the Philippines, that fertilizer applications do not increase financial risk.

Secondly, the conventional wisdom is supportable only if producers are utility-maximizers and are risk-averse. The expected utility theory (or Bernoullian decision theory) is, some maintain, the most intuitive way to incorporate risk and uncertainty into the decision-making process (Dillon [17] and Anderson [3]). This theory recognizes two necessary components for handling such issues: (1) personal valuation of consequences and (2) personal strengths of belief about occurrence of uncertain events.[1] The first of these is reflected in an individual's utility function, and the second refers to an individual's subjective probabilities associated with various outcomes.

Most studies analyzing risk preferences do so by using an objective probability measure. Woglin's study (74) is a typical case in point. He uses historical data to reflect the probability distributions of current output and prices. Anderson and Dillon argue instead for the use of personal probabilities of outcomes as the only useful and logical probability concept in decision making. While empirical efforts to do

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[1] J. L. Dillon. "An Expository Review of Bernoullian Decision Theory in Agriculture: Is Utility Futility?" Review of Marketing and and Agricultural Economics. 99 (March, 1971): p. 4.

this are few, Roumasset approached such a concept by determining the number of years in ten that farmers would expect a poor growing season.

Much more work has been done determining risk preferences. The assumption that they are risk-averse has not been irrefutably established, but the success of several studies is worth noting. Officer and Halter (50) found utility preferences of decision makers in their study to indicate risk aversion. Woglin used the expected utility approach in trying to explain cropping patterns by small farmers in Kenya. He found such farmers to be efficient risk-averse entrepreneurs. Dillon and Scandizzo in a study in Brazil found substantial numbers of risk-averse producers. Those that were risk-averse, however, exhibited extreme risk-aversion attitudes. Binswanger (6), interviewing farmers in India, found 82 percent of his sample to be moderately risk-averse.

The Bernoullian decision approach has also given useful results in several studies. Lin, Dean, and Moore (41) showed the superiority of assuming maximization of expected utility as opposed to maximization of profit. Moscardi and de Janvery (46) did not try to elicit a utility curve but instead solved residually for a risk parameter. Their results show that risk aversion explains the difference between actual demand for fertilizer and potential riskless demand.

Opponents of expected utility theory attack both the axioms on which it is based and the empirical difficulties of estimating utility functions. One of the more common alternative models that is found in the literature concerns the security or safety desires of the decision makers. In such studies some "rule of thumb" establishes a disaster level of income, a minimum return, or a suitable constraint such as

focus loss. Suitable examples of these three are found respectively in Pyle and Trunovsky (54), Roumasset, and Boussard and Petit (8). Not very different in approach are lexicographic orderings such as used by Rae (55). In fact, Roumasset combines these two in his safety-first rule. One problem with the above is trying to identify disaster levels and/or its determinants. It is interesting to note, while the safety rule approach is theoretically different from the expected utility theory, the interpretation of the results and the policy implications are frequently similar.

Following the lead of those noted above, this study utilizes a decision framework that maximizes utility which is a function of one attribute, income. This attribute is itself a function of two variables. They are expected income and the uncertainty of income--uncertainty being described by the variance of income, this variance being determined from subjective probabilities of expected wheat yields. The exact way in which risk is incorporated into the model will be left to the next section where the model is presented formally. Approaches of this nature have come to be classified as E-V analysis as suggested by Markowitz (44) in his study of portfolio analysis. E represents expected income and V the variance. While there is no explicit functional form estimated, there are implicit assumptions made. A quadratic function is one form which meets the necessary conditions of an E-V type problem. One can also approximate such a situation by taking Taylor's series expansion of other functional forms and still use E-V analysis by considering only the first two moments of the distribution. The omission of the higher moments is one obvious criticism of such an approach.

One should note, at this juncture, that the variance of expected income and expected yields referred to above is due to the variation in physical but noncontrollable inputs in the production process. Let

$$Y = F(X_i, Z_i)\varepsilon \tag{2.1}$$

represent the production function.

Y = output

X_i = controlled inputs

Z_i = noncontrolled inputs

ε = stochastic disturbance

The X_i's represent the typical inputs that the producer has control of, i.e., fertilizer, land, labor, and mechinery. The Z_i's, on the other hand, are taken as given, although unknown, at the time the input decision has to be made. The most likely example of such a varible is rainfall, although wind, hail, disease, and pests could qualify as well. It is this physical uncertainty that is generally used in the risk and uncertainty literature.

There is a second source of uncertainty, however, that is operative in agricultural production decisions. It is a subjective uncertainty that has to do with his familiarity and understanding of the production process, i.e., his knowledge of F in 2.1. More specifically, one can assume that the decision maker has control of the X_i's, has expectations of the mean and distribution of the Z_i's, and has subjective uncertainties about F.

There are a number of studies that have investigated the relationship between the farmer and his efficacy as a producer. These

studies can be grouped into three broad categories which are briefly reviewed here in an effort to show how previous work influenced the development of the model employed in this thesis. They are (1) studies of economic efficiency, (2) studies identifying the role of education and managerial ability in production, and (3) studies of technological adoption and diffusion.

Schultz's seminal article, mentioned in the introduction, notes "there are comparatively few significant inefficiencies in the allocation of the factors of production in traditional agriculture."[1] In general, attempts to test this hypothesis have been successful (Hooper [31], Yotopoulos [78], Yotopoulos and Nugent [76], and Massell [45]).

The steps normally followed to test for allocative efficiency are nicely illustrated in Yotopoulos and Nugent. If one assumes that firms possess the same technology have similar fixed factors and face the same prices, the test proceeds as follows:

1. A production function is fitted to the data.
2. Physical marginal productivities are calculated at some mean value.
3. Marginal value products are calculated reflecting implicit factor prices.
4. This implicit factor is then compared to the explicit or market price.

Economic efficiency can be conveniently broken down into two components--technical and allocative efficiency. Allocative efficiency

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[1] T. W. Schultz. Transforming Traditional Agriculture. 1964. P. 8.

implies that firms will utilize inputs at the point where the ratio of two marginal products are equal to their input price ratio. Figure II.1 illustrates this. Firms C and D are allocatively efficient, given the input price ratio, P_1/P_2, while A and B are not. This is a cost minimization point and does not consider output price. Setting the marginal product of either input equal to input-output price ratio completes the profit maximization picture.

To be technically efficient, one must be at a production maximum for any collection of inputs. Firms that need more inputs to reach a given output are therefore less efficient. All input bundles for producers A, B, C, and D yield the same output Y_o. B and D are technically inefficient as compared to A and C.

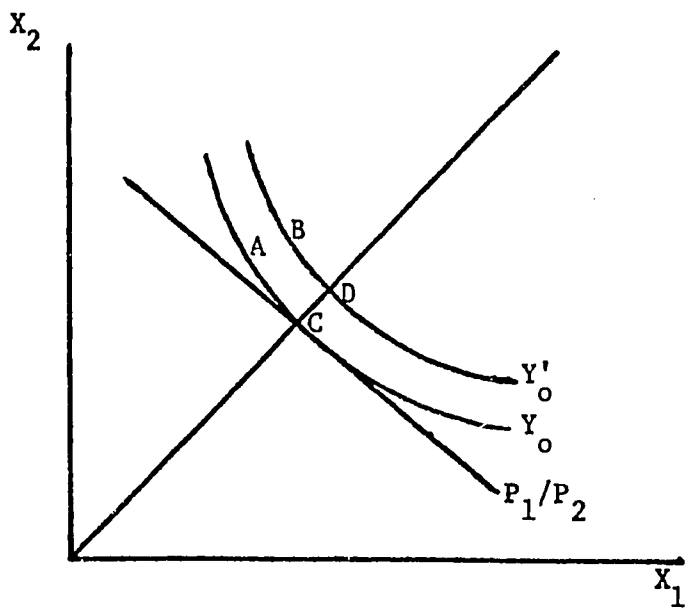

Figure II.1 Technical vs. Allocative Efficiency.

Yotopoulos and Nugent suggest that this is due to different fixed resources. In their framework, these differences are neutral,

i.e., do not affect relative factor productivities. Muller (48) suggests that such differences can be non-neutral. Using information and managerial differences in a production function setting, he shows that these have a direct and unique effect on each input as well as a neutral effect. In a Cobb-Douglas specification, Muller shows that information affects the coefficients of several of the inputs differently. Essentially, he derives a Cobb-Douglas function with variable elasticities.

It can be argued that technical inefficiency does not really exist since it can be explained by the inaccuracy in measuring physical inputs. Using fertilizer as an example, a simple number representing the amount of fertilizer applied does not contain a measure that includes the timeliness of application. This timeliness could be due to the managerial ability and knowledge.

Managerial ability is recognized as being important in the decision-making process. Much of the work attempting to quantify managerial ability focuses on the education variable, and Nelson and Phelps' 1966 article (49) seems to have set the direction of future inquiry. Their statement, "Education enhances one's ability to receive, decode, and understand information ...,"[1] is often repeated as several studies have pursued this concept.

While Nelson and Phelps' contribution was directionally important, Welch (70) set the stage by attempting to determine the production value

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[1]Richard R. Nelson and Edmund S. Phelps. "Investments in Humans, Technological Diffusion and Economic Growth." American Economic Review. 58 (May, 1968): p. 69.

of education. The "worker effect" is the marginal product of education in the normal sense; i.e., education is entered into the production function as a separate input. The "allocative effect" is "a worker's ability to acquire and decode information about costs and productive characteristics of other inputs."[1]

Following Welch's article, a number of people have attempted to quantify this allocative effect. Huffman (32), Fane (18), Khaldi (39), and Wu (75) have all added various dimensions. Huffman studied the allocative effect of U.S. farmers adjusting to changes in the optimum quantity of a single input, nitrogen fertilizer, in corn production. He demonstrates that, given disequilibrium, the rate of adjustment toward economically optimal choices is a function of farmers' contact with extension agents and farm size.

Fane and Khaldi concentrate on allocative efficiency in a cost framework. Fane measures the difference between minimum cost and observed cost in a factor-share setting. Factor share is defined as the percent of total costs that this factor comprises. He established that the loss associated with nonoptimal decisions is a function of education and the level of output.

Khaldi's approach is very similar. He constructs a cost inefficiency index and regresses this on education and research variables. Both Fane and Khaldi suggest that in addition to the allocative effect of education there exists a scale effect--the larger the farm operation,

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[1]F. Welch. "Education in Production." Journal of Political Economics. 78 (January/February, 1970): p. 42.

the more profitable it is to spend time and money on improving decisions.

Wu has the most inclusive or general study yet presented. He uses a profit-maximization model wherein he incorporates three effects into one mathematical expression, i.e., the worker effect, an allocative effect, and a scale effect. Wu is the only one of the four to use non-U.S. data by studying Taiwan.

It is worth noting that while Huffman found the allocative effect to be more important than the worker effect, Wu found the opposite to be true. This could have implications as to the different roles that education played in developed countries compared to those in the development process. All of the above four studies aim at explaining the role of education and conclude that education is indeed a productive agent in the decision process and its contribution is stronger than was originally recognized.

O'Mara (51) argues that the worker effect is simply a measure of misspecification of the physical inputs and inserting education as an independent variable in the production function is a proxy correcting the lack of perfectly measurable inputs. He notes, "... technical efficiency depends on differences in unmeasured inputs. Often, these are subsumed under the rubic 'superior managerial ability,' but this practice merely attaches a label to our ignorance."[1]

There are two ways this economic efficiency concept relates to the methodology being developed in this research. First, the allocative

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[1]Gerald O'Mara. "The Microeconomics of Technique Adoption by Small Holding Mexican Farmers." Programming Studies for Mexican Agricultural Policy. L. M. Bassoco, et al. (eds.), (forthcoming).

efficiency in the profit-maximization sense is necessary for comparison with utility-maximization optima. Secondly, the technical efficiency issues as well as the allocative and worker effect of nonphysical inputs suggests the importance of managerial ability and education in an adjustment process.

The way this adjustment works is not yet well-defined. It was noted above that studies of traditional agriculture find producers in their environments to be relatively efficient. If one introduces change into a stable system, producers have to adjust to stay efficient, and one can hypothesize that the optimal adjustments differ across firms.

Adoption of new technology studies have attempted to establish which variables characterize adopters and nonadopters. For example, the CIMMYT studies relate the importance of such variables as (1) agroclimatic zones and topography, (2) credit availability, (3) price differences, (4) seed availability, (5) education and extension services, (6) risk, and (7) farm size to adoption rates. The results are mixed, but the order in which they are listed above generally reflects their importance for adoption. The first, agroclimatic zones and topography, is clearly most important. The seventh, farm size, is confounded by multicollinearity with other explanatory variables. The importance of those in between vary across the seven studies. These and other similar adoption studies use single or multivariate analysis with the rate of adoption as the dependent variable.

Other studies have attempted to measure the importance of risk and uncertainty, information, and managerial ability in the adjustment process. Hiebert (30) notes, "As the innovation proceeds, decision

makers obtain additional information which, if new and relevant, reduces uncertainty and hence the possibility of making allocative mistakes."[1] At this point, the importance of the literature on the allocative effect of education becomes clearer. Welch notes that in a stagnant technological situation, only the worker effect counts.[2] Huffman's rate of adjustment and Wu's measurement of the importance of education under rapid development illustrates the usefulness of the allocative effect as well. Hiebert continues, "One reason for allocative error is that producers are mistaken about the true values of certain parameters of the production function."[3] A shortcoming of Hiebert's work is that he does not go to the next step and specify how these mistakes are perceived and/or corrected.

Kislev and Swchori-Bachrach (40) propose an innovation cycle in which the better-educated adopt new technology faster and thereby capture the economic rents that come from increased production. The slow adopters do not make allocative errors as Welch suggests but instead recognize their lower efficiency in production and, therefore, their decision to postpone adoption is perfectly rational.

The concept of disequilibrium is predicated on some measure of error. Whether producers recognize their inabilities as Kislev and

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[1] L. Dean Hiebert. "Risk, Learning and the Adoption of Fertilizer Responsive Seed Varieties." American Journal of Agricultural Economics. 56 (November, 1974): p. 764.

[2] Welch, op. cit., p. 42.

[3] Hiebert, op. cit., p. 766.

Swchori-Bachrach suggest is somewhat questionable. It is more likely that these people act as best they can given their ability and information. They make decisions based on their perceptions of reality. Should their perceptions of new technology be less accurate than for traditional techniques, they may adopt very slowly as they gain experience and knowledge. They may not adopt at all until they can gain from the experience and mistakes of others.

The difference between perception and reality is the allocative error referred to earlier, an error which can be measured by analyzing the production process. Such an error can manifest itself in the following way: The decision maker is mistaken with respect to the exact contribution that each controllable input has towards output.

Consider, for example, a situation in which all inputs are under the control of the producer. This assumption effectively removes the possibility of physical variance or sets the variance of output equal to zero. The producer can make his input decisions based on what he thinks the parameters on the inputs are. He will choose the amount of phosphate fertilizer, for example, based on his perceptions of its marginal product; i.e., in a profit-maximization world, he would apply phosphate to the level where its marginal product equals the phosphate input-output ratio. Since his perceptions of these parameters, in this case the marginal physical product of phosphate, may not be the same as the true parameters, he may be making an error.

One focus of this study is to construct a "perceived" production process that is operable at the time the producer makes his input decisions and then construct a second relationship that can be observed at the

time the production process is completed. Using these two relationships, the true production parameters are determined. A comparison of the observed and the true states can be made to measure the size of the error, if there is an error at all.

At this point, questions regarding the usefulness of this approach toward explaining wheat production in Tunisia and understanding the adoption of new varieties and other new technology can be entertained. Specifically, what is the value of distinguishing between physical uncertainty and subjective uncertainty? What explanatory power does the introduction of risk have towards understanding technological diffusion, particularly in the production of wheat in Tunisia and the adoption of new varieties? And finally, what can the identification of an allocative error add to these adoption issues?

The introduction of risk into the model is a step that is intuitively attractive in an attempt to better represent the decision-making process, particularly in developing agriculture. A set of hypotheses can be developed to test several bits of conventional wisdom:

1. High-yielding varieties are more risky to produce than ordinary varieties. This statement is rather loosely used, and a more accurate representation of what is trying to be communicated is that the variance of the subjective probability distribution of output is greater for the new varieties than for the old varieties.
2. Small farmers are more risk-averse than large farmers, especially in peasant economies. While the model used here can be applied to the above issue, a more interesting and

general formulation is to regress the degree of each farmer's risk aversion or preference on a set of possible determinants of that measure. The size of farm is one obvious candidate as an explanatory variable.

3. Farmers are reluctant to try new techniques because they are unsure of the new production relationship. One could hypothesize, then, that the errors associated with the new varieties are greater than errors associated with the old varieties, or one can generalize and propose a number of characteristics of individual farmers which might relate to the measure of allocative error used here. Possible candidates include

   a. managerial ability variables, such as experience, education, contact with extension agents,

   b. socio-economic variables, such as size of farm, size of parcel, importance of wheat in the general income scheme, and

   c. learning characteristics, such as years experience with the new varieties.

THE MODEL: UTILITY MAXIMIZATION

The general progression of the decision-making process is, according to the formulation used in this study, sequentially important. Therefore, this sequence is preserved as the model is presented.

Assume that one observes a continuous decision process at the moment when a producer is considering the initial input choices in a

production process. He perceives that some production function,

$$Y^P = F(X_i, Z_i, G)\varepsilon, \tag{2.2}$$

offers a reasonable explanation of the production process for output Y. The superscript P indicates perceptions and will shortly be necessary in order to differentiate perceived relationships from true and observed ones. As in 2.1, the X_i's are those inputs that are not under the producer's control. It is assumed that the decision maker formulates an expected value for those elements of Z_i that are not known at the time of seed bed preparation. G represents the sum of the fixed factors, both controllable and noncontrollable, but in either case already determined.

Examples of the three in an agricultural setting are X_i = fertilizer, Z_i = rainfall yet to come, and G_i = ground moisture.

Under profit-maximization rules, the first order conditions are well-known. These continue to hold as long as a producer has a linear utility function with profits or income as its attribute. If his utility curve is nonlinear, however, the first order conditions will change. The way this change affects the decision process depends on the decision maker's utility function.

This study assumes that a decision maker's attitude toward risk can be adequately captured by using an E-V analysis. Anderson, Dillon, and Hardaker (particularly Chapters 4 and 6), Moscardi (47), Magnusson, or Dillon develop in more detail the following approach: Given a utility function with a single attribute (such as income, perhaps represented by a producer's profits) can be respecified as an expected function defined in terms of the moments of the probability distribution of the attribute.

