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CONTENTS

RESOURCE USE IN AGRICULTURE:
APPLICATIONS OF THE PROFIT FUNCTION
TO SELECTED COUNTRIES

Pan A. Yotopoulos and Lawrence J. Lau

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Pan A. Yotopoulos and Lawrence J. Lau, Editors

CONTENTS

PREFACE

This volume reports one component of the research that originated directly or indirectly from Ford Foundation Grant No. 720-0432 of 1973 to Stanford University. The authors are grateful for this support.

The focal point of the grant was "The Analysis of the Output, Employment, and Income Distributional Effects of Selected Agricultural Policies: A Micro-Economic Approach." The research was organized in four phases: First, the relationships on the production side of the agricultural household were developed. Second, the relationships on the consumption side of the agricultural household were developed. Third, the micro-relations in production and consumption were linked to study the equilibrium of the household. Fourth, these micro-relations were incorporated into a simulation model to analyze the effects of changes in policy variables—such as price supports, taxes, or redistribution—on the aggregate values and on the distribution of the endogenous variables in the system. The studies in this volume report the results of the first phase of the work. The output of the other phases of the project has been reported in a number of separate publications (see Chapter 1 and Bibliography).

One link tying together the studies presented in this issue is the common methodological framework. They are also related through the Ford Foundation grant which financed the collection of primary farm household data in Thailand and Malaysia, the empirical analysis for Taiwan and Japan, and certain special aspects of the research in the other country studies.

The authors are grateful to a large number of graduate students at Stanford University who, unsuspecting but eager, contributed to the process that fashioned the ideas of the research into final shape. Among our colleagues, Carl H. Gotsch and William O. Jones of the Food Research Institute, and Dean T. Jamison of the World Bank contributed valuable comments at different stages of the work. We owe Walter P. Falcon a great debt for his editorial advice which has improved the manuscript significantly. Finally, we are thankful to Teresa A. Gaman for cheerfully typing an endless stream of rough drafts and to Linda W. Perry for her valuable editing.

Stanford, California
June 1979

Pan A. Yotopoulos
Lawrence J. Lau

CHAPTER I.

INTRODUCTION

PAN A. YOTOPOULOS AND LAWRENCE J. LAU

The analysis of agricultural production has become an important step in the formulation of agricultural policy. The policy objective is often to identify possibilities for increasing output while conserving resource use. The questions involved include those of relative efficiency, price responsiveness, economies of scale, efficiency in the allocation of the variable factors of production, and shadow pricing of the fixed factors of production. Such questions can be addressed within a linear programing framework or with neoclassical production functions. This volume is devoted to a subset of the neoclassical production analysis that evolves around applications of the profit function.

The profit function is a flexible tool which is being increasingly used for the empirical study of production. The methodological interest of this volume lies in utilizing the profit-function approach to address a broad range of development issues. The empirical applications are drawn on data from six countries—China, Japan, Malaysia, Taiwan, Thailand, and Turkey—with standard variations in agricultural environment, technology, and institutions. Chapter 1 highlights the methodological issues which are approached in a novel way through the profit function. The concluding Chapter 9 summarizes the insights into world agriculture provided by the country studies reported in the other chapters.

THE TRADITIONAL VERSUS THE PROFIT-FUNCTION APPROACH

The analysis of agricultural production is an integral part of development policy making because of the strategic position of agriculture in many developing countries. Whether this analysis is carried out within a neoclassical production function or a linear programming framework, two types of policy instruments are usually considered—market instruments such as prices and excise taxes, which take the institutional setting as given, and organizational instruments which attempt to change the institutional setting. An evaluation of the effectiveness of market instruments involves, for example, the estimation of demand and supply functions from which one may assess the responsiveness of the agricultural producers to changes in market prices. At this level of analysis, the existing behavioral pattern is usually taken as given and fixed, and policy consideration focuses on the effectiveness of price variables. Organizational instruments, on the other hand, are only indirectly involved with market prices. Instead, one compares different groups of farms, for example, on the basis of their institutional characteristics such as tenancy arrangements or levels of education, and asks the question whether the overall performance of the economy might be different if these characteristics were rearranged. The task here is to identify the particular characteristics that are relevant to production analysis and to predict responses associated with the rearrangement of these characteristics.

In the traditional neoclassical production-function analysis, there is more emphasis on the first set of instruments than on the second, while in linear programming analysis the emphasis is reversed. More specifically, the traditional neoclassical analysis of agricultural production involves the following steps:

1. A production function is estimated in which the quantity of output is the dependent (endogenous) variable and the quantities of the inputs of production are the independent (and exogenous) variables.
2. Profit maximization is assumed.
3. Based on 2, demand and supply functions (and elasticities) are derived by solving an optimization problem.
4. The effect of institutional factors on production is often introduced by separating the sample into groups of specific characteristics and repeating steps 1 through 3. These results are then used to determine the economic effects of the group-related characteristics.

On the other hand, the profit-function approach to the analysis of agricultural production, while still within the neoclassical production-function framework, involves an entirely different procedure. More specifically:

1. The normalized restricted profit function is estimated as a function of the prices of the variable inputs and the quantities of the fixed inputs of production under the assumption that they are the independent (and exogenous) variables. Often the factor-demand functions, or their transformations, are estimated jointly with the normalized restricted profit function.
2. Farms are assumed to behave in accordance with empirically estimable rules which include profit maximization as a special case.
3. Supply and demand functions are derived from a normalized profit function, rather than from an attempt to solve the profit-maximization problem itself, thus avoiding the potential difficulties (sometimes impossibility) of obtaining closed form solutions.
4. Effects of institutional characteristics are introduced directly into both the normalized profit function and the behavioral rules.

Finally, under standard assumptions, the traditional direct production-function approach using the ordinary least squares estimator may be subject to simultaneous equations bias and inconsistency. By contrast, under standard assumptions, the profit-function approach yields statistically consistent estimates.

INPUT DEMAND AND OUTPUT SUPPLY

The flexibility of the profit function as a tool of analysis is based on the duality between the profit and the production function. Chapter 2 elaborates on the properties of the profit function. The brief account in this chapter is intended as an impressionistic link between the policy issues raised in the previous section and the theory presented in the next chapter.

Let the production function of a farm be given by

$$V = F(X, Z), \tag{1.1}$$

where V is total quantity of output, X is the vector of quantities of the variable inputs of production, and Z is the vector of quantities of the fixed inputs.

The first-order conditions for the maximization of profit with respect to the variable inputs are

$$\frac{\partial F}{\partial X_j} = q_j, \quad j = 1, \ldots, m, \tag{1.2}$$

where q_j is the normalized price of the j^{th} variable input, that is, the nominal price divided by the price of output. The demand for the j^{th} variable input of the profit-maximizing farm can be solved from Equation (1.2) as

$$X_j^* = f_j(q, Z), \quad j = 1, \ldots, m, \tag{1.3}$$

where X_j^* denotes the optimal quantity of the j^{th} input, and q is the vector of normalized prices of the variable inputs.

Restricted profit is defined as

$$\Pi = p\left[V - \sum_{j=1}^{m} q_j X_j\right] \tag{1.4}$$

where p is the price of output. It is the total value of output minus the total cost of the variable inputs of production. Restricted profit then is equivalent to the "surplus" appropriated by the fixed inputs of production.

By substituting Equations (1.1) and (1.3) into Equation (1.4), profit can be expressed as a function of the normalized prices of the variable inputs and the quantities of the fixed inputs:

$$\Pi = p\left[F(f_1(q, Z), \ldots, f_m(q, Z), Z) - \sum_{j=1}^{m} q_j f_j(q, Z)\right]. \tag{1.5}$$

Normalized restricted profits, Π^*, are thus given by

$$\begin{aligned} \Pi^* &= \frac{\Pi}{p} \\ &= G(q, Z). \end{aligned}$$

If it is assumed that the production function is Cobb-Douglas, the normalized profit function takes the same form:

$$\Pi^* = A^* \prod_{j=1}^{m} q_j^{\alpha_j^*} \prod_{j=1}^{n} Z_j^{\beta_j^*}, \tag{1.6}$$

where α^*_j s, β^*_j's, and A^* are constants.

By Shephard's (1953) lemma, differentiation of the normalized profit function with respect to the normalized price of the j^{th} variable input gives the demand function for the j^{th} variable input:

$$-\frac{\partial \Pi^*}{\partial q_j} = X_j^*. \tag{1.7}$$

Furthermore, substituting Equation (1.7) into (1.4) and solving for output gives the output supply function

$$V^* = \Pi^*(q, Z) - \sum_{j=1}^{m} \frac{\partial \Pi}{\partial q_j} q_j. \tag{1.8}$$

From Equations (1.7) and (1.8) it becomes clear that given the profit function one can obtain estimates of price elasticities of supply and demand by direct differentiation.