Note that income and not wealth is the attribute. A Taylor's series expansion taken about the mean of profit, denoted by Π, is equivalent to

$$U(\Pi) = U[E(\Pi)] + U_1[E(\Pi)][\Pi - E(\Pi)] + U_2[E(\Pi)][\Pi - E(\Pi)]^2/2! + \ldots \quad (2.3)$$

Bernoulli's principle or the expected utility axiom allows one to take the expectation of 2.3 to obtain

$$U(\Pi) = U[E(\Pi)] + U_1[E(\Pi)]\ E(\Pi - E(\Pi)] + U_2[E(\Pi)]\ E(\Pi - E(\Pi)]^2/2 + \ldots \quad (2.4)$$

Note that since $E(\Pi - E(\Pi)] = 0$ and $E[\Pi - E(\Pi)]^2$ is the definition of variance, one has

$$U(\Pi) = U[E(\Pi)] + U_2[E(\Pi)]\ \mathrm{VAR}\ (\Pi)/2 + \ldots \quad (2.5)$$ [1]

Utility is now a function of the mean, the variance, the skewness parameter, and as many other moments as exist. If the attribute of the utility function is normally distributed, only the first two moments exist so that

$$U(\Pi) = f[E(\Pi), V(\Pi)]. \quad (2.6)$$

Other research efforts have taken a similar approach. Weins (71), in a study of peasant behavior in precommunist China, is such an example. Moscardi's approach is, instead, to assume that small farmers in Mexico

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[1] Jock R. Anderson, John L. Dillon, and J. Brian Hardaker. Agricultural Decision Analysis. 1977, p. 97.

do not consider moments beyond the second. Scandizzo and Dillon point out that human beings capable of utilizing statistical concepts will most likely include notions of central tendency and variation but nothing more. After citing psychological literature for support, they conclude:

> ... [I]n most of the practial applications, the advantages of specifying decision makers goals in terms of the first two moments of the distribution appear to largely outweigh the loss of rigor, if any.[1]

If one assumes a normally distributed attribute (Π), where Π is a function of output (Y), the utility function 2.6 can be maximized by setting its derivative equal to zero.

$$\frac{dU}{dY} = \frac{\partial U}{\partial E(\Pi)} \frac{dE(\Pi)}{dY} + \frac{\partial U}{\partial V(\Pi)} \frac{dV(\Pi)}{dY} = 0, \tag{2.7}$$

and rearranging,

$$\frac{dE(\Pi)}{dY} = \frac{\frac{\partial U}{\partial V(\Pi)}}{\frac{\partial U}{\partial E(\Pi)}} \frac{dV(\Pi)}{dY} = 0. \tag{2.8}$$

The portion of the second term involving partial derivatives is simply the negative of the slope of an iso-utility curve in E-V space. In terms more familiar, it is the marginal rate of substitution of $E(\Pi)$ for $V(\Pi)$ with utility held constant.

Again, if one utilizes 2.6 and totally differentiates,

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[1]Pasquale L. Scandizzo and John L. Dillon. Peasant Agriculture and Risk Preferences in Northeast Brazil: A Statistical Sampling Approach. March, 1976, p. 8.

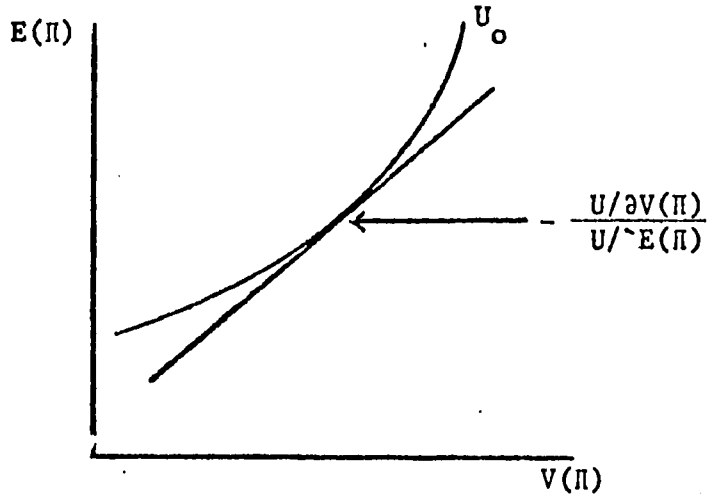


Figure II.2. Iso-utility Curves and a Risk Parameter.

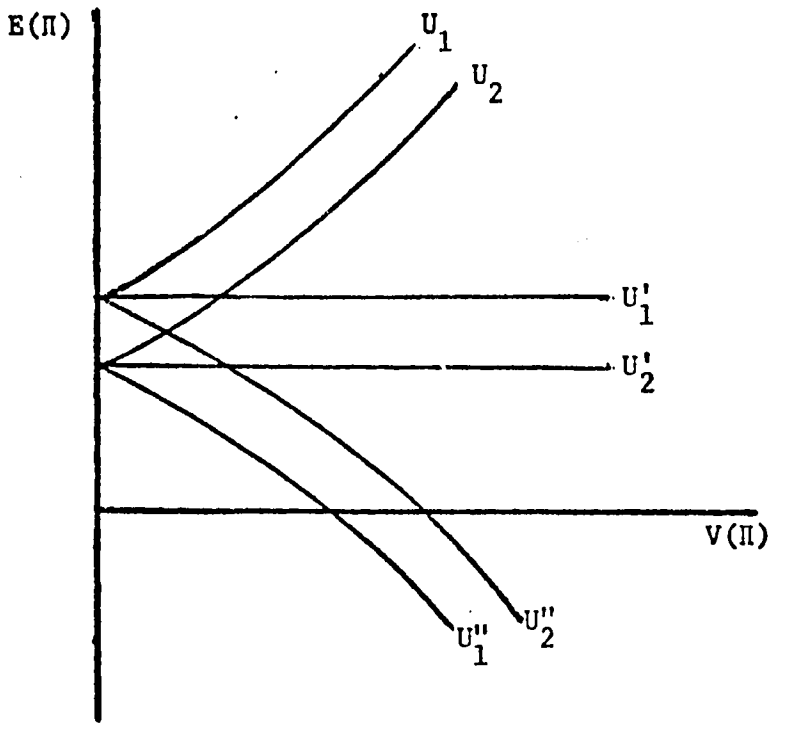
$$dU = \frac{\partial U}{\partial E(\Pi)} \quad dE(\Pi) + \frac{\partial U}{\partial V(\Pi)} \cdot dV(\Pi) \tag{2.9}$$

and keeps U constant and rearranges terms

$$\left.\frac{dE(\Pi)}{V(\Pi)}\right|_U = - \frac{\frac{\partial U}{\partial V(\Pi)}}{\frac{\partial U}{\partial E(\Pi)}} . \tag{2.10}$$

A risk averter must get more income to induce him to accept more risk and remain indifferent, and, therefore, the right side of 2.10, call it θ, a risk parameter, must have a non-zero absolute value, or θ itself must be negative. Similarly, for a risk-neutral person, θ equals zero, and for a risk preferrer, θ is positive. Figure II.2 can be expanded now to show all three results.

Frequently, E-V analysis is equated with a quadratic utility curve. Indeed, a quadratic form allows one to derive 2.6 exactly. However, the quadratic is much criticized because it is (1) not monotonically increasing, (2) only has two moments, and (3) exhibits increasing risk aversion as income increases. In fact, increasing risk aversion as income



Where U represents risk aversion, U' risk indifference, and U'' risk preference. $U_1 > U_2$ in each case.

Figure II.3. Iso-utility Curves Representing Risk Preference, Neutrality, and Aversion.

or wealth increases runs counter to much of the development literature that suggests big farmers are less risk-averse than small.[1] However, E-V analysis is not limited to a quadratic utility curve.

One can now proceed to use the above to illustrate how a producer reacts to a risky outcome. Begin with production function 2.2. Since the decision maker is required to make input decisions before knowing the input of, for example, rainfall, he formulates expectations on Z_i,

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[1]A functional form that is compatible with this reasoning would be, for example, $U = bx^c$ where $0 < c < 1$. There is a body of literature that includes articles by Hanoch and Levy (27), Borch (7), and Feldstein (19), who develop conditions under which E-V analysis is appropriate.

$E(Z_i)$, and perceives the production relationship as indicated below.

$$Y^P = F(x_i, Z_i) \equiv f(x_i)u \tag{2.11}$$

and

$$E(Y^P) = f(x_i) \tag{2.12}$$

where u is a random operator on production which includes the variance of Z_i about $E(Z_i)$. It is assumed that $u = N(1, \sigma)$. Prices are nonstochastic and assumed to be known with certainty since prices of purchased inputs and wheat are set and controlled by the Tunisian Office de Cereals. These prices are set prior to seed bed preparation and remain fixed for the crop year.

Therefore, the perceived profit equation becomes

$$\Pi = Pf(x_i)u - P_i x_i - FC \tag{2.13}$$

where

FC = fixed costs,

P = price of the output,

P_i = price of input i.

Expected profit is

$$E(\Pi) = PE(Y^P) - P_i x_i - FC. \tag{2.14}$$

Expected variance of profit becomes

$$V(\Pi) = P^2 E(Y^P)^2 V(u). \tag{2.15}$$

From the definition of variance, one derives

$$V(\Pi) = E[Pf(x_i)u - P_i x_i - E(Pf(X_i)u - P_i x_i)]^2 \tag{2.16}$$

$$= E[Pf(x_i)u - P_i x_i - Pf(x_i)E(u) + p_i x_i)]^2$$

$$= E[Pf(x_i)u - Pf(x_i)\ E(u)]^2$$

$$= P^2[E(Y^P)]^2\ E(u - E(u)]^2.$$

Finally,

$$V(\Pi) = P^2[E(Y^P)]^2\ V(u). \tag{2.17}$$

Maximizing $U(\Pi)$ where utility is a function of the first two moments of the distribution

$$U(\Pi) = U[E(\Pi),\ V(\Pi)], \tag{2.18}$$

one can proceed as follows:

$$U(\Pi) = U[P\ E(Y^P) - P_i x_i,\ P^2[E(Y^P)]^2\ V(u)] + \lambda(Y^{P_o} - f(x_i)] \tag{2.19}$$

where output $E(Y^P) = f(x_i)$.

Differentiating 2.19 with respect to Y, x, and λ and setting these first order equations equal to zero leads to

$$\frac{\partial U}{\partial E(Y^P)} = \frac{\partial U}{\partial E(\Pi)}\ \frac{\partial E(\Pi)}{\partial E(Y^P)} + \frac{\partial U}{\partial V(\Pi)} + \lambda = 0, \tag{2.20}$$

or

$$= \frac{\partial U}{\partial E(\Pi)}\ P + \frac{\partial U}{\partial V(\Pi)}\ \ 2E(Y^P)\ P^2\ V(u) + \lambda = 0, \tag{2.21}$$

$$\frac{\partial U}{\partial x_i} = -\ \frac{\partial U}{\partial E(\Pi)}\ P_i + \lambda\ \frac{\partial f}{\partial x_i} = 0 \tag{2.22}$$

(assuming none of the inputs are constrained) and

$$\frac{\partial U}{\partial \lambda} = Y^{\circ} - f(x_i) = 0. \tag{2.23}$$

Solving 2.22 for λ, one obtains

$$\lambda = \frac{-\frac{\partial U}{\partial E(\Pi)} P_i}{\frac{\partial f}{\partial x_i}},$$

which can be substituted into 2.21.

$$\frac{\partial U}{\partial E(\Pi)} P + \frac{\partial U}{\partial V(\Pi)} 2E(Y^P)P^2 \; V(u) \; \frac{-\frac{\partial}{\partial E}}{} \tag{2.24}$$

or, rearranging terms,

$$P + \frac{\frac{\partial U}{\partial V(\Pi)}}{\frac{\partial U}{\partial E(\Pi)}} 2E(Y^P)P^2 \; V(u) = \frac{P_i}{\frac{\partial f}{\partial x_i}} \tag{2.25}$$

for all x_i.

Recall that

$$\frac{\frac{\partial U}{\partial V(\Pi)}}{\frac{\partial U}{\partial E(\Pi)}}$$

is Magnusson's measure of risk aversion (preference). Henceforth, this will be signified as θ. Notice that the right-hand side of Equation 2.25 is simply the marginal cost of x_i, which is familiar from the profit-

maximization conditions.

Incorporating risk into the decision rule is now complete. Expression 2.25 can be arranged in other ways, but it is stated above so as to indicate the deduction that takes place due to risky outcomes if the enterpreneur is risk-averse. ($\theta < 0$ indicates risk aversion; $\theta = 0$ suggests risk neutrality, and $\theta > 0$ corresponds with risk preference.)

Equation 2.25 implies that a risk-averse decision maker will choose an output such that marginal cost is less than marginal revenue (in this case output price) by $\theta\ 2P^2\ E(Y^P)\ V(u)$. The amount of the discount depends on the size of θ, a measure of his risk aversion, and the probability distribution associated with u. A large $V(u)$ and/or a large θ increases the discount.

If one has two inputs, x_1 and x_2, notice that the producer is still on the cost-minimization expansion path. From 2.22 we derive

$$\frac{\frac{\partial U}{\partial E(\Pi)}}{\frac{\partial f}{\partial x_1}} P_1 = \lambda = \frac{\frac{\partial U}{\partial E(\Pi)}}{\frac{\partial f}{\partial x_2}} P_2 \tag{2.26}$$

and rearrange to give

$$\frac{\frac{\partial f}{\partial x_1}}{\frac{\partial f}{\partial x_2}} = \frac{P_1}{P_2}. \tag{2.27}$$

Risk only plays a role as an output price distorter.

Assume for a moment that the probability distribution of u is solely determined by rainfall. Knowledge of $V(u)$, the producer's probability distribution of u, is sufficient information to produce a

decision rule with respect to input use.

Anderson, Dillon, and Hardaker emphasize the importance of subjective probability distributions. Most studies that use an approach similar to the above derive an objective distribution. This thesis focuses on the decision-maker's perceptions--not only regarding the production function and input parameters but also regarding perceptions of the distribution of u. More is said with respect to this point in the empirical chapter.

Finally, there remains one unknown, θ. If the perceived production function has been correctly specified, the model can be solved for θ as a residual. In this case, the notation θ explains why the producer is using less (more) than optimal quantities of inputs in the profit-maximizing sense.

Before we go on to develop the distinction among perceived, true, and observed relationships, it is useful to illustrate how introducing risk into the decision-making process can allow a different choice of technology compared to that of profit-maximization criteria.

The argument rests on the assumption that the subjective probability distribution for high-yielding varieties is greater than for ordinary varieties. Those studies that have looked at this question have done so using an objective variance measure. In general, they have concluded that the variance is greater for the new varieties.

Sidhu (66), using Indian data, found this to be true. The CIMMYT studies, while somewhat inconclusive, found that when the yield variation was clearly greater for the HYV's, the adoption rates were strongly affected. Hiebert also indentifies cases where new seed varieties were

more variable than others.

This study uses a subjective measure as advocated by Anderson, Dillon, and Hardaker. The derivation of such measure is presented in the empirical chapter. The argument proceeds assuming different variances for different techniques. For purposes of convenience, let the traditional variety's output be known with certainty; i.e., $Y^P = g(x_i)$.

In the absence of constraints, the first order conditions are

$$\frac{\partial f}{\partial x_{ij}} (P + \theta K) = \frac{\partial g}{\partial x_{ij}} \tag{2.28}$$

for $i = 1, \ldots, n$ inputs, and

$j = 1, 2$ where $1 = HYV$

$2 = OV$

where $K = 2P^2 E(Y^P) V(u)$.

$$Y^{HYV} = f(x_i)$$

and

$$Y^{OV} = g(x_i).$$

Since $\theta < 0$ for a risk averter, he will allocate more x_i to ordinary varieties than would normally be the case under profit-maximization conditions.

In a utility-maximization setting, K is a function of E(Y), which plays a key role in land allocation. As $E(Y^P)$ increases, K increases. Consequently, a risk-averse person will spread risk by allocating his land among products with differing levels of variability depending on the magnitudes of θ and K. Figure II.4 is useful for illustrating this.

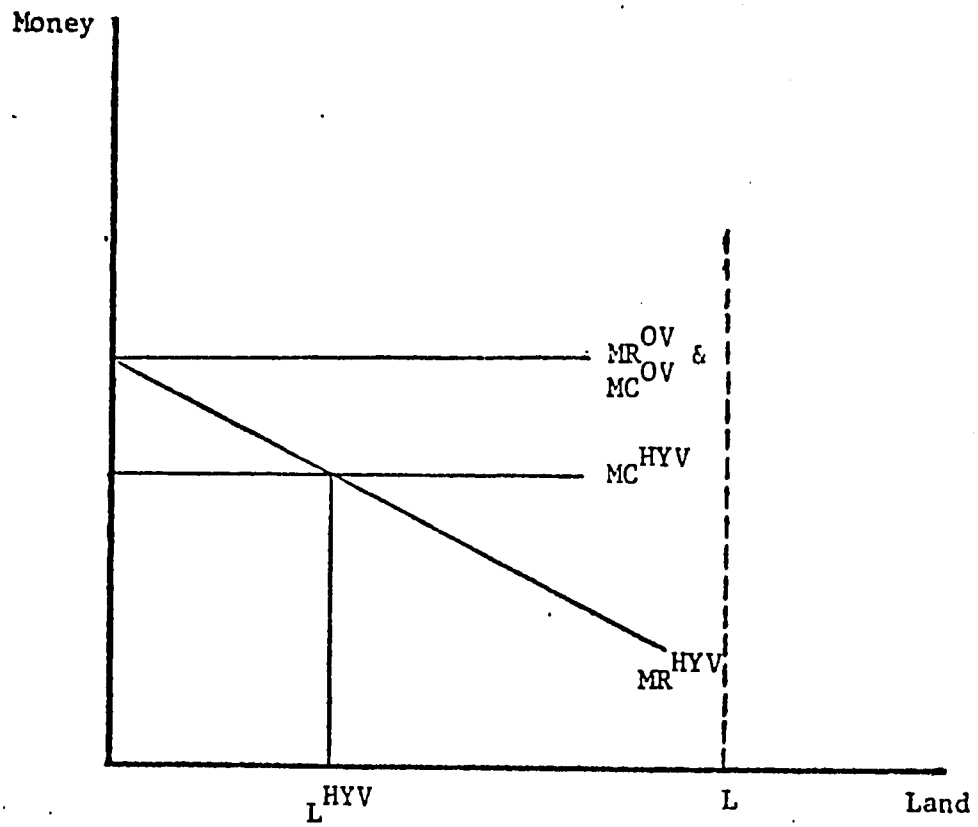

Figure II.4. Land Allocation to HYV's, OV's, or Both.

The producer allocates land to the production of HYV's to the point where marginal revenue equals marginal cost ($MR^{HYV} = MC^{HYV}$). MR for HYV's decreases, if $\theta < 0$, as more land is planted to the new technology since $E(Y^P)$ increases proportionately. Therefore, L^{HYV} in Figure II.4 is planted to HYV's and the rest, $L - L_{HYV}$, is sown to ordinary varieties. MC's are horizontal under the assumption of a homogeneous production function of degree one.

Other explanations have been advanced to explain this diversification of varieties which is so common. Different output prices and non-homogeneous land are two frequently mentioned candidates. The intent of this discussion was to illustrate that high θ's and/or K's can dampen

producers' adoption of new techniques. Indeed, this is consistent with observations in Tunisia and elsewhere. There is another explanation of slow or partial adoption rates that hinges on the likelihood of making allocative errors on new production processes that are greater than similar errors in older, more familiar process. That is the subject of the next portion of the theoretical model.