Relative Efficiency

The study of efficiency is associated with the observations that different farms produce different quantities of output from a given set of measured inputs of production, and that different farms with the same set of fixed inputs and facing the same set of normalized prices of variable inputs have different profits. Such observations are consistent only if one or more of the following statements hold:

1. There exist differences in technology, that is, different farms have different production functions.
2. There exist differences in *price efficiency*, that is, different farms vary in their abilities to maximize profits, that is, to equate the value of the marginal product of each variable input to its normalized price.
3. There exist differences in prices, that is, different farms may face different sets of effective prices. These differences in effective prices paid and received may arise from differences in transportation costs, retail margins, or other forms of market imperfection.

The conventional production function is sufficient to measure the technical component of efficiency. The combination, however, of technical efficiency, price efficiency, and effective price differences, which underlie the concept of *economic efficiency*, can be analyzed by using the profit function introduced above. The formulation of the profit function in Equation (1.5) implies that two identical farms (to be defined later as farms of equal technical and price efficiency) that have successfully maximized profits may still have different values of profits as long as they face different effective prices. These price differences may be readily accommodated in the profit-function approach.

For empirical applications in this volume consideration of differences in the technology is limited to only neutral shifts of the production function. If two groups of farms have production functions identical up to a neutral multiplicative parameter, Equation (1.1) can be rewritten with superscripts 1 and 2 identifying the farm group:

$$V^1 = A^1F(X^1, Z^1);\ V^2 = A^2F(X^2, Z^2), \tag{1.9}$$

where A is the group-specific technical efficiency parameter. Farm group 1 is considered more technical-efficient than farm group 2 if, given the same quantities of inputs, it consistently produces a larger output, that is, $A^1 > A^2$.

In the case of price efficiency, a farm is price-efficient if it maximizes profits. Consider two complications in the traditional approach to price efficiency. First, the prices of inputs may be different for each farm, so that price-efficient farms equate the value of the marginal product of each variable input to its farm-specific opportunity cost. Second, farms may not necessarily maximize profits. For such farms, the usual marginal conditions may not hold; it is assumed that they equate the value of the marginal product of each variable input to a constant (which may be farm- and input-specific) proportion, k, of the respective farm-specific input prices. For farm groups 1 and 2, this may be expressed as

$$\frac{\partial A^1F(X^1, Z^1)}{\partial X_j^1} = k_j^1q_j^1;\ \frac{\partial A^2F(X^2, Z^2)}{\partial X_j^2} = k_j^2q_j^2,\quad j = 1, \ldots, m. \tag{1.10}$$

In this case, k_j^1 indexes the decision rule that describes the farm's "profit-maximizing" behavior with respect to variable input j. Perfect profit maximization is encompassed as a special case with $k_j = 1$ for all j.

Between two groups of farms both successfully maximizing profits, the profit function of the group with a higher technical efficiency parameter will be higher at every set of prices. Between two groups of farms with the same technical efficiency parameter, the profit function of the group successfully maximizing profits will be higher than or equal to the other at every set of prices. In these cases the relative levels of the profit function can be used as an indicator of relative efficiency.

But how should relative economic efficiency be evaluated between two groups of farms, both unsuccessfully maximizing profits and, furthermore, both having different technical efficiency parameters? The profit function can be used here as an indicator of relative efficiency in this case as well, although it is possible that one group of farms may be more efficient at one set of prices and less efficient at others. In the Cobb-Douglas case, however, the two profit functions will differ only by the A^* factor in Equation (1.6). One can hence use A^* as an indicator of relative efficiency. As shown in Equation (1.6), A^* encompasses the effects of differences in group-specific technical efficiency, A^1 and A^2, and price efficiency, k^1 and k^2. Furthermore, by solving the system of demand functions of Equation (1.3)—and by correspondence (1.10)—jointly with the production function (1.1)—and by correspondence (1.9)—the A and k components of economic efficiency can be decomposed and identified separately.

In summary, the advantage of using the profit function is that it allows one to capture all three components in the determination of relative economic efficiency. The first component is technological. It is reflected in the technical efficiency parameter and in the coefficients of the production function. The second component is economic. It is introduced through prices and profit-maximization considerations. Profit maximization becomes a testable hypothesis within the profit-function framework, and the possibility of errors in maximization is specifically recognized. In addition, account is explicitly taken of the fact that farms may face different input and output prices. The third component is social and enters the study of efficiency in at least two ways. In agriculture the impact of imperfect markets is probably not random. There is often a direct correlation between the size of the operation and the ability to command resources: access to machinery, fertilizer, water, and productive soil. The maximizing decisions of the small farmer, therefore, may be carried out differently when purchased versus owned variable factors of production are involved. Further, the social component of economic efficiency is recognized through the differentiation of socioeconomic groups. It can be determined, for example, whether share-tenants have different technical and/or price-efficiency characteristics from owner-operators.