To briefly summarize, using a perceived production function, the decision maker has made input decisions based on a utility-maximizing criterion which includes adjustment for risk--risk being viewed as uncertain profits due to stochastic and noncontrollable variables that are unknown at the time when input decisions are made. Empirically, it is recognized that solving for θ residually, as was shown above, will contain some error due to estimation problems. It will, nevertheless, give an indication of adjustments that are made in recognition of output variability. It is important to emphasize that θ is derived from the perceived function, contrary to previous contributions. It is, therefore, a subjective value and more consistent with the type of decision-making problem posed by Anderson et al.

THE MODEL: PERCEPTION VS. TRUE RELATIONSHIPS

We now have a decision rule that provides for utility maximization of the perceived production relationship. After input decisions have been made and the production process proceeds, it is not controlled or explained by the perceived production function, but by the true one. Since these two relationships may not be the same, the producer can make an error--an allocative error--due to imperfect information and/or lack

of ability to correctly interpret that information that he does have.

This error reduces profits and consequently distorts resource allocation. Identifying producer characteristics that are associated with these errors might explain some of the difficulty of introducing a new technology and offer suggestions as to what policymakers can do from a cost-benefit perspective to reduce such allocative inefficiencies. The next step is to present a methodological approach which will allow the empirical testing of such an error.

Up to this point, one has only been concerned with the perceived production function equation 2.2, which is denoted by superscript P. This is the functional relationship on which the enterpreneur makes his input decisions based on utility-maximization objectives. For simplicity, one can delete and later retrieve the Z_i from the specification without affecting the analysis.

There also exists a true state of nature that actually operates on these inputs as they are converted in output Y. This can be specified as

$$E(Y^T) = g^T(x_i). \tag{2.29}$$

Only with perfect information would $f(x_i) = g(x_i)$. Assume that they are not equal.

A normative profit function can be derived from both of the production functions.

$$\Pi^P = PE(Y^P) - P_i x_i + \lambda[(Y^P)^o - f(x_i)]. \tag{2.30}$$

and

$$\Pi^T = PE(Y^T) - P_i x_i + \lambda[(Y^T)^o - g(x_i)] \tag{2.31}$$

The x_i's are selected from maximizing 2.30. First order conditions are

$$\frac{P_i}{\frac{\partial f}{\partial x_i}} = P - \theta K$$

where $K = 2P^2\ E(Y^P)\ V(u)$. (2.32)

Instead, the inputs should have been derived from maximizing 2.31, giving the first order conditions as

$$\frac{P_i}{\frac{\partial g}{\partial x_i}} = P - \theta K. \tag{2.33}$$

The actual profit picture is, consequently, a combination of the two. One observes profits that would generally not be at a maximum. Observed profits will be

$$\Pi^o = PY^T - P\bar{x}_i + \lambda[(Y^T)^o - g(\bar{x}_i)] \tag{2.34}$$

where x_i's are optimal inputs given the perception $f^P(x_i)$.

It is clear that condition 2.31 is violated if $f \neq g$. It follows that

$$\Pi^T \neq \Pi^0, \tag{2.35}$$

or more specifically,

$$\Pi^T \geq \Pi^0. \tag{2.36}$$

Rearranging, we have

$$\Pi^T - \Pi^0 \geq 0. \qquad (2.$$

This represents the error caused by mistaken perceptions of the true state of nature.

Since output price is assumed given, it is somewhat simpler to work with cost curves which capture the error just as well. One can identify three cost relationships: C^P, C^T, C^0, representing, respectively, perceived, true, and observed cost curves.

The Cobb-Douglas production function specification lends itself nicely for illustration of the above mechanism. Let

$$Y^P = A\Pi x_i^{\alpha_i}, \qquad (2.38)$$

or, for a two-input case, let

$$Y^P = Ax_1^{\alpha_1} x_2^{\alpha_2} \qquad (2.39)$$

be the perceived production function and

$$Y^T = Bx_1^{\beta_1} x_2^{\beta_2} \qquad (2.40)$$

be the true function.

Perceived profits,

$$\Pi^P = PE(Y^P) - P_i x_i + \lambda[(Y^P)^o - f^P(x_i)], \qquad (2.41)$$

are maximized to yield optimal quantities of x_1 and x_2, which will be noted by a bar, i.e., $\bar{x}_1$ and $\bar{x}_2$.

He perceives cost to be

$$C^P = P_1\bar{x}_1 + P_2\bar{x}_2. \qquad (2.42)$$

This can be better represented by a cost curve derived from 2.41 above. First order conditions are

$$\frac{\alpha_1 \bar{x}_2}{\alpha_2 \bar{x}_2} = \frac{P_1}{P_2}.$$

Solving for either $\bar{x}_2$ or $\bar{x}_1$ yields

$$\bar{x}_1 = \frac{\alpha_1}{\alpha_2} \frac{P_2}{P_1} \bar{x}_2, \text{ or } \bar{x}_2 = \frac{\alpha_2}{\alpha_1} \frac{P_1}{P_2} \bar{x}_1. \tag{2.43}$$

Substituting these optimal quantities into 2.39 yields

$$\bar{x}_1^{\alpha_1} = \frac{Y}{A} \left(\frac{\alpha_2}{\alpha_1} \cdot \frac{P_1}{P_2} \bar{x}_1\right)^{-\alpha_2}. \tag{2.44}$$

Solving for $\bar{x}_1$ yields

$$\bar{x}_1 = \left(\frac{Y}{A}\right)^{\frac{1}{\gamma}} \left(\frac{\alpha_2}{\alpha_1} \frac{P_1}{P_2}\right)^{\frac{-\alpha_2}{\gamma}} \tag{2.45}$$

where $\gamma = \alpha_1 + \alpha_2$.

Similarly,

$$\bar{x}_2 = \left(\frac{Y}{A}\right)^{\frac{1}{\gamma}} \left(\frac{\alpha_1}{\alpha_2} \frac{P_2}{P_1}\right)^{\frac{-\alpha_1}{\gamma}}. \tag{2.46}$$

Now 2.45 and 2.46 can be substituted into 2.42.

$$C^P = P_1 \left(\frac{Y}{A}\right)^{\frac{1}{\gamma}} \left(\frac{\alpha_2}{\alpha_1} \frac{P_1}{P_2}\right)^{\frac{-\alpha_2}{\gamma}} + P_2 \left(\frac{Y}{A}\right)^{\frac{1}{\gamma}} \left(\frac{\alpha_1}{\alpha_2} \frac{P_2}{P_1}\right)^{\frac{-\alpha_1}{\gamma}}. \tag{2.47}$$

This equation can be rearranged to yield

$$C^P = \gamma\left(\alpha_1^{\alpha_1}\alpha_2^{\alpha_2}\right)^{-\frac{1}{\gamma}} A^{-\frac{1}{\gamma}} Y^{\frac{1}{\gamma}} P_1^{\frac{\alpha_1}{\gamma}} P_2^{\frac{\alpha_2}{\gamma}}. \tag{2.48}$$

Differentiating with repsect to Y yields the perceived marginal cost function

$$MC^P = \left(\alpha_1^{\alpha_1}\alpha_2^{\alpha_2}\right)^{-\frac{1}{\gamma}} A^{-\frac{1}{\gamma}} Y^{\frac{1-\gamma}{\gamma}} P_1^{\frac{\alpha_1}{\gamma}} P_2^{\frac{\alpha_2}{\gamma}}. \tag{2.49}$$

Similarly, the true profit function can be maximized to yield cost and marginal cost curves:

$$C^T = \delta\left(\beta_1^{\beta_1}\beta_2^{\beta_2}\right)^{-\frac{1}{\delta}} B^{-\frac{1}{\delta}} Y^{\frac{1}{\delta}} P_1^{\frac{\beta_1}{\delta}} P_2^{\frac{\beta_2}{\delta}}. \tag{2.50}$$

$$MC^T = \left(\beta_1^{\beta_1}\beta_2^{\beta_2}\right)^{-\frac{1}{\delta}} B^{-\frac{1}{\delta}} Y^{\frac{1-\delta}{\delta}} P_1^{\frac{\beta_1}{\delta}} P_2^{\frac{\beta_2}{\delta}} \tag{2.51}$$

where $\delta = \beta_1 + \beta_2$.

There is nothing that can be said at this stage about the relationship between C^P and C^T:

$$C^P \gtreqless C^T, \tag{2.52}$$

since, a priori, the agent may over- or underestimate g. Of primary interest here is the fact that $C^O \geq C^T$ where C^O is observed cost.

Contrary to step 2.44, $\bar{x}_1$ and $\bar{x}_2$ from 2.43 are substituted into 2.40.

$$\bar{x}_1^{\beta_1} = \frac{Y}{B}\left(\frac{\alpha_2}{\alpha_1}\frac{P_1}{P_2}\bar{x}_1\right)^{-\beta_2} \tag{2.53}$$

which in turn is substituted into $C^0 = P_1\bar{x}_1 - P_2\bar{x}_2$ to yield

$$C^0 = \gamma\left(\alpha_1^{\beta_1}\alpha_2^{\beta_2}\right)^{-\frac{1}{\delta}} B^{-\frac{1}{\delta}} Y^{+\frac{1}{\delta}} P_1^{\frac{\beta_1}{\delta}} P_2^{\frac{\beta_2}{\delta}} \tag{2.54}$$

and

$$MC^0 = \frac{\gamma}{\delta}\left(\alpha_1^{\beta_1}\alpha_2^{\beta_2}\right)^{-\frac{1}{\delta}} B^{-\frac{1}{\delta}} Y^{\frac{1-\delta}{\delta}} P_1^{\frac{\beta_1}{\delta}} P_2^{\frac{\beta_2}{\delta}}. \tag{2.55}$$

If Π^T represents the best combinations of inputs at varying levels of P, P_1, and P_2, then Π^0 with possible errors is less than or equal to Π^T. Thus $C^T - C^0 \leq 0$ holds from 2.50 and 2.54.

$$C^T - C^0 = \delta\left(\beta_1^{\beta_1}\beta_2^{\beta_2}\right)^{-\frac{1}{\delta}} - \gamma\left(\alpha_1^{\beta_1}\alpha_2^{\beta_2}\right)^{-\frac{1}{\gamma}} \leq 0. \tag{2.56}$$

If $\alpha_1 = \beta_1$ and $\alpha_2 = \beta_2$, the equality holds. When $\alpha_i \neq \beta_i$, C^T differs from C^0 by a multiplicative constant.

$C^T - C^0$ is not a complete measure of allocative error but is useful in exposition. The allocative error can be illustrated by deriving MC^P, MC^T, and MC^0.

In Figure II.5.A, the input decisions are made by setting $MC^P = P - \theta K$. These inputs are converted to Y via production function Y^T. With perfect knowledge, the agent would have produced Y^T and earned profit equal to area A (see Figure II.5.B). However, mistaking the value of the β coefficinets, he earned substantially less than area A.

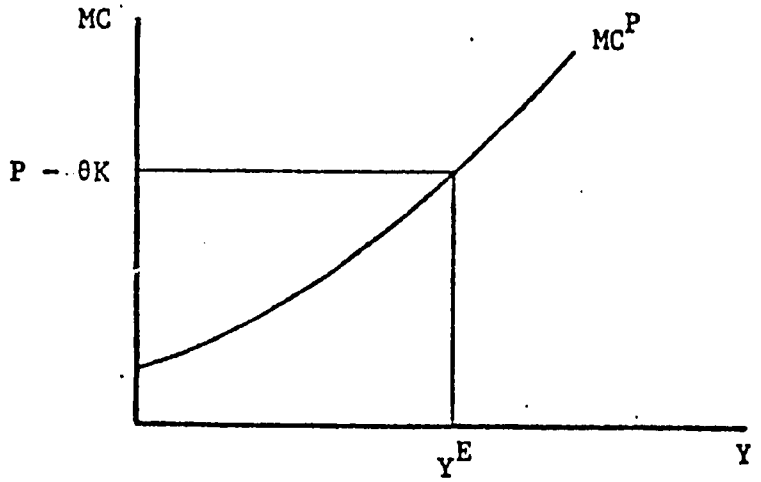

Figure II.5.A.

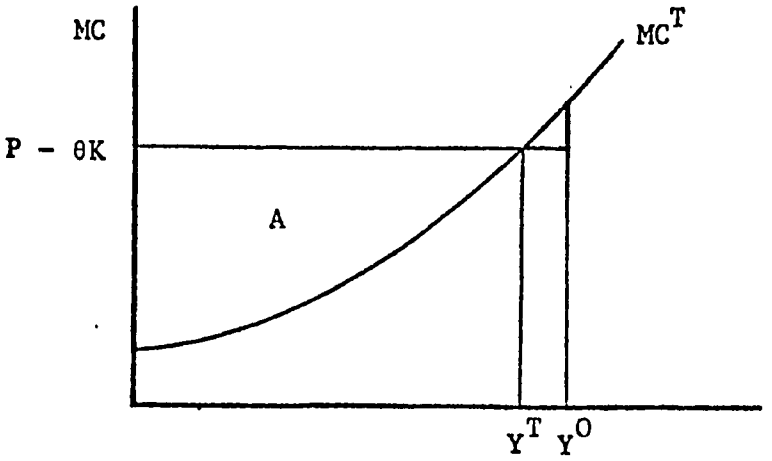

Figure II.5.B.

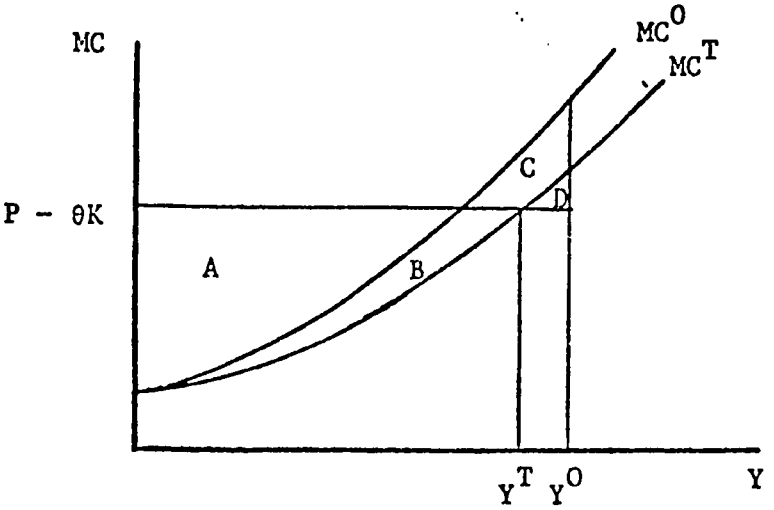

Figure II.5.C.

Figure II.5. Allocative Errors due to Mistaken Perceptions of Cost Relationships.

In fact, following Figure II.5.C, A + B represents maximum profits while A - C - D represents actual profits. $\Pi^T - \Pi^0 = A + B - (A - C - D)$. This difference, representing allocative error, is indicated by area B + C + D.

An important assumption is that of independence of the inputs. The β's that are derived from observed output are, in fact, the true β's. Of course, specification error would destroy this result. In this study, for example, a poor rainfall would, theoretically at least, be observed as a shift in the constant term of the production function $Y^0 = B\bar{x}_1^{\beta_1}\bar{x}_2^{\beta_2}$ and not in the β's themselves. This will be treated in more detail in the empirical chapter.

The relationship between the perceived production parameters and the true parameters is hypothesized as being a function of the producer's ability and experience. The more able the producer is, the more quickly his perceptions merge to the true parameters. Similarly, the more experience that he has with a particular input or technique, the better his perceptions become.

A large error can greatly reduce profits. If the error on HYV's is greater than the error on OV's, this offers insight into the adoption process. A producer makes a choice based on its profitability, which is closely tied to his ability to understand the adoption process. He may, for example, try new techniques on very small parcels of land until he gains a knowledge of the parameters and the perceived profits converge to the true profits. In such a case, the percent of land allocated to HYV's should increase over time.

Alternately, a previous experience with a new variety that was

characterized by large errors could effectively deter him from adopting until his perceptions change. The problem clearly requires a time dimension and a convergence theory, which is beyond the scope of this study.

In this research, with cross-sectional data from northern Tunisia, the most interesting approach is to identify those characteristics of the farmers interviewed with different allocative errors. Reducing this error would be of substantial benefit to Tunisia due to a gain in efficiency. If this involves HYV's, Tunisia could take advantage of the potential profitability that the new varieties claim to offer.

In brief, the framework presented in this chapter has developed two possible explanations as to why producers may be inefficient in resource use as well as reluctant to adopt new technologies. Understanding these inefficiencies is the first step to take toward improving resource use. Risk-averse producers with uncertain profits will underutilize inputs such as fertilizer and may be less likely to adopt new practices such as new seed varieties. Information, knowledge, and managerial ability are important determinants of perceptions of production parameters and therefore play a role in efficient resource use. Misperceptions of reality result in allocative errors. If these errors are larger for new techniques than they are for traditional techniques, the profitability of new techniques is diminished. This could be a second explanation of low or slow adoption rates.

Now the application of the model to Tunisia can proceed. First, a description of the Tunisian wheat sector is in order with special emphasis on issues that the theory might reasonably explain. This discussion of Tunisia is the subject of the next chapter.

CHAPTER III

SOME CHARACTERISTICS OF THE TUNISIAN WHEAT SECTOR, THE 1976/77 CROP YEAR, AND THE DATA COLLECTION PROCESS

This chapter focuses on the Tunisian wheat sector. Before one empirically tests the methodology developed in Chapter II, an explanation of the situation in Tunisia and a description of the data collection effort are helpful. There are two sections. The first outlines some general characteristics of the Tunisian wheat sector and emphasizes those that apply to this research. The second section describes in some detail the sampling technique, the interview procedure, and the questionnaire.

WHEAT PRODUCTION IN TUNISIA

The wheat sector plays an important role in Tunisian agriculture, contributing between 20 to 30 percent, in value terms, to agricultural production. Agriculture in turn contributes about 20 percent to GNP. Others--Gasfsi, Gafsi and Roe (22), Purvis (53), Hyslop and Dahl (34)--have adequately described the wheat sector, its problems, and its role in development. A brief overview is, nevertheless, helpful.

In the crop year 1975/76 total wheat area was 1,391,900 hectares. In the northern portion of the country, which is clearly the agro-climatological area best-suited to wheat production, there were 699,440 hectares. Durum wheat is by far the most important part of the wheat

sector comprising 91 percent of the wheat area in northern Tunisia.[1] Durum wheat is a staple in the Tunisian diet and efforts on the part of the government to increase bread wheat hectarage have been unsuccessful to date. In total production terms, these percentages change only slightly. About 89 percent of total production in the north is attributable to durum wheat. For the whole country, these statistics favor durum wheat even more strongly. (See Table III.1.)

The Ministry of Agriculture has made a recent effort to increase productivity in the wheat sector. It has received financial and technical assistance from FAO, USAID, CIMMYT, The Ford Foundation, and others to help reach higher production goals. In general, the efforts have concentrated on new wheat varieties and new techniques as the highest payoff to public investments in the wheat sector.

Yet the increase in wheat production has not been impressive. During the Fourth Development Plan, from 1972-1976 production increased by less than one percent per year.[2] The Fifth Development Plan calls for a rate of growth in the agricultural sector of 6.6 percent and an increase in the wheat sector of 5.2 percent.[3] 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 with HYV's. It would appear, based on previous experience, that these adoption rates and growth rates will be difficult to achieve unless the constraints to

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[1] "Enquete par Measure Objective sur les Rendiments Cerealiers." Aout, 1976.