POSSIBLE EXTENSIONS

The analysis of farm household production reported in this volume is based entirely on a partial equilibrium framework. Each farm household is assumed to be a price-taker on the output and variable inputs markets. The prices of the output and the variable inputs are assumed to be given exogenously. Similarly, the endowments of the fixed inputs—capital and land—are also assumed to be given exogenously. Within this framework the effects of changes in the exogenous variables can be studied, such as prices of output and variable inputs and the quantities of the fixed inputs, on the output supply, input demands, and the profit of each household (Lau, Yotopoulos, Lin, and Chou, 1978).

In order to derive general equilibrium results, it is necessary to aggregate the individual output supply and input demand functions for the agricultural sector as a whole, taking into account the distribution of farm households by their characteristics (for example, the distribution by farm size) (Lau, Lin, and Yotopoulos, 1978). Second, it is necessary to estimate the consumption demands for both agricultural and non-agricultural commodities and for leisure of the individual households. This has been done for Japan (Kuroda and Yotopoulos, 1978, 1980), Taiwan (Lau, Lin, and Yotopoulos, 1978) and Thailand Adulavidhaya, Kuroda, Lau, Lerttamrab, and Yotopoulos, 1976) and will be reported in another volume. By aggregating the individual consumption demand functions for the agricultural sector as a whole, the aggregate demand functions can be obtained.

Finally, the crucial missing link between partial and general equilibrium analysis is provided by the aggregate demand function for agricultural output of the rest of the economy and the aggregate supply function of inputs to agriculture from the rest of the economy. This has been done for India by using a heuristic aggregate demand function (Yotopoulos and Lau, 1974).

Given the general equilibrium framework outlined above, one can in principle determine the equilibrium prices and quantities of agricultural output and variable inputs as well as the consumption demands. There are, however, alternative ways for closing the system other than the simultaneous equilibration of supply and demand. For example, one can consider an agricultural price-support program in which the government undertakes to purchase all outputs offered for sale at a floor price. In this case, the output price may not be the same as the equilibrium market price. For another example, one can consider an agricultural fertilizer supply program in which the fertilizer is priced below cost but strictly rationed. The price of fertilizer and the quantity of fertilizer will in general not coincide with those determined by supply and demand. For still another example, one can consider a limitation of migration from the villages to the cities, thus effectively closing off the labor market of the agricultural sector. These results can be compared to the free market solution. The range of possibilities has been illustrated for India (Yotopoulos and Lau, 1974).

A PREVIEW

The breadth of the issues addressed by the profit-function approach is indicated by the bibliography that concludes this volume. The six country studies which form the backbone of this volume are among the first ever attempted using consistently the methodology of the profit function. As such they are of interest both for their didactic value and their policy implications.

The specification of the variables is often a compromise between the ideal and the feasible. Each author solved this problem in his own way, consistent with the data availability and the institutional setting of the case studied. In certain cases, the discussion of the specification of variables is rather extensive so that it can provide an example of proper specification and of variable aggregation for the practitioner of the art.

In most cases output represents a weighted sum of farm products. The exceptions are Malaysia, where the sample refers to monoculture rice farms, and Turkey with wheat farms. The choice in the former case represented data availability, while in the latter wheat was chosen with the objective of testing the relative efficiency of two distinct dryland cultivation technologies which were in competition. The choice was a false dilemma and the traditional technology, at least for the year of the survey, was not less efficient than the modern technology which involved early plowing of land.

In the study of agriculture the minimum requisite set of variables is labor and land. There is little difference in the treatment of labor and land among the six studies. However, the policy implications that arise are more interesting when additional sets of variable factors of production can be identified, especially fertilizer and operating capital. The studies present a broad range of alternatives on this issue. In Taiwan, for instance, only chemical and organic fertilizers are included in the fertilizer input. In Japan, on the other hand, the fertilizer input is a composite of chemical and organic fertilizers, feed, and agrichemicals. In Turkey, fertilizer is not considered because little if any is used in dryland wheat production, while in China it does not appear due to lack of data for the 1940-41 period of observation.

Animal input is an important variable factor of production in many less developed countries. In certain cases—such as Taiwan, Malaysia, and Thailand—there are quantities of animal input and their hire rates. The handling of that case is relatively simple. It is analogous to the case of mechanical input when both machine hours and rentals are available, as exemplified again in the cases of Taiwan, Malaysia, and Thailand.

Along with land, the quantity of fixed capital assets—such as warehouses, irrigation works, and a portion of the family house—also enter into the profit function. In this case the problem is in converting capital stocks to service flows (Yotopoulos, 1967a, 1967b). It has been solved in different ways by the authors. Japan presents an example of an *ad hoc* simple technique which proved adequate. Such conversion is not always possible. In the case of China fixed capital assets represent the total number in physical units of farm structures and work animals. Despite the obvious misspecification of the variable, the profit function approach "worked."