[2] Ministere de l'Agriculture Preparation du Veme Plan, p. 3.

[3] Ibid., p. 7.

Table III.1. Cultivated Wheat Area, 1975/76, in Hectares.

	Durum Wheat		Bread Wheat	
	OV's	HYV's	OV's	HYV's
North	476,300 (34.2)*	160,200 (11.5)	29,000 (2.1)	33,900 (2.4)
Sahel and Center	533,400 (38.3)	9,200 (0.7)	55,700 (4.0)	2,400 (0.2)
South	86,200 (6.2)	--	5,400 (0.4)	--
Total	1,096,100	169,400	90,100	36,300

Total Hectares for All Wheat = 1,391,900

*Percentages given in parentheses.

Source: Republique Tunisienne, Ministere de l'Agriculture, Direction du Plan. "Budget Economique." Various issues.

Table III.2. Total Wheat Production, 1975/76, in Quintals.

	Durum Wheat		Bread Wheat	
	OV's	HYV's	OV's	HYV's
North	4,641,000 (41.1)*	1,518,000 (13.4)	336,000 (2.9)	521,000 (4.6)
Sahel and Center	3,425,000 (30.3)	96,000 (0.8)	389,000 (3.4)	NA
South	362,000 (3.2)	--	11,000 (0.1)	--
Total	8,428,000 (74.6)	1,614,000 (14.3)	736,000 (6.5)	521,000 (4.6)

Total Wheat Production = 11,299,000

*Percentages given in parentheses.

Source: Republique Tunisienne, Ministere de l'Agriculture, Direction du Plan. "Budget Economique." Various issues.

adoption and increasing yields are both identified and alleviated.

High-yielding varieties of soft wheat were introduced into Tunisia in 1967. Soft wheat comprises a small percent, 9 percent, of the wheat area. Thus, the real potential of the HYV's did not present itself until the 1970's when HYV's of durum wheat were made available to Tunisian farmers. Today, there are four varieties of high-yielding durum wheat being grown and two more about to be released. All of these have been bred in Tunisia and, therefore, are compatible with Tunisian agro-climatic conditions.

INIA, a Mexican soft wheat variety, was the first HYV introduced into Tunisia. That year had a poor growing season, and many farmers experienced poor results and have subsequently been discourage from trying other HYV's. Seventy-five percent of those farmers visited in this study who had tried INIA reported unsatisfactory results. There have been no similar disasters with respect to HYV durum wheats. Amel has been criticized for being too short a variety but has shown good yields.

The impetus for this study came from earlier research on the Tunisian wheat sector. Gafsi analyzed the adoption of high-yielding wheat varieties in Tunisia for the 1972/73 crop year. One of the findings in the study was the evidence of the economic superiority of the new varieties over the old. He found, estimating production functions, that HYV's of durum wheat were superior to ordinary varieties as indicated by a neutral shift in the production function of 16 percent. In the case of bread wheats, the upward shift in the production function

amounted to 13 percent for HYV's compared with OV's.[1] In a profit-maximization framework, such a shift would indicate that wheat farmers should be economically motivated to adopt new varieties.

If this is the case, why has adoption and productivity growth in Tunisia been so slow? Gafsi suggests "that institution constraints are the major obstacle to the rapid spread of high yielding varieties."[2] It has been substantiated in Tunisia and elsewhere that the lack of credit, weak marketing channels, and poor dissemination of information have slowed productivity growth in wheat production. The number of agricultural credit programs in Tunisia today attest to the recognition that these constraints are binding.

However, Gafsi and Roe go on to emphasize that the problem of high-yielding variety diffusion is more complex than just alleviating institutional constraints. During the 15 months the author spent in Tunisia, he became aware of several additional issues regarding wheat production. In contact with the farmers themselves, six concerns or observations appear to dominate their opinions on input decisions including variety choice. These six observations have helped to develop the hypotheses tested in this research. They are

1. amount of chemical fertilizer usage,
2. uncertainty with respect to production yields,
3. large differences between expectations and realizations,

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[1] Salem Gafsi. Green Revolution: The Tunisian Experience. August 1975. P. 188.

[2] Ibid., p. 263.

4. the importance of location and land quality differences among farmers,
5. the importance of differences in wheat quality among varieties, and
6. the lack of an effective means by the government to disseminate useful information to the farmers.

Of these six observations, only the sixth directly involves institutions and related constraints. Information dissemination is one of the constraints frequently cited in the literature, in addition to such things as credit availability, bottlenecks at distribution points and a transportation infrastructure. With respect to the public sector's role in transmitting important information to the agricultural producers, a large portion, 70 percent of the farmers, had no contact with extension agents during the last year. However, improving the transfer and use of information is not simply a matter of increasing extension visits. Farmers need to be informed in a useful and convincing manner that they may gain from switching to another variety or utilizing another technique. On-site demonstration plots appear to be one of the most useful ways for such information to be transferred. There are, indeed, very few such plots, even in the major wheat areas of Tunisia. Those that exist are located on the best land available rather than in several locations with varying land qualities. If one considers the other five observations in turn, the first is in regards to fertilizer usage.

Actual chemical fertilizer usage falls short of the recommendations of the Wheat Project, a branch of the Ministry of Agriculture.

Table III.3 indicates this gap by comparing recommendations with actual usage found in this research, those reported by Gafsi for 1972/73, and the project's recommendations.[1] While the explanation for this gap will be dealt with in more detail in Chapter IV, it is mentioned here as an item of concern.

Secondly, wheat production in Tunisia depends greatly on adequate rainfall, and, consequently, total yields vary over time as indicated by Table III.4. There is further evidence to suggest that among individual farmers the variability in yields is also substantial. Based on series of questions about previous yields of individual varieties, over 60 percent indicated a range over several years of 15 quintals or more. More specific questions about expected yields allow one to determine approximations of expected yield variability. Again, a range of 15 quintals or more was given by 30 percent of the sample. The average standard deviation of expected yields in this study was 5.1 quintals (see Appendix III for a listing of this measure for each parcel).

This variation in expected yields results in equally large variations in expected profits. Since the wheat prices in Tunisia are quite stable, due to government intervention in the market, the variance in profits from wheat production is mostly caused by output variation. The government sets the price in Tunisia for wheat that is purchased by the Office de Cereals. Such action is generally defended by government officials as adding some certainty to the wheat sector; i.e., farmers can make input decisions with certainty about the output price. In

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[1]See Appendix V for averages of other inputs.

Table III.3 Chemical Fertilizer Usage,* in Pure Kilograms.

	1976/77	1972/73	Recommendations
	---------- Phosphate ----------		
HYV's durum wheat	27.9 n = 128	--	--
OV's durum wheat	21.2 n = 100	--	--
Average	25.0 n = 228	27.9	67.5
	---------- Nitrogen ----------		
HYV's durum wheat	19.2 n = 128	--	--
OV's durum wheat	14.7 n = 100	--	--
Average	17.3 n = 228	23.1	45.0

*See Appendix V for averages of other inputs.

Sources: Survey, 1976/77; Salem Gafsi. Green Revolution: The Tunisian Experience. August, 1975, pp. 89 and 21.

Table III.4. Wheat Production, 1962-1976, in Metric Tons.

Year	Durum Wheat	Bread Wheat	Total
1962	321,050	71,500	392,550
1973	530,000	125,000	655,000
1964	350,000	81,000	431,000
1965	420,000	100,000	520,000
1966	300,000	49,000	349,000
1967	240,000	42,000	282,000
1968	425,000	73,000	498,000
1969	301,000	80,000	381,000
1970	369,000	150,000	519,000
1971	400,000	200,000	600,000
1972	707,000	258,000	965,000
1973	655,000	235,000	890,000
1974	655,000	202,000	957,000
1975	803,000	162,000	965,000
1976	940,000	210,000	1,150,000

Sources: Ministere de l'Agriculture. "Tableau No. 1, Les Cereals en Tunisie." Preparation du Veme Plan. Juin 1975.

addition, such a measure insulates the farmer from the vagaries of a very irregular international price.

The third observation was that there was a large difference between expectations and realizations of yields. In part, this supports the uncertainty issue discussed above. Farmers for the crop year 1976/77 expected, in general, higher yields than they received. Since they made their input decisions on expectations, they made severe allocative errors that year. If part of that error is due not to a poor growing season but to misperceptions of the parameters of the production function, the uncertainty issue is more complex than variance due to weather, pests, and disease. There is uncertainty due to the lack of knowledge of the production function parameters.

Fourthly, there are very large differences in land quality even in the center of the best wheat territory in the north. Farmers recognize that difference when evaluating the experiences--the successes and failures--of others trying different wheat varieties. One of the resulting mistakes is recommendations by the extension service of a technological package that is similar for all farmers in a geographical zone. One of the most frequent responses to questions about information desired by the farmer if he were to consider adopting a new variety had to do with the location of demonstration plots and whether or not the new variety is suited to his farm with particular soil, topography, and geographical characteristics. More than 82 percent of farmers sampled in this research gave such a response.

The importance of recognizing these differences among farmers would allow the government to set more realistic production goals or

targets. If variety increases yields on an experimental farm by 35 percent, it may do much less well elsewhere. Goals in the Fifth Development Plan indicate that hectares planted to HYV's will double and assume that yields on the new land will maintain the average yields found on HYV's plots today. Such projections are troubling since they suggest that the large land quality differences across northern Tunisia, and the resulting potential yield differences, are not being recognized or taken into account.

Finally, the question of quality differences across varieties is noted. It was mentioned earlier that prices are set by the Office de Cereals, and they will buy wheat at that price after adjusting for quality differences and deducting a production tax. There exists an illegal but tolerated market of wheat trade in the towns and villages. Prices in the market are somewhat higher than those set by the Office de Cereals. Gafsi investigated this issue thoroughly and estimated the Office price to be 15 percent lower than the market price. Very little HYV wheat moves through the tolerated market, and intuition suggests the existence of a price differential between OV's and HYV's that favors the ordinary varieties. Quality differences between OV's and HYV's in the marketplace are great enough to depress the market price of HYV's to or near Office de Cereals levels.[1] A lower economic incentive to trade in the illegal market and accepting the risk associated with illegality encourages one to sell HYV's to the Office de Cereals.

It is also evident that this price differential is a result of

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[1]Ibid., p. 152.

consumer preferences. The OV's make better country ovenbread and better homemade couscous, both staples in Tunisian diets. For example, one of the least appealing characteristics of the HYV durum wheats is their darker color, noticeable in both bread and couscous. Since the price system in this case measures quality differences, the price differences between the OV's and the HYV's will be used in this study to recognize the essential issue of quality difference.

The preceding discussion was intended to give one a background of the Tunisian wheat sector with a focus on those issues which need to be examined in an attempt to understand adoption patterns and other productivity issues. The agricultural and socio-economic characteristics of those farmers visited in this research are presented in Chapter IV. First, however, the sample, the questionnaire, and the interview process that was undertaken in Tunisia in 1976/77 are outlined. This is done in the next section.

THE DATA COLLECTION PROCESS

In cooperation with the Agricultural Institute in Tunisia (Institut National Agronomique de Tunisie [INAT]) and a grant from the United States Agency for International Development (USAID), administered by the Economic Development Center at the University of Minnesota, the data for this research were collected in Tunisia during the 1976/77 wheat growing season. This section describes the sampling procedure, the questionnaire, and the data collection effort.

In 1973, Winkelmann organized a data collection effort working with Project Blé in Tunisia. This was one of eight efforts that

Winkelmann coordinated for CIMMYT looking at adoption in different parts of the world. The initial interview was completed by a team of interviewers (personnel of Project Blé) on 375 private wheat farms in northern Tunisia. This interview process was begun after the 1972/73 wheat crop was harvested in July and was completed in October of that year. Gafsi joined the research project and subsequently organized a second visit in which the farmers were revisited to complete the data set. This second visit was made in March and April of 1974.

The current research effort did not, ex ante, envisage revisiting the farmers in the Gafsi study. However, it was to focus on approximately the same area, i.e., northern Tunisian private wheat farmers. It is only in this higher rainfall sector that farmers have been exposed to high-yielding varieties. In light of the lack of accurate census lists of wheat producers in Tunisia, it was decided that a subsample of the 1972/73 study was the best alternative available. It was also felt, in this study, that one interview team would provide better and more consistent data, particularly in light of the scarcity of qualified and experienced interviewers and the difficulty of the questionnaire. In addition, due to the nature of this study, it was decided that data collection should be completed in as short a time frame as possible, i.e., no more than one month in duration. This was necessary in order to visit each farmer at approximately the same time in their production cycle. Thus, the following systematic subsampling procedure was used.

The original population had been organized into governmental units called "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 sub was drawn from these lists by choosing a random number from one to c. selecting the farmer associated with that random number and thereafter every third one on the list. This assured the maintenance of the size distribution of the original sample.

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 seven occasions, the producer listed on either side of the original choice was chosen by a flip of a coin.

The crucial element of the data gathering process was the necessity of getting data that would allow the estimation of both a perceived and observed production function. This was accomplished by visiting each producer twice. The first visit took place in February and the second in July.

Wheat in northern Tunisia is planted in the second half of November and is generally harvested in June and July. At planting, the farmer has 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 purpose of this first visit in February was, most importantly, to gather information relating to the producer's expectations. A number of questions were posed whose responses would indicate the anticipated

yields under various conditions. 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.

Three questions posed during that visit that have been used in the analysis are worth discussing. (See Appendix II for a copy of the questionnaire.) These questions sought answers that would allow an approximation of each farmer's subjective expected variance of wheat yields for each variety grown. In pretesting the questionnaire, an effort was made to get yield expectations for (1) an average year, (2) a poor year (poor being the worse year in a ten-year cycle), and (3) a good year (the best year in ten-year cycle). This line of questioning was difficult to develop in the interview setting, and a similar line of questioning was adopted, leaving out references to the number of years.

The two-visit procedure also 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 February visit, the producer's recall regarding fertilizer inputs, machine use for land preparation, and input procurement problems was good--better than it would have been if these same questions were asked six months later. Additionally, the two-visit format allowed one to gather data regarding income and consumption in two stages which minimized somewhat the traditional hesitancy Tunisian farmers have about revealing too much personal information.

The second visit in July was specifically designated to gather

information on outcomes. In addition, questions on input applications subsequent to the first visit were asked, and some other general questions were posed. In a few cases, an effort was made to clarify confusing or contradictory information collected in February. The total time spent with each farmer varied from two to four hours, but the split interview procedure certaintly improved the information collected.

One can now proceed to the empirical analysis, which is presented in the next chapter.

CHAPTER IV

EMPIRICAL RESULTS AND THEIR IMPLICATIONS

The results from fitting the theoretical model developed in Chapter II to the data on 125 wheat farms in northern Tunisia are reported in this chapter. The chapter is divided into four sections. The first explains the estimation of the perceived production function. The second section derives the risk parameters from a utility-maximizing decision rule, attempts to explain the variation in the risk parameter, and relates the importance of risk perceptions to adoption rates.

The third section estimates the true production functions. Normative cost curves are derived for both the perceived and true cases, and these are compared to assess the extent of allocative error. The final section summarizes the empirical findings and discusses their importance for Tunisia. Throughout the chapter, an emphasis is placed on the strengths and weaknesses of the analysis, the assumptions made, and the effect these assumptions have on interpreting the results.

THE PERCEIVED PRODUCTION FUNCTIONS

The information collected during the two interviews allows one to estimate two functions. At the time of the first visit, a series of questions was asked regarding yield expectations from wheat fields five months before harvest time. The first interview was conducted in February, about two months after planting. The plants, having experienced

a normal season to date, were at the tillering stage of the production cycle. Questions were asked about output expectations if (1) a normal growing season ensued, (2) a good season were to be experienced, or (3) a poor year were to be experienced. These three classifications were generally interpreted by producers as dependent on the weather although pests and disease were also considered.

A production function was estimated with the dependent variable being the farmer's statement of the expected yield per hectare he felt he would attain in a normal year. This perceived function is strictly a behavioral relation. An effort was made to determine what variables the producer thought were important and derive the magnitudes of their coefficients. This allows one to include nonphysical variables into an expression that is normally physical output.

A Cobb-Douglas functional form was taken as representative of wheat production in northern Tunisia. In light of the complexities of the theoretical framework, the tractability of the Cobb-Douglas form also makes it attractive.

The model estimated for the perceived production function is

$$Y^P = A\, Ph^{\alpha_1}\, N^{\alpha_2}\, M^{\alpha_3}\, L^{\alpha_4}\, Ex^{\alpha_5}\, e^{\alpha_6 D_1 + \alpha_7 D_2 + \alpha_8 D_3} \tag{4.1}$$

where

Y^P = expected output in quintals,

A = ln a, a constant term,

Ph = quantity of phosphate in kilograms,

N = quantity of nitrogen in kilograms,

M = monetary value of mechanized processes. These include four:

(1) deep plowing, (2) discing, (3) planting, and (4) harvesting. The value is expressed in Tunisian dinars in terms of rental rates as determined in the interview or the opportunity cost, i.e., rental value, if owned.

L = land in hectares,

Ex = inverse of years of experience with this variety,

D_1 = dummy variable for variety,

where D = 0 if ordinary variety,

D = 1 if high-yielding variety,

D_2 = dummy variable for soil,

where D = 0 if poor soil in producer's opinion,

D = 1 if good soil in producer's opinion.

D_3 = dummy varible for zone,

where D = 0 if high rainfall zone (Jendouba),

D = 1 if low rainfall zone (El Kef).

The production functions are estimated using the ordinary least squares procedure (OLS) where the following are assumed:

1. Normality,
2. Zero mean,
3. Homoscedasticity,
4. Nonautoregression,
5. Nonstochastic X: Independent [illegible] X is a nonstochastic variable, thus the [illegible]ution of ε_i does not depend on X.

In the case of [illegible] Cobb-Douglas function, the OLS procedure is used after [illegible] a logrithmic transformation of both the independent and [illegible]pendent variables. Consequently, the error is distributed log normally;

i.e., $E(\ln \varepsilon_j) = 0$, and

$$E(\ln \varepsilon_i - E(\ln \varepsilon_i))^2 = \sigma^2.$$

Thus, the ε_i's are distributed

$$E(\varepsilon_i) = e^{\frac{1}{2}\sigma^2}$$

and

$$E(\varepsilon_i = E(\varepsilon_i))^2 = e^{\sigma^2}(e^{\sigma^2} - 1).$$[1]

The coefficients are given in Table IV.1. The estimates of the independent variables on all positive and have reasonable magnitudes. The coefficients on the dummy variables also have the expected sign with the exception of the sign α_8, the zone shifter. One would expect this to be positive with higher output in the higher rainfall zone. One possible explanation of this is that those farmers in the low rainfall zone are almost entirely wheat farmers. They practice a biennial rotation with wheat following fallow. The farmers in the high rainfall zone are more diversified, and wheat frequently follows watermelon or a forage crop. However, a neutral dummy variable for rotation was fit to the data and was not significant. Since it is positively correlated with the zone dummy variable, this may account for the positive sign. Therefore, the zone dummy variable reflects zones that differ in average rainfall and other ways that affect wheat yields.

Of the five assumptions required for OLS estimation, the

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[1] G. S. Maddala. Econometrics. 1977, p. 3.

Table IV.1. Perceived Production Function Estimates.

	Regression I		Regression II		Regression III		Regression IV	
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	
$\sum x_i$	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.

assumption of homoscedasticity is the most troubling in a cross-sectional sample, such as used here. Since the sample contains fields from one-half hectare to 100 hectares, the assumption of constant variance was tested. Using the Goldfeld-Quant method to test for homoscedasticity, the 72 largest parcels were used to fit the function and compared to a similar function for the 72 smallest:

$$F_{\frac{N-L-2K}{2},\ \frac{N-L-2K}{2}} = \frac{SSE_2}{SSE_1},$$

where

$N = 228$ = total sample size;

$L = 84$ = observations omitted from the middle;

$K = 8$ = the number of parameters to be estimated;

S_i = sum of squared residuals for group $i = 1, 2$ where 1 is the small parcel group.

$F = 1.40$ is less than $F_{68,68} = 1.52$ at the 95-percent level. The null hypothesis that the error term is homoscedastic cannot be rejected.

The sum of the coefficients of the independent variables is not significantly different from 1 as established with a t test. Thus, the hypothesis that the perceived production function exhibits constant returns to scale cannot be rejected.

$$t = \frac{\sum \alpha_i - 1}{V(\alpha_i) + 2COV(\alpha_i \alpha_j)}$$

$t = 1.82$, which is less than 1.96 from the t distribution at .975 level of significance and 220 degrees of freedom. Table IV.1 contains total

production functions and per-hectare estimates.

An F test was conducted to determine if there was a structural difference between farmers' perceptions of the production relationship of ordinary varieties and high-yielding varieties. Using a Chow test, one cannot reject the null hypothesis that the two production relationships are structurally the same.

$$F_{K,N-K} = \frac{SSE_r - SSE_u/K}{SSE_u/N-K},$$

where

r = regression imposed,

u = unrestricted regression,

K = number of restrictions.

F = .5905, which is less than the value $F_{7,221}$ of 2.09 at the .95 level of significance.

The first regression in Table IV.1 is an estimate of total production with land included an an independent input. Regression III is a similar production function, only on a hectare basis. In keeping with the effort to estimate a behavioral relationship, experience is included as an independent variable. The reciprocal of experience was fitted to capture its diminishing importance as experience increases; i.e., the first years of experience are more important than the sixth year. The negative value of the coefficient suggests that as experience increases, the expected yield increases. The results suggest that Tunisian farmers on the average underestimate new varieties and increase these expectations of yield as experience grows. Inclusion of this experience variable stresses the behavioral nature of the perceived function.

Regressions II and IV are similar to I and III except that experience has been dropped from the estimate. One can observe that the coefficients of the remaining variable are very stable; i.e., their numerical variable changes very little when the experience variable is deleted.

A number of other nonphysical variables were tried in an effort to capture the differences in producer perceptions. One might expect that the expected coefficient on phosphate would depend on education, years of experience, or contact with extension agents. The addition of such a nonphysical variable has been defended by others as correcting for misspecification of the production function since, for example, the timeliness of fertilizer application is not indicated in the phosphate input. Its interpretation here is somewhat different. Since this is a behavioral relation, different farmers with similar physical inputs can perceive different yields and different coefficients on the same estimated parameters even though actual yields and coefficients for the two might be the same. Since these perceived parameters are those on which input decisions are made, it is logical to use these estimates to calculate optimal input requirements and to discuss possible divergences from such optima.

A number of other dummy shifters were fitted to the data and dropped. It was felt that a shifter for rented land vs. owned land would improve the estimate. A similar expectation was made with respect to a dummy variable indicating crop rotation. Since none of these variables entered the production function with significant values and their addition or deletion did not change the values of the remaining coefficients, they were dropped from the final estimate. (See Appendix I for an

example of such an estimation.)

DERIVING THE RISK PARAMETER

It follows from the theoretical framework section, that if the utility functions are nonlinear, different optimal input levels result even if prices and perceptions are identical. This section derives a risk parameter for each farmer under the assumption of utility maximization.

Observations in Tunisia report underutilization of some inputs, e.g., chemical fertilizers in comparison to the wheat project's recommendations (Table III.3). Take the case of phosphate fertilizer. If the perceived production function is correctly specified, producers are knowledgeable of its potential, and producers are not constrained in acquiring it in adequate quantities, they should use phosphate to the point where the value of the perceived marginal product of phosphate equals its price. Using the theory presented in Chapter II, one can solve for a risk parameter, θ, as the residual from Equation 2.23.

It needs to be emphasized that it was decided to solve for the risk parameters from the first order conditions for the input phosphate. This is the best input choice for the following reasons: First, phosphate and land were the only inputs that were completely committed to the production process when questions were asked about perceptions during the first interview. Additional applications of nitrogen dependend on subsequent rainfall, and equipment costs, including the harvest costs, were dependent on actual yields.

Secondly, the accuracy of solving for risk as proposed requires good price data. The most accurate price data for the four inputs are on

phosphate and nitrogen. Land prices are very difficult to determine, and in many cases the best one can do is to compute the averages gathered in the rental market. Equipment prices are better since there is a well-developed rental market in Tunisia, but the constraints for the small farmer might be more binding due to his location and/or indivisible costs.

Fertilizer is easily divisible, and the very small applications were observed. While phosphate is purchased in 50-pound sacks, it can be spread over several hectares or saved for use at a later date. Equipment is only available in much larger fixed units whether it is rented or purchased.

By process of elimination, phosphate was chosen as the best candidate to use in the calculation of the risk parameter. The one constraint on fertilizer usage would be credit availability. A number of questions were asked to determine if this constraint were binding. Of the 122 durum wheat producers, 15 indicated such constraints and were subsequently omitted from the risk parameter calculations. A Θ was calculated for the remaining 107 producers.

Reproducing 2.28 after rearranging terms, one has

$$P = \theta K = \frac{Px_i}{f(X_i)}. \tag{4.1}$$

Recall that

$$\theta = \frac{\dfrac{\partial U}{\partial V(\Pi)}}{\dfrac{\partial U}{E(\Pi)}}$$

and

$$K = 2P^2E(Y)\ Var(u).$$

For the Cobb-Douglas function using the marginal conditions on phosphate, 4.1 becomes

$$P - \theta K = \frac{P_1}{\frac{\alpha_1 Y_i}{Ph_j}}, \tag{4.2}$$

where

P_{PH} = price of phosphate,

α_1 = .0406, and

j = 1, ..., 228 parcels.

θK is the discount (premium) that a risk-averse (preferring) producer applies to the output price. If $\theta < 0$, the producer is risk-averse Note that K is always positive. The letter K represents that derivative of the variance of profit with respect to output, and the derivation of V(u) has not yet been explained.

V(u) is derived from the subjective probability distribution of expected output. The questionnaire was designed to allow the estimation of V(u). Assuming the probability distribution is normally distributed, one can determine its mean and variance with two pieces of information: namely, a lower limit for which there is a 90-percent change that output lies above and an upper limit for which there is a similar probability that output lies below. Questions were asked which give an approximation of $V(Y^P)$. It is an approximation due to the difficulty encountered in the interview of establishing the 90-percent confidence limit concept as

a basis for high-low expectations.

This distribution is transformed to have a mean of 1 and a normal variance V(u) for each parcel. Multiplying V(u) by $2P^2E(Y^P)$ gives an approximation of K. Now θ can be derived.

The original sample had 228 durum wheat parcels. Most of the producers had two parcels, several had three, and a few had more. Theoretically, the determination of the risk-aversion parameter should be the same for every parcel belonging to the same producer, since risk aversion is a function of utility, not production. In practice this is not the case since the calculation of θ should include a covariance term. With two parcels, V(Π) becomes

$$V(\Pi) = P^2(E(Y_1))^2\ V(u_1) + P^2(E(Y_2))^2\ V(u_2) + 2P^2(EY_1)(E(Y_2))\ \mathrm{Cov}\ (u_1u_2),$$

where P is the same for both Y_1 and Y_2.

Therefore,

$$\frac{dV(\Pi)}{dY_1} = 2P^2\ E(Y_1)\ V(u_1) + 2P^2\ \mathrm{Cov}\ (u_1u_2).$$

If the covariance is positive, the estimates of θ made here would be too high, and the converse is true if the covariance is negative. It is most probable that the covariance is positive. If it is small, the omission is not serious. However, there are no data available to allow the estimation of the covariance, and thus no support can be given to the conjectural statements above regarding the sign and size of Cov (u_1u_2).

In order to obtain an estimate for θ by producer, the risk parameters obtained by solving 4.1 for θ were averaged for each farmer. The

results for the calculation of $E(\Pi)$, $V(\Pi)^{.5}$, and θ are given in Appendix III. Table IV.2 is a partial listing for the first eight farmers.

The results suggest that 73 percent of the 107 producers for which a θ was derived were risk-averse. Of the remaining 29, 8 were risk-preferrers, but with very small positive values ($\theta = 1 \times 10^{-4}$). The last 21 show much stronger risk preferences. For ease of presentation, it is preferable to switch the sign θ, so from this juncture, larger values of θ refer to increases in risk aversion. Subsequently, references to θ will be the negative of the θ in Table IV.2.

In order for the theoretical model to be useful in explaining the adoption of high-yielding varieties, three conditions must hold:

1. $E(\Pi)_{HYV} > E(\Pi)_{OV}$.
2. $V(\Pi)_{HYV} > V(\Pi)_{OV}$.
3. The producers must be risk-averse.

This can be illustrated in E-V space as shown in Figure IV.1 below. Taking the square root of the variance of profits, the horizontal

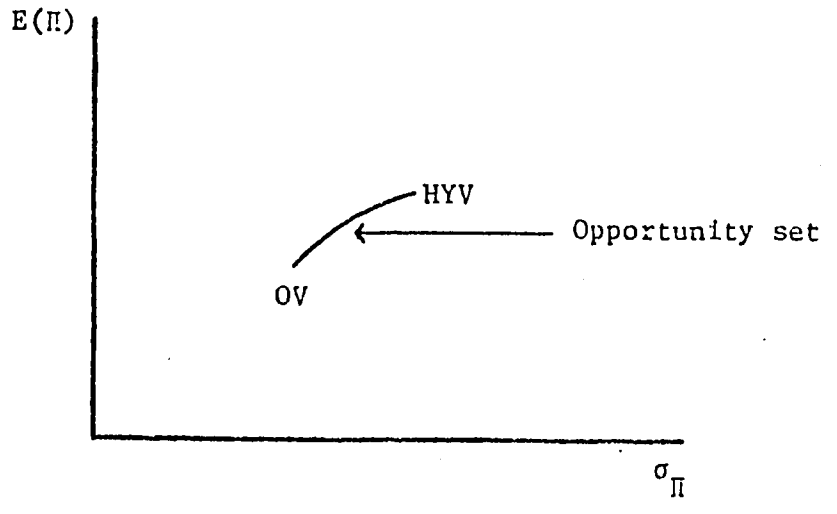

Figure IV.1. Set of Available Choices for Allocating Wheat Production.

Table IV.2. Risk Parameters.

Farmer	Parcel	E(Π)/ha	$V(\Pi)^{.5}$/ha	θK	θ	Ave. θ
1	1	148.400	34.3	-3.023	-.004055	-.003803
1	2	209.653	60.9	-4.057	-.003550	
2	1	120.283	95.2	-1.848	-.002972	-.002104
2	2	99.000	69.9	-0.738	-.001235	
3	1	105.000	44.0	-4.068	-.008558	-.001409
3	2	57.622	29.9	3.789	.005741	
4	1	74.200	44.0	-7.225	-.027046	-.027046
5	1	140.000	80.6	-5.219	-.001413	-.002263
5	2	143.800	49.4	-4.963	-.003112	
6	1	29.680	12.3	-6.931	-.038576	-.038576
7	1	140.485	60.9	-5.465	-.001818	-.001303
7	2	73.033	55.0	-4.185	-.060787	
8	1	29.680	9.7	-6.931	-.011621	-.011621

axis now measures the standard deviation of profits.

The point labeled HYV indicates the amount of σ_{Π} that must be accepted to get $E(\Pi_{HYV})$. A similar interpretation can be made for point OV. The curve connecting OV and HYV is a function of the covariance of HYV and OV. Notice that for independent variables

$$\rho_{1,2} = \frac{\sigma_{1,2}}{\sigma_1 \sigma_2},$$

where

ρ = correlation coefficient,

$\sigma_{1,2}$ = covariance,

σ_i = S.D. $i = 1, 2$.

Therefore,

$$\rho_{1,2} = \rho_{1,2}\ \sigma_1 \sigma_2.$$

Anderson, Dillon, and Hardaker have shown that if $\rho_{1,2} = 1$, the the curve connecting OV and HYV is linear. If $\rho_{1,2} < 1$, it is concave with the concavity increasing as ρ decreases.[1]

A number of possibilities exist given Figure IV.1.

Case I: A risk-neutral producer will produce only HYV's.

Case II: If the producer is risk-averse and θ is less than the slope of the opportunity set at HYV, he will specialize in HYV's.

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[1]Jock R. Anderson, John L. Dillon, and J. Brian Hardaker. Agricultural Decision Analysis. 1977, p. 193.

Case III: If θ is greater than the slope of the opportunity set $\geq$ OV, he will specialize in OV's.

Case IV: If θ is between these extremes, he will be a partial adopter.

A comparison of the averages for all producers supports the hypothesis that risk aversion inhibits adoption. A comparison of the means of expected outcomes between varieties indicates that on average $E(Y_{HYV}) > E(Y_{OV})$. The mean yield of HYV's is 13.195 quintals per hectare compared to 8.565 quintals per hectare for OV's. These means are statistically different at the 99-percent level of significance.

Of greater interest, however, is the expected profit and variance of expected profit. Computations of the means of expected profit per hectare and the means of the variance of expected profits per hectare are shown in Table IV.3. It is also worthwhile to break down the parcels by soil quality as well as by variety.

Table IV.3. Expected Means and Standard Deviations of Profit for Different Varieties Under Different Soil Conditions.

	n	Mean Expected Profit	Mean of the Standard Deviation of Profit
1. HYV	128	92.244	45.58
OV	100	61.465	33.27
2. HYV, good soil	68	104.706	51.04
OV, good soil	41	75.860	37.51
3. HYV, poor soil	60	78.120	38.47
OV, poor soil	59	51.461	28.06

As mentioned earlier, the opportunity set will be concave if

$\rho_{HYV,OV} < 1$. All of the comparisons of the means in Table IV.3 and Figure IV.2 are significantly different at the 99-percent level. For example,

$$t = \frac{E(\Pi_{HYV\ GOOD\ SOIL}) - E(\Pi_{OV\ GOOD\ SOIL})}{\left(\frac{V[E(\Pi_{HYV\ GS})]}{n_{HYV}}\right) + \left(\frac{V[E(\Pi_{OV\ GS})]}{n_{OV}}\right)^{.5}}$$

$$= 4.71 > t_{01} = 2.42.$$

Thus it has been established that, on average, the basic conditions are met that allow for the nonadoption, partial adoption, or complete adoption, depending on the size of the risk-aversion coefficient.

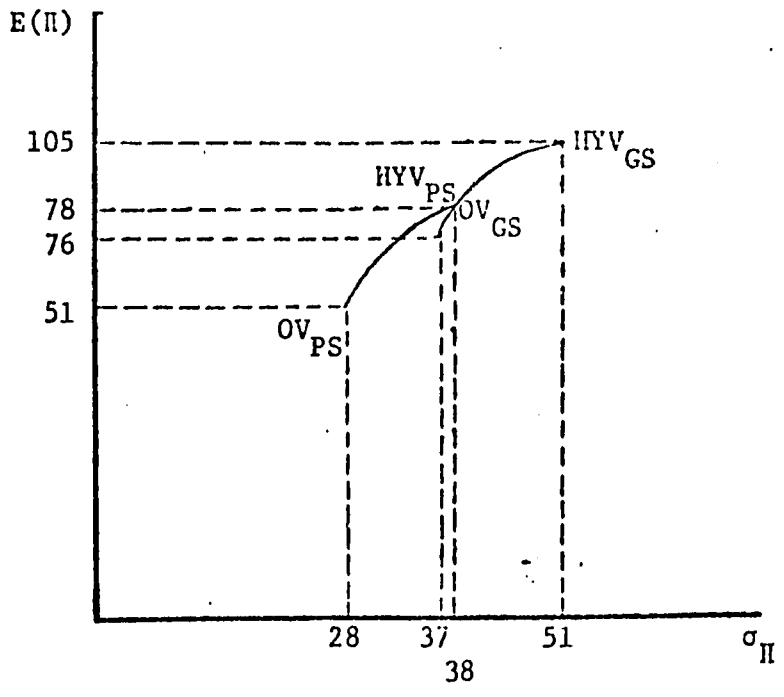

Figure IV.2. Graphing of Expected Means and Standard Deviations of Profit for Different Varieties Under Different Soil Conditions.

Averages are not, however, a confirmation of the general hypothesis that risk aversion is inhibiting the adoption of new wheat varieties in Tunisia. In order to make that confirmation, one would need, in addition to the data used in this thesis, two other pieces of information. First, one would need two points in E-V space for each producer. Of the 107 producers in this study for whom a θ was calculated, only 27 grew both OV's and HYV's. A second requirement would be to determine a covariance term allowing the estimation of the slope of the opportunity set between HYV's and OV's. The difficulty of obtaining such a measure has been discussed above.

Additional insights into the relationship between risk aversion and the adoption of new wheat varieties in Tunisia can be obtained. A regression of the rate of adoption on θ and other explanatory variables should illustrate the relationship between risk aversion and adoption better than a simple comparison of means. This was done by regressing the rate of adoption on four independent variables and two shift or dummy variables. Rate of adoption is defined as the percentage of durum wheat area allocated to HYV's. A second regression was estimated by changing the dependent variable slightly. In Regression Two, the rate of adoption is calculated as a percentage of total wheat area allocated to HYV's. Using a log-linear function, the results shown in Table IV.4 were obtained.

The signs of the coefficients of each independent variable conform with expectations. Education has very little explanatory power, while farm size and a zone dummy have more explanatory power but are still not highly significant. Of key interest is the risk parameter, which has the hypothesized sign and is significant at the 97.5-percent

Table IV.4 Adoption of HYV's as a Function of Socio-economic Variables.

$$\ln R = A + \alpha_1 B + \alpha_2 FS + \alpha_3 Ext + \alpha_4 Ed + \alpha_5 T + \alpha_6 Z$$

R = dependent variable	Regression I $\ln\left(\frac{\text{hec. HYV's durum wheat}}{\text{total hec. durum wheat}}\right)$		Regression II $\ln\left(\frac{\text{hec. HYV's}}{\text{total hec. wheat}}\right)$	
A = constant term	-2.3536	(4.09)**	-2.4399	(4.33)**
θ = risk parameter	-27.5069	(2.07)*	-27.1688	(2.09)
FS = farm size	.0049	(1.61)	.0046	(1.54)
Ext = extension contact	.0385	(0.89)	.0305	(0.72)
Ed = education	.0015	(0.04)	.0010	(0.02)
T = topography	1.1396	(2.39)**	1.2370	(2.64)
Z = zone	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.
R = rate of adoption.
Topography = dummy variable where 1 = valley land
0 = hilly land.
Zone = dummy variable which is the same as in production function estimates.
t values are in parentheses.

level.

The above relationships were estimated by including only those producers who are risk-averse. Estimates were tried using all 107 farmers, and only farm size and the topography dummy were significant. A visual inspection of the 29 risk preferrers indicates that these producers operate at the extremes of the production function. For example, a number of those 29 producers were small, isolated farmers who used exceptionally large amounts of fertilizer with low expectations of output. Such an individual would be a risk preferrer according to the methodology. At the other extreme are some large farmers, highly modern in their use of mechanized inputs, who are more characteristic of what one would expect of a risk preferrer. The fact that the value of θ is sensitive at the extremes can be expected from OLS estimation procedures since the variance of the estimates are lowest at the means and diverge as one moves away.

Since the theory explains adoption only in the case of risk aversion, the risk preferrers were dropped and the 78 remaining producers were maintained in the estimates reported in Table IV.4. The results, as hypothesized, indicate an inverse relationship between risk aversion and adoption. This estimate is similar to other efforts explaining adoption rates with one exception--a risk-aversion parameter is included as an independent variable. Since few other studies have a quantifiable risk parameter available to include in an estimate of adoption rates, it is generally omitted. It can be argued that such an omission may result in a specification bias of the parameters of the included independent variables.

If risk aversion is an important factor inhibiting the adoption of new technology, it is useful to try to identify those determinants of the risk-averse producers. Thus, this relationship is estimated by regressing on θ (1) education, (2) age, (3) farm size, (4) percentage of consumption that is home produced, (5) land owned as a percentage of land farmed, (6) a dummy variable for topography, and (7) a dummy variable for producers whose only income is from farming. Table IV.5 shows these estimates.

Before interpreting these results, a digression on assumptions of utility functions underlying this analysis is in order. The theoretical section outlined a methodology allowing the derivation of a risk parameter without specifying a specific utility function. The calculation itself could be made without specifying a functional form and did not require that the form be similar across farmers. To take the next step and regress θ on farmer characteristics and use those results in Tunisia is predicated on the assumption that the utility functions are similar for all producers considered.

Notice that the size of the coefficient on farm size is negative. Assuming farm size to be a fair proxy for wealth, as wealth increases, risk decreases. This effectively rules out the quadratic function as being operative since this form exhibits increasing risk aversion. These results confirm the general rule of thumb that small farmers are more risk-averse than large farmers. It also supports the empirical findings of others, such as Moscardi. Relating these findings to other farmers in the population or even suggesting that farmers in the sample will be less risk-averse if they become larger requires an assumption

Table IV.5. Risk as a Function of Socio-economic Variables.

$$\ln \theta = A + \alpha_1 Ed = \alpha_2 A_j + \alpha_3 FS + \alpha_4 Ow + \alpha_5 T + \alpha_6 I + \alpha_7 (\frac{1}{Con})$$

θ = Dependent variable	ln (θ)	
A = constant	-6.0724	(7.3)**
Ed = education in years	-.0218	(0.7)
Ag = age	.0279	(2.4)**
FS = farm size	-.0112	(5.3)**
Ow = land ownership	.3967	(0.7)
T = topography	-1.2183	(3.9)**
I = income source	.5246	(1.5)
Con = consumption	.0105	(0.9)
R^2	.51	
SSE	90.76	
f	10.69	
n	78	

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

Land ownership = percent of land farmed that is owned by the producer.
Consumption = percent of food consumption that is home produced.
Income source = dummy variable where 0 = some off-farm income
1 = no off-farm income

that the utility function is similar across individuals.

Having made this assumption, one can interpret the results shown in Table IV.5. In addition to the farm size issue, older farmers are more risk-averse than younger farmers. Isolated farmers are more risk-averse than those farmers on the valley floor near the distribution cneters, and farmers totally dependent on their farms for livelihood are more risk-averse than those with off-farm income. All of these results are intuitively sensible.

Returning to the adoption issue, one can visualize the omitted variable bias that will characterize efforts to explain adoption rates. If, as has been found in this study, adoption is in part dependent on risk aversion and risk aversion is, in turn, a function of farm size, age, etc., estimating adoption rates as a function of age and farm size can be misleading. The estimates above give empirical support to the explanation of a more complex adoption process.

This section has described the derivation of a risk parameter and estimated functional relationships that identify some of the characteristics of risk-averse producers in Tunisia and of HYV adopters. It established the relationship between rates and risk aversion. The role that allocative error plays in the allocation of inputs including variety choice is explored in the next section.

TRUE PRODUCTION FUNCTION, PERCEIVED AND TRUE COST CURVES

The relationship that was established between risk aversion and adoption in the preceding section utilized the estimates of the parameters of the perceived production function. It was argued that input decisions

are made on the basis of perceptions without perfect knowledge of the true parameters. This section estimates the true parameters and uses both the perceived and the true parameters to derive normative perceived and true cost curves. These are compared, resulting in an allocative error estimated for each parcel.

The hypotheses to be tested are, first, the allocative error is greater for HYV's than for OV's and, second, the error is negatively related to years of experience with that activity. It is plausible to conceive of a repetitive production process in which (1) decisions are made based on perceptions of production parameters, (2) the results of these decisions are observed, and (3) the information gained from the experience helps one prepare for the next iteration. Limited to cross-sectional data, one can gain insight into such a temporal process by comparing individuals with different years of experience to test whether or not allocative errors and experience are negatively correlated. A second similar test is to compare means to test if errors made in producing HYV's are greater than in the production of OV's. Without question, farmers have much more experience with the ordinary varieties.

It is not an objective of this research to describe a learning process. A product of the research, however, is to suggest that such a description is the next step to take in understanding the decision-making process which affects technological diffusion. This will be discussed after the allocative error is derived and analyzed.

A conventional or true production function is estimated using the true yield as the dependent variable. The farmers were visited a second time in July, after the wheat was harvested. One of the objectives of

this visit was to gather information on the yields the producer actually obtained for each parcel. This allows one to estimate the true production function.

$$Y^T = BPh^{\beta_1} N^{\beta_2} M^{\beta_3} L^{\beta_4} e^{\beta_5 D_1 + \beta_6 D_2}, \tag{4.3}$$

where the independent inputs are the defined ones in 4.1.

The results of this estimate are given in Table IV.6. A Chow test was administered to test whether there is a structural difference between the parameters for the HYV's and the OV's. The null hypothesis that $\beta_i^{HVY} = \beta_i^{OV}$ where i = 1, ..., 4 for the independent variables was rejected at the 95-percent level of significance. F = 2.597, which is greater than $F_{4,214} = 2.45$. Thus, Table IV.6 gives one esimate for the HYV true production function and a second for the OV production function. Furthermore, none of the five assumptions required for best linear unbiased estimates using OLS appears to be violated.

The 1976/77 crop year in Tunisia was a poor year for wheat due to a deficiency of rainfall in the month of February. The production estimates are based on cross-sectional data over a geographical area which received a uniform distribution of rainfall for the 1976/77 crop year. Therefore, it is not possible to specify rainfall as an independent variable. Furthermore, data on the variation of soil moisture-holding capacity was not obtained.

The independence of the explanatory variables required for the OLS technique implies that the estimates of those four included variables should not be biased. In empirical estimation, of course, this independence assumption breaks down. The impact on the allocative estimates

Table IV.6. True Production Functions.

Regression I: $Y^T_{HYV} = B\ Ph^{\beta_1}\ N^{\beta_2}\ M^{\beta_3}\ L^{\beta_4}\ e^{\beta_6 D_2 + \beta_7 D_3}$

Regression II: $Y^T_{OV} = B\ Ph^{\beta_1}\ N^{\beta_2}\ M^{\beta_3}\ L^{\beta_4}\ e^{\beta_6 D_2 + \beta_7 D_3}$

Regression III: $Y^P = A\ Ph^{\alpha_1}\ N^{\alpha_2}\ M^{\alpha_3}\ L^{\alpha_4}\ e^{\alpha_5 D_1 + \alpha_6 D_2 + \alpha_7 D_3}$

Variables	HYV True I		OV True II		Perceived III	
A = constant term	.5425	(2.1)	.7595	(4.8)	1.3412	(17.2)
D_1 = HYV					.2908	(5.7)
D_2 = soil	.3712	(3.1)	.3959	(2.9)	.2849	(5.4)
D_3 = zone	-.3887	(3.3)	-.2987	(2.3)	.1345	(2.8)
Ph = phosphate	.1525	(3.2)	.1031	(2.4)	.0413	(2.3)
N = nitrogen	.0163	(0.4)	-.0134	(0.3)	.0658	(3.7)
M = machinery	.3375	(4.0)	.1856	(3.0)	.1099	(3.8)
L = land	.3718	(3.0)	.7874	(7.6)	.8279	(18.4)
R^2	77		79		93	
SSE	47.42		28.02		26.84	
$\sum x_i$	.8781		1.063		1.0449	
n	127		98		228	
F	72.5		61.06		434.37	

t statistics are in parentheses.

All coefficients are significant at the 99-percent level except the nitrogen coefficient in Regressions I and II.

could be fairly strong depending on the growing season and on how biased the true estimates are due to the omission of a rainfall variable. This possible source of bias should be kept in mind when interpreting the results. However, the extent of the bias should not be so serious as to sufficiently negate the results. Because of the shift dummies, a large part of the effect of poor weather is reflected in the constant term. This is as it should be under the independence assumption. Some effect of the weather on the parameters of the independent variables is recognized, and the results will be interpreted accordingly.

The above emphasizes the problem of drawing inferences from observed production function estimates using cross-sectional data for one year. Perceived functions are based on expectations--a mean response characterized by some distribution. Using observed results from poor years can confirm hypotheses of the critics of the green revolution just as good years can be used to support the rationale of the proponents of new technological superiority. The use of a perceived function insulates the impact that the analysis of a poor year may have on the results.

There is a sizeable difference in the coefficients on the inputs when comparing the HYV's and OV's estimates. Statistical tests show that there is not a significant difference between the coefficients on nitrogen or phosphate. In the case of land and machinery, the coefficients are statistically different. This suggests that the HYV's are more equipment intensive than the OV's, at least for this year. This reinforces those who criticize the HYV's as favoring big, modern farmers. Again, returning to the perceived functions, one should emphasize that these differences were not recognized by the producers. Since, as has

been argued here, it is the perceived functions that guide input decisions including variety choice, these true relationships are not affecting HYV adoption. Perhaps the relatively unfavorable weather in this year has affected the estimates of the true coefficients of the independent variables.

Recall that the perceived production function estimate for the HYV's was not shown to be significantly different structurally from the OV's. A neutral positive shift in the function for HYV's was all that was indicated. Comparing the perceived and true estimates are, therefore, interesting and revealing.

The durum wheat producers in northern Tunisia perceived new wheat varieties to be neutrally superior to the traditional varieties. However, for the 1976/77 crop season, the differences between varieties indicate non-neutral changes as well. The true production functions for OV's and HYV's actually cross, with OV's being higher producers at low levels of input use. The marginal productivities of machinery use and fertilizer are higher for the HYV's. (See Gafsi and Roe for a discussion of such non-neutral technological changes.)

In order to illustrate the cost to the producer of his misperceptions, one can use the cost function derived for Chapter II. If the producer possessed perfect information, he could do no better in allocating inputs to the production of wheat than is indicated by the true cost function, 2.50. His perceptions, however, were different from the actual results, as is indicated by differences in the production functions, so he is making an error in allocating his resources.

The theoretical chapter suggests a comparison of the observed

with the true total cost to determine this error. This approach is preferable if one could estimate a perceived production function for each producer, or if the estimates of the perceived parameters were functions of other variables (seeds, experience, education) rather than constants. In such a case comparison of observed costs and true costs would be in order. The output elasticities as estimated in this study, however, are not variable. Therefore, the difference between C^O and C^T is a multiplicative constant across all farmers.[1]

Perhaps a more valid comparison, given the data available, is between C^P and C^T. If C^P is divided by Y^P and C^T by Y^T, one has costs per unit of production. This is necessary so that errors can be compared across many producers with different sized parcels. A ratio is obtained by dividing AC^P/AC^T. If this ratio equals one, there is no allocative error. As the ratio moves away from one, the error increases. Due to the large negative neutral shift due to the poor weather, almost all ratios were less than one, i.e., $AC^P < AC^T$.

This error was calculated for 225 parcels. See Table IV.7 for a partial listing and Appendix VI for a complete listing. A comparison of the means of this ratio for HYV's and OV's indicates that they are statistically different from each other at the 99-percent level of significance. The mean of the ratios for all HYV's is 0.480, while the mean of the OV's is 0.609. Since 0.480 is further away from 1, i.e.,

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[1] $C^O - C^T = \gamma\left(\alpha_1^{\beta_2}\ \alpha_2^{\beta_2}\right)^{-\frac{1}{\delta}}$

Table IV.7. Allocative Errors.

Farmer	Variety	AC^P	AC^T	AC^P/AC^T
1	HYV	4.0167	4.1622	.9650
1	HYV	5.2433	9.4478	.5549
2	HYV	1.5636	6.5725	.2379
2	OV	2.0445	4.6900	.4359
3	OV	2.7110	7.0457	.3848
3	HYV	3.5549	6.3501	.5598
4	HYV	3.8729	8.9055	.4349
5	HYV	3.8136	8.5489	.4461
5	HYV	4.0100	6.6801	.6003
6	HYV	2.8187	5.5144	.5111
7	OV	2.9743	5.4272	.5480
7	OV	2.5126	4.4293	.5547
8	OV	3.4819	7.2753	.4786

perfection, those farmers growing HYV's are, on average, making larger errors. Producers are 48-percent effective at perceiving their costs when producing HYV's and 60.9-percent effective when producing OV's.

A stronger relationship can be tested to see if experience with

the variety affects the size of the allocative error made. A functional relationship was calculated to test the hypothesis that experience reduces allocative errors.

Again, a log-linear functional form appeared to give the best fit. The log-linear, log-log, and log-inverse functions were also fit to the data. The results of the regression are reported in Table IV.8.

Recall that approaching 1 implies a reduction in error. Therefore, the results are interpreted in the following way: Those farmers in the low rainfall zone, with constraints on modern input usage, make larger allocative errors since these are dummy variables. Size of parcel, experience with variety, and distance from Office du Cereals are continuous variables. Size and distance have negative coefficients. Thus errors increase as the parcel decreases.

In the case of parcel size, the percentage change in error is small for a given change in parcel size. However, the change is negative and significant, implying that big farmers make bigger errors. This is contrary to much of the conventional wisdom in agricultural development and may be due to the particular year in question. In the previous section the results suggest that big farmers are more likely adopters, and it is implied above that the error for HYV's was larger than for OV's. In an average year larger producers may do better.

Distance from the market is really a proxy for isolation or distance from the information source. The sign is plausible but, at least in this estimate, of little explanatory value as indicated by its t value.

It remains to interpret experience in regards to its importance

Table IV.8. Allocative Errors as a Function of Socio-economic Variables.

$$\ln E = A + \alpha_1 EX + \alpha_2 S + \alpha_3 Dt + \alpha_4 C + \alpha_5 Z$$

E = dependent variable	$\ln AC^P/AC^T$	
A = constant term	-.5329	(11.3)**
Ex = experience	.0372	(5.3)**
S = size of parcel	-.0115	(7.3)**
Dt = distance from parcel to Office de Cereals	-.0159	(1.2)
C = constraint dummy	-.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.
Contraint = dummy variable where D = 1 if the producer is constrained in any way in input use
D = 0 if no constraints were indicated.

as an explanatory variable. The positive coefficient implies that one approches zero error as experience increases. This is a cautious confirmation of the hypothesis that error is greater for new adopters. Another set of observations in another year would be necessary before one could comfortably feel that a theoretical explanation had validity. The step taken here, while not conclusive, certainly supports the theory, and one is encouraged to repeat the tests on a second set of data.

If this error potential is recognized by producers, it can both inhibit producer adoption or encourage slow adoption until one's knowledge of the parameters of the production process are known with more certainty.

The application of the theory to Tunisian data has established some links between adoption and risk as well as allocative error, variety, and experience with that variety. The usefulness of these findings is explored in the next and final section of this chapter.

IMPLICATIONS FOR TUNISIA

The preceding three sections of this chapter have established that risk perception and risky prospects are elements in the Tunisian wheat producer's decision process. They affect input use and variety choice. Secondly, it was established that these same producers make errors of perception that cause resource misallocation. These errors were shown to decrease as one gains experience with the varieties.

The implications of these results appear to fall into two general categories. The first category includes issues that can be affected by

available policy instruments--issues that are within the government's control. The second category includes issues that policymakers and agricultural scientists must recognize even though they may not be directly influenced by policy instruments.

Tunisia just entered the first year of the Fifth Development Plan. Production targets for the wheat sector include a growth rate of 5.2 percent.[1] To reach this goal, high-yielding durum wheat hectarage must double, and average yields of 18 quintals need to be attained. In 1975/76, a reasonably good year for wheat production, yields of HYV's of durum wheat averaged only 15.7 quintals.[2]

The wheat production goals of the Fifth Development do not take into consideration (1) agroclimatic differences that exist in northern Tunisia, (2) the impact risk and uncertaintly has in limiting resource use and adoption, and (3) lack of information that characterizes producer operations. This study has identified and quantified factors which can be influenced by policy instruments, can increase adoption, and can increase allocative efficiency. Increasing land area sown to HYV's appears to be difficult enough, but to double this area and increase average yields as well may be too optimistic.

That is not to say that improvements cannot be made. It was shown in the calculation of a risk parameter that input use of nitrogen was reduced due to the output price deflating effect of θK if producers

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[1] Republique Tunisienne. Preparation du Veme Plan: Retrospective et Projection Preliminaire. Janviere, 1976. Chapter 2, p. 7.

[2] Republique Tunisienne. Enqûete par Measure Objective sur les Rendements Cerealiers. Août 1976, appendices.

are risk-averse. It was further determined that 73 percent of the farmers sampled were risk-averse, and that this risk aversion was partially explained by farm size, farm location, and producer age.

This information can be used to focus extension efforts on the producers more likely to adopt the technological package that is being offered and adjust the recommendations for the other producers to meet their more specific situations. For example, the profit-maximizing optimum amount of fertilizer is less on the hillside than in the valley, other things being equal, as is indicated from the perceived production function. In addition, it was determined that these hillside producers are, on average, more risk-averse. Fertilizer recommendation based on utility-maximization criteria are going to be different from those currently being recommended. This information does not simplify the job of allocating extension funds, but it should improve social return to such expenditures.

Since most Tunisian wheat producers sampled were risk-averse, policymakers can increase the use of input allocated to wheat production by concentrating on K. Recall that K was the derivative of the variance of profits with respect to expected output. K is a function of yield variability, and plant breeders need to put more emphasis into yield stability as an objective even at the expense of lower yields.

An indication of the importance of foregone production due to the discount effect of θK for risk-averse producers is illustrative. The average value of θK for the farmers sampled in this study was equivalent to reducing the price of wheat by 1.812 dinars per quintal. If phosphate alone were increased to the profit-maximization optimum levels, wheat

production would, on average, increase by 25 kilograms per hectare.[1] If the sample is representative of northern Tunisia, more than 16 thousand tons of wheat were lost in 1976. Since small farmers are more risk-averse than large farmers, this estimate may be slightly high. Certainly the estimate would be much larger if one considered the possible underutilization of other controllable inputs. While these are rough calculations, they indicate just how important risk aversion can be.

Stablization schemes are available instruments to decrease variability in profits. Insurance programs, either private or public, are frequently mentioned candidates. Insurance that would guarantee either production or total revenue would effectively raise input use for risk-averse producers.

When one includes the additional loss in wheat production in Tunisia due to the hesitancy of risk-averse adapters to adopt high-yielding varieties, the cost of income instability becomes even more pronounced. Since the perceived production function estimates indicate a positive neutral shift for high-yielding varieties, low adoption rates will be costly. Again the goals of plant breeding become important. Now, not only does the trade-off between the mean yield and its variation become important, but the covariance of risky prospects becomes an issue. If the variation in yields of two varieties is not highly positively correlated, a risk-averse producer can gain from diversification.

It is also apparent that the Tunisian government could use its

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[1]This was computed from 2.25 (p. 32) with $\theta K = 1.812$. The respective optimal quanities of phosphate were substituted into Regression IV, Table IV.1.

wheat pricing policy to increase adoption rates by risk-averse producers. Some variation in price would act as a profit stabilizer and have a positive effect on both adoption rates and general productivity. Thus, the policymakers should increase prices during production short falls. The argument has been made that fixed wheat prices insulate Tunisian wheat producers from the vagaries of the international market. A strong case is made here to stabilize profits, not prices, as some price variability needs to be allowed to accomplish such profit stability.

While misperceptions of production parameters cause allocative errors, similarly, misperceptions of output variability would cause lower input use and lower adoption rates for risk-averse producers. This stresses the value of information. If, for example, a demonstration plot were located on poor, hilly soil, it could increase the information set for farmers with similar parcels regarding not only production parameters but also yield variability. This study did not compare expected variances with real variances, and the above only suggests an interesting extension of the theory.

In the previous section, a ratio was calculated indicating that there were substantial allocative errors made due to the producer's misperceptions of the parameters of production. In monetary terms a value can be put on the cost of the resulting misallocation of resources. The best allocation of resources that could be achieved given perfect knowledge of the production parameters can be calculated from 2.50 (p. 42). In 1976/77 the true cost for one quintal of wheat was, on average, 5.95 dinars. Since allocative errors were made, the actual cost for that year, calculated from 2.54, was 8.21 dinars. Better and more accurate

information on the production process would have saved, on average, 2.26 dinars. The effect of a dry winter in Tunisia was emphasized earlier. Thus, one is hesitant to emphasize such numerical calculations since the cost of allocative errors in a better year may be less. In this year, however, durum wheat production in northern Tunisia may have lost 13.9 million dinars if the area sampled is representative.

It was established that experience was inversely related to the size of the allocative error. Extension efforts undertaken in the Tunisian wheat sector should aim at demonstrating new varieties and techniques in such a way that producers will become more familiar with the changes in the production parameters. The closer the demonstrations are to the farmer's actual situation, the higher the probability of influencing the farmer's perceptions. The better the farmer's perceptions, the smaller the allocative error. Thus, the benefits accrue to the individual farmers and Tunisia as well.

Furthermore, the comparision made here includes only one part of total allocative error. Comparisons of cost minimization are valid and worthwhile, but ideally one would like to consider the additional error of being on the expansion path but not at the profit-maximizing point.

The insights gained this year on allocative errors caused by misspecification need to be reinforced with a second year of data. Nevertheless, the fact that the error was costly to Tunisia in 1976/77 is apparent. Improving the information flow, particularly regarding new technology, to wheat producers has indeed the potential for a high payoff.

CHAPTER V

SUMMARY

Faced with low adoption rates and low production growth in wheat, Tunisia is searching for ways to solve these problems. Other adoption studies have emphasized the importance of agroclimatic and geographical characteristics to adoption. Gafsi and Roe indicated the impact of some technical and institutional constraints to adoption. As more information becomes available, the complexity of the adoption process and the lack of simple solutions are accentuated.

The roles of risk and uncertainty and allocative error are frequently mentioned as constraints to productivity growth and adoption, yet their roles have not been well-established empirically. With respect to risk and uncertainty, Woglin found Kenyan farmers to be efficient utility maximizers, and Moscardi found Mexican farmers to underutilize inputs due to risk aversion. A number of studies have looked at allocative errors and the importance of education and information. Hoffman, Khaldi, Hiebert, Wu, and Fane are some of the studies discussed in Chapter II as making contributions, yet virtually no empirical research has established the role of allocative error in this process.

The problem faced in this thesis was gaining an understanding of what adjustments producers make in the decision-making process and how these adjustments affect the adoption of new techniques. The objectives

were (1) to explore producer expectations and show how these expectations affect input use and choice and (2) compare these expectations with actual results.

More specifically, this research proposed to

1. estimate a perceived production function,
2. determine the impact risk and uncertainty have on decision processes,
3. derive misspecifications of production parameters and the resulting allocative error caused by these mistakes, and
4. specify the role farm and farmer characteristics have in the decision-making process.

The theoretical model, the empirical findings, and an interpretation of these results are summarized below. A utility-maximization rule was established with profit as its attribute. Assuming profit to be normally distributed, an E-V analysis was constructed to explain underutilization of inputs and nonadoption if producers were risk-averse. This formulation was empirically tested using a perceived production function based on producer expectations at the time input decisions were made.

Data were gathered from 125 wheat farmers in northern Tunisia during the 1976/77 wheat season. A risk parameter was calculated for 107 of these producers. Seventy-nine percent were found to be risk-averse. Risk aversion and variable profits caused inputs to be underutilized relative to profit maximization optima, which may explain the hesitancy farmers exhibit toward adopting HYV's of durum wheat. The effect of risk and uncertainty was neutral with respect to input use.

Risk-averse producers were still on the expansion path but short of the profit maximum. Since the covariances of the varieties studied were not known, the opportunity set in E-V space could not be calculated for each farmer. The rate of adoption was regressed on the risk parameter and other explanatory variables to determine if risk partially explained adoption rates. Indeed, risk aversion was found to be significant and negatively related to adoption. Adoption was also found to be higher on valley land and, although less significant, positively related to farm size.

In addition, age, farm size, topography, and percent of total income from farming explains over 50 percent of the variability in the risk parameter for risk-averse producers. It is not suggested that risk preferences can be affected by policy instruments of the government. Understanding the importance of these preferences will allow the Tunisian Ministry of Agriculture to set more realistic production targets.

For risk-averse producers, the variance in profits becomes very important, and policy instruments are available to reduce this variance. Plant breeders, policy price schemes, and insurance programs could reduce this variability. These findings in this study indicate that productivity and HYV adoption would increase if policy instruments could successfully reduce profit variability.

The input-output relationship used above was that perceived by the producer. Since perceptions are not usually perfectly accurate, these producers make allocative errors. Such an error was constructed by comparing perceived costs with true cost. The results of this

comparison are affected by a dry spring in 1977, and the results need to be interpreted accordingly. Most farmers overestimated output during this year, and, consequently, true costs were higher than perceived costs. It was determined that the error for HYV's was greater than the error for ordinary varieties and that this error was negatively related to the experience that farmers have with the variety; i.e., as experience increased, the error decreased. It is perhaps possible that education and information would have a similar impact. Those farmers facing input constraints make larger errors than those that are unconstrained. In addition, large farmers make slightly greater errors than small farmers.

These findings emphasize the importance of information and extension work. On-farm demonstrations, in the hills as well as the valleys, will reduce allocative errors that waste resources. Small plots in the early stages of adoption should be encouraged. The problem is even greater than presented here because an additional allocative error exists, namely that of not operating at a profit-maximization optimum. Thus, the government should provide information through trials, etc. on different levels of input use which would give farmers information on the shape of the production surface.

Since the study used only one year of data, the method needs to be tested again, and it is hoped the results arrived at in this thesis encourage other efforts toward specifying allocative error in this way. The results do, however, confirm intuition by emphasizing the learnning element in production decisions.

Tunisia has embarked on an ambitious development program and has wisely placed as much inportance on agricultural development as that of

other sectors. It appears, however, that production goals, at least in the wheat sector, are overly optimistic unless institutional constraints are alleviated and output variability and allocative errors are reduced. This research has tried to point out the importance of these errors and has suggested what policymakers could do to improve the situation.

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APPENDIX I

SUPPLEMENTARY REGRESSION

SUPPLEMENTARY REGRESSIONS

$$Y = e^{A+d_1D_1+d_2D_2+d_3D_3+d_4D_4+d_5D_5} Ph^{\alpha_1+d_6D_6} N^{\alpha_2+d_7D_7} M^{\alpha_3} L^{\alpha_4}$$

A = constant term	1.4515	(13.3)
D_1 = HYV	.2934	(5.7)
D_2 = soil	.2875	(5.5)
D_3 = zone	.1503	(2.8)
Ph = phosphate	.0480	(2.0)
N = nitrogen	.0604	(2.6)
M = machinery	.1163	(4.0)
L = land	.8275	(18.3)
D_4 = rented parcel	-.0961	(1.4)
D_5 = crop rotation	-.0789	(1.4)
D_6 = education dummy on phosphate	.0012	(0.5)
D_7 = education dummy on nitrogen	.0010	(0.03)
R^2	.93	
SSE	26.23	
n	228	
F	278.17	

Rented parcel dummy: D = 1 if owned

D = 0 if rented

Crop rotation dummy: D = 1 if preceeding crop was fallow

D = 0 if otherwise

APPENDIX II

SAMPLE OF QUESTIONNAIRE

ENQUETE: LA PRODUCTION DU BLE EN TUNISIE

CAMPAGNE 1976/77

Gouvernorat _____

Delegation _____

Cheikhat _____

Lieu dit _____

Nom de l'exploitant _____

Localisation:

Date 1ere visite _____ 2eme visite _____

Pluviometrie ___ ___ ___mm

-- Repartition cette année
1 - excessive
2 - normale
3 - insuffisante
4 - tardive

Automne ___

Hiver ___

Printemps ___

Relief general 1 - plaine 2 - coteaux ___

Observations:

No. identification

_____

_____

CARTE DE L'EXPLOITATION

SUPERFICIE

1. Superficie totale de l'exploitation __ __ __,__ __ha.

2. Superficie en blé dur __ __ __,__ __

   -- Superficie par variété première parcelle __ __ __,__ __ha.

   deuxième parcelle __ __ __,__ __

   troisième parcelle__ __ __,__ __

3. Superficie en blé tendre __ __ __,__ __

   -- Superficie par variété première parcelle __ __ __,__ __

   deuxième parcelle __ __ __,__ __

   troisième parcelle__ __ __,__ __

4. Superficie en orge __ __ __,__ __

5. Superficie en fourrages __ __ __,__ __

6. Superficie en jachère __ __ __,__ __

7. Superficie en legumineuses __ __ __,__ __

8. Autres superficies agricoles __ __ __,__ __

9. Terres non agricole __ __ __,__ __

---

10. Superficie blé totale en 1975/76 __ __ __,__ __

    1974/75 __ __ __,__ __

    L'intention pour l'annee prochaine 1977/78 __ __ __,__ __

11. Mode de faire valoir 1 - propriété 2 - copropriété
    3 - location 4 - gérance 5 - métayer 6- autre __

    -- Si location, quelle est la valeur location de la terre dans cette region __ __,__ __D/ha.

EXPLOITATION DU BLE

Parcelle _____

Variété _____

Superficie ___,___

Relief 1 - plaine
2 - coteaux
3 - combinaison

Preparation du sol, combien d'etapes ___

Assolement précédent
1 - blé ou orge 1975/76 ___
2 - vesce avoine
3 - medic 1974/75 ___
4 - jachère travaillée
5 - jachère morte 1973/74 ___
6 - jachère terre en herbe
7 - maraichères 1972/73 ___
8 - legumineuses
9 - combinaison
10 - autres

Mode de faire valoir _____
1 - propriété
2 - copropriété
3 - location
4 - gérance
5 - métayer
6 - autre

Sol 1 - bon _____
2 - mauvais
3 - moyen

ACTIVITES	Date 1 - janvier 2 - fevrier	Main d'oeuvre	Durée par heure ou jour	Mode traction 1 - animal 2 - mécanique	Si mécanique 1 - propriété 2 - location	Si location coût par heure	Ou Coût Total	Si mécanique Où vient-il 1 - voisin 2 - société privée 3 - gouvernement 4 - cooperative 5 - autre
Preparation du sol Gros labours								
Hersage								
Recroisement Première								
Deuxième								
Troisième								
Autres								
Recolte								
Moisson								
Battage								
Autres								
Transport au marché								
Autres activités								

Avez-vous utilisé le fumier cette année 0 - non 1 - oui ___

— Si oui, quelle date mois _____ année ___ ___ ___

— Combien de charrates par ha ___ ___

	SUPER 16	SUPER 45	APPOINTE PREMIERE	DEUXIEME	TROISIEME	SEMIS	DESHERBAGE CHIMIQUE	MANUEL	TRAITEMENT
Date 1 - Janvier 2 - Fevrier									
Quantité par ha.									
Ou quantité totale									
Origine 1 - stock 2 - voisin 3 - off de c 4 - marché 5 - autre									
Moyen d'achat 1 - comptant 2 - credit 3 - echange									
Moyen du tran 1 - tract 2 - animal 3 - livrasion 4 - autre									
Durée du transport									
Distance aller et ret									
Moyen d'epandage 1 - manuel 2 - mecanique									
Main d'oeuvre nombre									
Durée d'epand heures ou jours									
Disponibilité 1 - suffisant 2 - insuffisant 3 - tardiff 4 - non dispon									

1. Raison du choix de ces semences ___
   1 - par experience 2 - conseil du voisin 3 - conseli du vulgaris
   4 - demonstration 5 - radio ou tele 6 - autre

PREVISIONS

1. Rendement de cette variété dans la campagne précédente __ __,__qx/ha

   dans l'annee 1974/75 __ __,__

2. Rendement le plus élevé obtenu de la variété sur l'exploitat. __ __,__

   moins __ __,__

3. Rendement le plus élevé obtenu de la variété entendu parler __ __,__

   moins __ __,__

4. Rendement attendu __ __,__

   Max rendement attendu __ __,__

   Min rendement attendu __ __,__

BLE A HAUT RENDEMENT

1. Nombre d'années depuis la première adoption de la variété ___ans

   Première fois l'exploitant en a entendu parler ___

   (Calculez la difference entre les deux) ___

2. Superficie qu-il a utiliesée l'année 1975/76 pour cette variété __ __ __,__ha

   1974/75 __ __ __,__

   1973/74 __ __ __,__

   1972/73 __ __ __,__

   -- Raison du changement _____

   _____

3. Raison d'adoption _____

   _____

   _____

RESULTAT

1. Rendement par ha __ __ __,__qx/ha
   ou total __ __ __ __,__qx

2. Répartition de la production

   A. Semences __ __% __ __ __ __qx

   B. Réserve __ __% __ __ __ __qx

   C. Auto consommation __ __% __ __ __ __qx

   D. Vendu aux organismes publics __ __% __ __ __ __qx __ __,__ __ __TD

   E. Vendu sur le marché __ __% __ __ __ __qx __ __,__ __ __TD

   F. Paiements en nature __ __% __ __ __ __qx

3. Votre evaluation du rendement pour cette année était _____qx/ha.
   Comment expliquez-vous la difference entre le rendement prevu et le rendement obtenu.

   1 - climat
   2 - maladie
   3 - variété
   4 - equipement
   5 - autres

   Facteur plus important _____

   Deuxième facteur _____

   Troisième facteur _____

4. Si vous auriez au les conditions de cette année avant la compagne agricole quels changement auriez-vous faits. _____

   _____

   _____

5. Allez-vous cultiver cette variété l'année prochaine. oui non

   Pourpuoi _____

   _____

   _____

6. Avez-vous vu une démonstration de cette variété. oui non

   Si oui, ou. _____

7. Difficultés particulières rencontrées avec cette variété. _____

   _____

   _____

QUESTIONS GENERALES

1. Age de l'exploitant ___ ___ans

2. Nombre d'années en agriculture ___ ___

3. Nombre d'années sur l'exploitation ___ ___

4. Niveau scolaire _____ _____

5. Nombre de personnes dans la famille ___ ___

   Nombre des enfants moins de 4 ans ___

6. L'exploitant travaille hors de la ferme 0 - non
   1 - oui, agricole 2 - oui, non agricole 3 - oui, les deux

   -- Revenu par rapport au revenu total ___ ___%

7. Revenue d'agriculture vient-il principalement de(s)
   1 - céréales 2 - l'elevage 3 - maraichères 4 - fruitiers ___

8. Blé dur Connsaissance 0 - non 1 - oui Utilisation 0 - non 1 - oui

Mahmoudi	___	___	INRAT 69 (50-25)	___	___
Chili	___	___	Bedri 117 (56-3a)	___	___
Kokini	___	___	Amel	___	___
Beskri	___	___	Maghrabi	___	___
			Autre	___	___

Blé tendre

Ariana	___	___	Carthage	___	___
Florence aurora	___	___	Siete Cerros	___	___
INIA	___	___	Tobari	___	___
Soltan	___	___	Autre	___	___

S'il y a des nouvelles variétés qu'il a utilisées avant mais pas cette annee, expliquez pourquoi.

_____

_____

_____

9. Nombre de visites de vulgarisation sur l'exploitation. _____

Sujet de chaque visite. _____

_____

10. Nombre de contacts faits par l'exploitant avec les services de la vulgarisation. _____

11. Vous discutez de vos problems agricoles avec _____
1 - membres de la famille 2 - le voisin
3 - l'agent vulgarisation 4 - autres

12. Quels sont les renseignnements que vous demanderiez avant l'adoption d'une nouvelle variété. _____

_____

_____

13. Combien avez-vous de bovins _____

ovins _____

chèvres_____

14. Quel est le prix moyen de location de la terre dans votre region. (Dinars/ha/annee) __ __,__ __

15. Consommation alimentaire % cultivé sur la ferme _____%

% achèté sur le marché _____%

Valeur en Dinars __ __,__ __TD

APPENDIX III

RISK PARAMETERS

(Continuation of Table IV.2)

Farmer	E(Π)/ha	$V(\Pi)^{.5}$/ha	θK	θ	$V(Y)^{.5}$/ha
1	148.400	43.443	-3.023	-.004055	5.885
1	209.653	54.554	-4.057	-.003550	7.806
2	120.283	67.070	-1.848	-.002972	9.758
2	99.000	51.522	-.738	-.001235	7.806
3	105.000	46.448	-4.069	-.008558	6.635
3	57.622	39.359	3.789	.005741	5.464
4	74.200	49.235	-7.225	-.027046	6.635
5	140.000	62.842	-5.219	-.001413	8.977
5	143.800	50.515	-4.963	-.003112	7.026
6	29.680	26.066	-6.931	-.038576	3.513
7	140.485	54.834	-5.466	-.001818	7.806
7	73.033	54.162	-4.186	-.000787	7.416
9	107.200	33.997	-1.204	-.001592	5.074
9	102.369	39.957	-.962	-.000285	5.855
9	108.629	50.880	-1.380	-.000129	7.026
10	167.733	52.376	-4.928	-.002395	7.806
10	102.000	66.354	-3.831	-.002937	9.758
10	107.569	69.977	-4.202	-.002896	9.758
11	118.800	79.859	-2.692	-.005935	12.100
11	96.460	52.131	-2.009	-.008215	7.026
12	89.040	46.339	-3.709	-.010363	6.245
13	102.592	71.057	-4.677	-.001667	9.758
14	87.456	51.204	.040	.000054	7.026
14	56.192	16.450	3.968	.044909	2.342
16	53.260	28.584	-1.091	-.003765	4.294
16	109.066	55.091	-3.796	-.002354	8.587
17	96.460	52.131	-2.910	-.001757	7.026
18	66.680	26.066	-1.235	-.002839	3.513
18	70.200	28.337	-2.889	-.004509	4.294
18	79.200	28.337	-2.889	-.013528	4.294
19	100.839	41.983	-.785	-.000178	6.245
19	111.300	37.650	-1.482	-.000423	5.074
20	44.520	17.377	1.487	.008043	2.342
21	51.940	20.273	-2.876	-.003016	2.732
22	92.750	46.339	-3.857	-.001408	6.245
23	59.360	34.754	-3.245	-.008395	4.684
23	74.200	40.546	-4.080	-.020970	5.464
24	74.200	36.202	-2.966	-.010698	4.879
24	74.200	40.546	-7.225	-.009283	5.464
25	48.230	40.546	6.283	.009408	5.464
26	99.000	23.185	-.738	-.005495	3.513
27	55.278	26.970	6.839	.005869	3.903
27	82.500	36.066	2.194	.005700	5.464
28	160.000	37.471	-4.483	-.004597	4.684
29	84.103	21.885	-2.123	-.007450	3.123
29	63.077	16.414	-2.123	-.014595	2.342

Farmer	E(Π)/ha	V(Π)$^{.5}$/ha	θK	θ	V(Y)$^{.5}$/ha
29	56.069	24.620	-.139	-.000394	3.513
30	89.040	34.754	-7.257	-.024534	4.684
31	148.400	92.678	-7.322	-.007694	12.490
32	91.839	69.038	-1.592	-.000085	10.148
32	67.000	65.379	.335	.000041	9.758
33	37.100	28.962	-7.029	-.003159	3.903
33	89.895	29.690	-6.765	-.002220	4.294
33	92.258	30.470	-6.946	-.001924	4.294
34	56.000	24.980	-3.436	-.012586	3.123
34	64.000	24.980	-4.007	-.020064	3.123
35	74.200	40.546	-7.-25	-.009887	5.464
38	44.520	23.169	-.328	-.000544	3.123
38	47.840	29.343	-.756	-.000494	4.294
39	105.090	35.550	-1.995	-.001264	5.074
39	87.333	51.132	-.186	-.000063	7.026
40	82.879	60.385	-5.395	-.004350	10.929
40	110.000	32.201	-5.402	-.007326	5.855
40	89.040	37.650	-7.257	-.001944	5.074
41	66.780	40.546	-3.244	-.001776	5.464
41	66.780	36.202	-7.203	-.013062	4.879
42	111.300	31.858	-7.290	-.003596	4.294
43	68.768	32.210	.640	.000386	4.684
44	120.000	40.593	-7.870	-.003825	5.074
45	83.200	49.961	.146	.000025	7.806
45	84.500	50.742	.046	.000008	7.806
45	74.200	43.443	1.090	.000226	5.855
45	64.500	37.763	2.060	.001128	5.855
45	78.000	2.5371	.592	.000862	3.903
46	51.940	43.443	-7.141	-.035742	5.855
46	59.360	49.235	-7.176	-.012234	6.635
47	81.620	43.443	-7.242	-.009085	5.855
47	81.620	46.339	-7.242	-.015024	6.245
48	174.389	81.681	-3.572	-.000112	11.710
48	198.600	51.678	-3.783	-.000850	7.805
49	56.718	27.673	3.548	.001954	3.903
49	65.000	35.519	2.010	.001205	5.464
50	109.550	69.841	-3.521	-.002820	9.563
52	97.500	50.742	-1.489	-.000514	7.806
52	78.000	25.371	-.236	-.000858	3.903
53	62.244	44.541	-4.828	-.000933	6.440
53	50.250	32.689	-4.194	-.000668	4.879
54	66.817	114.100	2.285	.000112	13.661
54	59.360	57.923	3.217	.001998	7.806
54	126.140	60.820	-2.414	-.002018	8.197
54	66.780	49.235	2.035	.001041	6.635
55	59.360	17.377	4.325	.007252	2.342
56	40.600	37.354	2.254	.000398	6.440

Farmer	E(Π)/ha	V(Π)$^{.5}$/ha	θK	θ	V(Y)$^{.5}$/ha
93	96.460	57.923	-.568	-.000657	7.806
93	85.330	28.962	.325	.004389	3.903
93	40.937	26.621	-6.497	-.008245	3.903
94	119.340	27.400	-4.400	-.002298	3.903
94	101.580	21.146	-3.803	-.007258	3.123
95	38.904	27.609	1.024	.000630	3.903
95	64.398	36.308	-2.207	-.012301	5.074
95	14.152	16.571	9.625	.039429	2.342
96	42.294	37.361	-7.077	-.091356	5.035
97	51.940	36.202	5.159	.016247	4.879
97	40.810	30.410	6.706	.026395	4.098
97	22.260	14.481	-6.768	-.022415	1.952
97	37.100	30.410	-7.029	-.019976	4.098
98	87.024	35.383	-3.583	-.005637	4.879
98	61.679	25.491	-2.077	-.005922	3.513
98	56.270	21.963	-1.440	-.005074	3.318
99	29.480	23.013	-1.867	-.003525	3.123
99	21.860	28.441	7.389	.074598	3.903
99	92.750	34.754	-4.778	-.015508	4.684
100	63.660	23.467	-6.856	-.029178	3.318
100	57.312	12.583	-6.920	-.077453	1.756
100	62.400	24.356	-4.650	-.027471	5.074
100	43.200	12.178	-4.583	-.090183	2.537
104	111.300	62.268	-1.550	-.003291	8.392
104	96.460	78.197	-.647	-.002937	10.539
104	91.530	46.311	-.257	-.000130	6.831
105	51.870	26.995	4.825	.022609	3.903
105	72.870	31.151	2.045	.025169	4.489
107	102.300	36.066	-.919	-.00329	5.464
107	107.188	37.789	-1.234	-.000322	5.464
107	103.880	49.235	-1.130	-.000520	6.635
108	59.360	33.306	-7.176	-.006289	4.489
108	63.070	43.443	07.190	-.012354	5.855
108	51.940	23.169	-7.141	-.024323	3.123
108	55.650	28.962	-7.159	-.022761	3.903
109	50.400	19.672	-1.121	-.002991	2.732
109	35.100	13.700	-7.366	-.016396	1.756
109	39.000	10.656	4.965	.060260	1.366
109	27.300	6.611	1.926	.013355	.976
110	62.736	27.368	2.631	.003101	3.708
110	72.000	32.787	1.455	.000894	4.098
111	29.680	14.481	3.217	.029008	1.952
111	40.810	18.825	.316	.001848	2.537
111	40.810	24.617	.316	.000831	3.318
113	38.500	25.956	3.831	.005048	3.708
114	51.940	11.585	-.3354	-.017544	1.561

Farmer	E(Π)/ha	V(Π)$^{.5}$/ha	θK	θ	V(Y)$^{.5}$/ha
56	65.000	22.834	-.862	-.000228	3.513
57	48.230	31.858	-7.119	-.011399	4.294
58	141.750	24.898	-2.634	-.003720	3.513
58	123.300	53.474	-1.902	-.000328	7.806
59	72.762	42.601	-4.159	-.003158	5.855
60	108.660	73.514	-5.759	-.010266	10.148
61	128.115	25.003	-3.454	-.011670	3.513
62	158.124	26.834	-3.052	-.001392	3.903
63	183.500	47.272	-3.777	-.009940	6.440
64	22.260	18.825	7.425	.015758	2.537
64	46.340	31.007	-.258	-.000310	4.684
66	74.200	60.820	-3.903	-.003049	8.197
67	119.129	38.749	-1.733	-.000281	5.855
67	111.300	37.650	-7.290	-.001786	5.074
68	116.416	17.040	-7.154	-.031788	2.342
69	59.495	35.516	3.479	.011723	5.074
69	104.702	57.214	-1.042	-.001083	8.197
70	84.900	37.280	-5.219	-.004237	5.269
71	103.605	53.919	-1.045	-.001916	7.806
71	89.791	26.959	-.143	-.000680	3.903
72	98.232	84.352	-.611	-.000088	12.881
72	98.371	51.195	-.620	-.000253	7.806
73	64.000	15.613	-4.521	-.016300	1.952
75	89.040	20.273	-3.709	-.033149	2.732
75	92.750	23.169	-3.857	-.024286	3.123
75	99.000	20.609	-3.631	-.014590	3.123
75	91.216	31.495	-3.591	-.008078	4.489
77	29.680	11.585	.003	.000020	1.561
78	46.800	12.646	-4.345	-.015870	1.756
79	40.810	17.377	.677	.003331	2.342
80	148.400	43.443	-3.903	-.005234	5.855
80	85.800	58.607	-1.043	-.000387	8.197
81	155.147	67.285	-2.987	-.000111	9.758
82	109.371	42.690	-.592	-.000947	5.855
83	44.520	14.481	.003	.000007	1.952
84	137.624	94.006	-2.484	-.000307	13.661
85	74.200	36.202	1.374	.004954	4.879
86	37.100	20.273	-7.029	-.036128	2.732
86	22.260	11.585	-6.768	-1.34488	1.561
88	133.560	37.650	1.589	.008723	5.074
88	133.560	37.650	6.141	.020592	5.074
89	48.230	17.377	-.568	-.007095	2.342
90	48.230	26.066	-2.281	-.018662	3.513
91	111.300	52.131	-1.482	-.000267	7.026
91	99.000	46.370	-.662	-.000453	7.026
92	81.620	34.754	-3.418	-.005209	4.684
93	92.750	21.721	-.294	-.003651	2.927

Farmer	E(Π)/ha	$V(\Pi)^{.5}$/ha	θK	θ	$V(Y)^{.5}$/ha
116	74.200	31.858	-2.688	-.003649	4.294
116	37.100	26.066	2.045	.033860	3.513
117	51.940	14.481	7.776	.074498	1.952
118	91.260	23.290	-.247	-.001010	3.318
118	94.770	23.290	-.497	-.006898	3.318
118	91.607	26.129	-.273	-.001193	3.708
118	91.780	22.045	-.287	-.001192	3.123
119	74.200	46.339	1.385	.001452	6.245
121	66.781	37.796	2.127	.000403	5.660
121	68.961	26.917	1.909	.000659	3.903
123	127.824	60.680	-2.150	-.004450	8.782
123	97.457	33.964	-.672	-.001462	4.879
124	109.440	42.717	-1.425	-.003988	5.855
125	112.200	39.813	-1.463	-.002142	5.855
125	105.670	54.994	-.1174	-.000207	7.806
125	141.061	41.294	-2.650	-.002810	5.855

Farmer	Ave. θ	Farmer	Ave. θ	Farmer	Ave
1	.003802	40	.004540	80	.003
2	.002103	41	.007419	81	.000
3	.001408	42	.003596	82	.000
4	.027046	43	-.000386	83	-.000
5	.002263	44	.003825	84	.000
6	.038576	45	-.000450	85	-.004
7	.001302	46	.023988	86	.085
9	.000667	47	.012054	88	-.014
10	.002743	48	.000481	89	.007
11	.007070	49	-.001579	90	.018
12	.010363	50	.002820	91	.000
13	.001670	52	.000686	92	.0052
14	-.022725	53	.000800	93	.00204
15	.003059	54	-.000283	94	.00477
17	.001757	55	-.007252	95	-.00925
18	.010438	56	-.000085	96	.091356
19	.000251	58	.002024	97	-.000063
20	-.008043	59	.003158	98	.005544
21	.003016	60	.010266	99	-.018522
22	.001408	61	.011670	100	.056071
23	.014682	62	.001392	104	.002116
24	.009991	63	.009940	105	-.023619
25	-.009408	64	-.007724	107	.000390
26	.005495	66	.003049	108	.016432
27	-.005784	67	.000740	109	-.013557
28	.004597	68	.031788	110	-.001997
29	.008480	69	-.005320	111	-.010562
30	.024534	70	.004237	113	-.005048
31	.007694	71	.001298	114	.017544
32	.000022	72	.000170	116	-.015105
33	.002434	73	.016300	117	-.074498
34	.016325	75	.020026	118	.002573
35	.038576	77	-.000020	119	-.001452
38	.000519	78	.015870	121	-.000531
39	.000663	79	-.003331	124	.002142
				125	.003017

APPENDIX IV

ALLOCATIVE ERRORS

(Continuation of Table IV.4)

Farmer	HYV Dummy	AC^P	AC^T	AC^P/AC^T
1	1	4.02	4.16	.97
1	1	5.24	9.45	.55
2	1	1.56	6.57	.24
2	0	2.04	4.69	.44
3	1	2.71	7.05	.38
3	0	3.55	6.35	.56
4	1	3.87	8.91	.43
5	1	3.81	8.55	.45
5	1	4.01	6.68	.60
6	1	2.82	5.51	.51
7	0	2.97	5.43	.55
7	0	2.51	4.53	.55
8	0	3.48	7.28	.48
9	1	3.40	8.27	.41
9	1	4.40	13.15	.33
9	0	5.60	10.84	.52
10	0	2.60	5.10	.51
10	1	2.03	6.59	.31
10	1	2.03	6.80	.30
11	1	2.12	4.96	.43
11	1	2.15	5.11	.42
12	1	2.17	7.14	.30
13	1	2.33	6.85	.34
14	0	3.82	7.01	.55
14	0	4.00	7.67	.52
15	0	1.57	3.76	.42
15	1	1.16	5.20	.22
16	0	3.41	7.08	.48
16	1	2.43	7.03	.35
17	1	1.99	6.48	.31
18	0	3.24	1.74	.54
18	1	2.72	2.44	.90
18	1	2.85	2.63	.92
19	1	2.67	10.90	.24
19	1	2.01	7.02	.29
20	0	3.57	8.59	.42
21	1	2.57	8.13	.32
22	1	3.39	5.10	.66
23	0	3.45	8.03	.43
24	1	2.67	7.11	.38
24	0	3.38	8.10	.42
25	0	3.60	9.26	.39
26	1	2.40	6.13	.39
27	1	3.45	9.31	.37
27	1	4.76	9.22	.52

Farmer	HYV Dummy	AC^P	AC^T	AC^P/AC^T
28	1	4.27	13.09	.33
29	1	2.57	8.41	.31
29	1	2.60	8.41	.31
29	1	2.58	8.76	.30
30	1	2.10	5.11	.41
31	1	2.44	6.17	.40
32	1	2.81	13.83	.20
32	1	2.95	11.16	.26
33	0	2.32	5.35	.43
33	1	1.69	8.19	.21
34	0	3.55	9.11	.39
35	0	1.53	3.56	.43
36	0	4.53	10.37	.44
36	0	3.63	7.70	.47
37	0	3.55	7.59	.47
38	0	1.81	3.75	.48
38	1	1.31	4.72	.28
39	1	2.56	11.09	.23
39	1	1.94	7.59	.26
40	1	1.50	5.13	.29
40	0	1.91	.376	.51
40	0	2.49	5.48	.45
41	0	2.16	4.73	.46
41	1	2.21	5.84	.38
42	1	1.52	5.26	.29
43	0	1.53	3.06	.50
44	1	1.81	7.16	.25
45	1	1.77	8.29	.21
45	1	1.34	5.65	.24
45	0	1.80	3.60	.50
45	0	1.85	3.81	.48
45	1	1.39	5.55	.25
46	1	1.47	3.29	.45
46	0	2.46	6.28	.39
47	0	6.00	12.94	.46
48	1	1.76	8.62	.20
48	1	1.81	7.71	.23
49	0	2.28	5.12	.45
49	1	1.74	7.98	.22
50	1	3.53	8.14	.43
51	1	.275	8.06	.34
52	1	2.44	6.34	.38
52	0	3.43	6.24	.55
53	0	1.94	4.20	.46
53	1	1.45	7.40	.20
54	1	2.05	4.74	.43
54	1	2.17	2.20	.98

Farmer	HYV Dummy	AC^P	AC^T	AC^P/AC^T
55	1	5.45	15.85	.34
56	1	1.67	8.93	.19
56	1	1.64	9.16	.18
57	1	2.48	5.29	.47
58	1	4.25	7.02	.61
58	1	4.16	7.29	.57
59	0	2.62	3.68	.71
60	0	4.85	6.46	.75
61	1	3.11	5.51	.56
62	1	4.40	6.58	.67
63	1	3.23	5.19	.62
64	0	1.88	2.48	.76
64	0	1.81	2.68	.68
66	1	3.97	5.85	.68
67	1	2.46	5.04	.49
67	1	2.40	5.28	.45
67	0	3.31	4.04	.82
68	1	4.05	7.08	.57
69	1	.402	4.74	.85
69	1	4.93	8.57	.58
70	0	7.22	8.58	.84
71	1	2.97	4.35	.68
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

Farmer	HYV Dummy	AC^P	AC^T	AC^P/AC^T
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

Farmer	HYV Dummy	AC^P	AC^T	AC^P/AC^T
107	0	3.01	3.97	[illegible]
108	1	3.53	6.15	[illegible]
108	1	2.80	3.60	[illegible]
108	0	4.85	7.57	[illegible]
109	1	2.45	4.86	[illegible]
109	0	3.28	4.84	.6[illegible]
109	0	3.42	5.28	.6[illegible]
109	0	3.34	5.07	.6[illegible]
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

APPENDIX V

MEANS AND STANDARD DEVIATIONS OF INDEPENDENT VARIABLES USED IN THE PRODUCTION FUNCTION ANALYSIS

		HYV	OV	Total
Macinery	Means	18.86	13.65	16.58
	S.D.	(6.62)	(8.60)	(7.97)
Land	Means	9.77	4.39	7.41
	S.D.	(13.09)	(4.89)	(10.65)
Nitrogen	Means	19.48	15.22	17.61
	S.D.	(14.66)	(13.96)	(14.48)
Phosphate	Means	28.09	21.51	2.520
	S.D.	(16.60)	(20.88)	(18.84)
Perceived yields	Means	13.20	8.49	11.134
	S.D.	(4.91)	(4.14)	(5.142)
True yields	Means	7.51	5.44	6.60
	S.D.	(5.26)	(3.63)	(4.72)

	Number
Good soil	119
Poor soil	109
Low rainfall zone	102
High rainfall zone	126
Flat land	129
Hilly land	99
HYV's	128
OV's	100