An interesting question of research methodology arises with respect to the reporting of results. Obviously, the estimates reported in this volume were not the only ones attempted. Like in many other cases of econometric research, some early runs produced dry holes. These are not commonly reported, for the same reason that "Dog Bites Man" does not make news! Both theory and empirical research lead to strong priors in relation to certain "reputable hypotheses"—such as the downward slope of the demand curves for inputs. The application of Occam's razor to results contrary to these hypotheses suggests that errors in the data, in measurement and in technique, may be the culprits for failure. "Data massaging" in these cases typically consists of successive iterations in specification until the results come out right.

From the successful applications of the profit function in this volume, one cannot generalize that maximization will be observed in all future attempts, even if the techniques are applied correctly. However, the remarkable feature of the studies reported here is that the profit-function approach appears to have worked well despite the diversity in countries, periods, institutional environments, and data bases.

Given the difference in specification of the statistical relationships in different countries, one should not be surprised to find differences in the coefficients that were estimated. The surprise is that most of the results are plausible and that a priori reasons for this plausibility exist. This becomes obvious in Chapter 9 where the results on production coefficients, maximization hypotheses, and price elasticities are presented in tabular form for easy comparison. It is also evident in the individual country studies where independent estimates by other researchers were available for comparative analysis.

The elasticity values reported in detail in each chapter are important for providing policy answers to the questions raised in the beginning of this chapter, such as price response, economies of scale, efficiency in the allocation of the variable factors of production, and shadow pricing of the fixed factors. The ranking of the various factors by price and output elasticity differs from country to country as discussed in the individual chapters. The general conclusion, however, emerges that output price and wage rate are crucial policy-control instruments.

Beyond these similarities, the various chapters probe in different directions, depending on data availability and the importance of specific policy problems. In Taiwan, for example, the question of relative efficiency is addressed between two different years, while in China and Malaysia it is addressed for different land tenure arrangements. In Turkey relative efficiency is tested for two different types of technology—early tillage and late tillage—and between tractor ownership and custom services. The finding that no differences in relative efficiency exist under these various institutional settings is consistent with the underlying rationality of resource allocation and of agricultural organization.

The presentation of these studies in one volume is of methodological interest. Most importantly, however, it serves to illustrate a varying range of policy alternatives which have vital importance for resource use and agricultural development.

CHAPTER II.

THE METHODOLOGICAL FRAMEWORK

LAWRENCE J. LAU AND PAN A. YOTOPOULOS

The country studies of this volume follow a common methodology based on the normalized restricted profit function. In this chapter the profit-function relationships of special interest for the study of the agricultural household are developed and an empirical model is formulated to study economic efficiency. To simplify the presentation the concept of the normalized restricted profit function is first introduced within the context of a one-output, one-variable-input production function. The concept is next expanded to the one-output, multiple-input Cobb-Douglas production-function case in the empirical specification

THE NORMALIZED RESTRICTED PROFIT FUNCTION

The production function of a farm is given by $V = F(X)$. It is assumed that the farm operator maximizes profit, defined as $P = p_0 F(X) - q^* X$, where P_0 is the price of output and q^* is the price of the variable input. The farm operator selects the quantity of the variable input, X, which maximizes the profit of the farm. Whatever maximizes profit, P, also maximizes normalized profit, P^*, which is defined as

$$P^* = P / p_0 = F(X) - q X \,, \qquad (2.1)$$

where $q \equiv q^*/p_0$ may be referred to as the normalized price of the variable input. As a result, one may equivalently consider the maximization of normalized profit in the analysis of the production behavior of the farm.

The first order condition for maximization of normalized profit is given by the usual rule that equates marginal product of an input to its opportunity cost,

$$\frac{dF}{dX} = q. \qquad (2.2)$$

Under mild regularity conditions, Equation (2.2) may be solved for X as a function of q, say, $X = D(q)$. Then $D(q)$ gives the quantity of the profit-maximizing-variable-input demanded as a function of its normalized price q.

Substituting the demand function back into Equation (2.1), one obtains

$$P^* = F(D(q)) - qD(q), \tag{2.3}$$

so that the maximized normalized profit can be expressed as a function of q alone. Equation (2.3) thus gives the *maximized* value of normalized profit at normalized price q. In other words, given any normalized input price q, if the farm maximizes profit then its maximized normalized profit will be given by Equation (2.3). Of course, to the extent that the farm fails to maximize profit, its actual normalized profit will be less than the maximized normalized profit. The function on the right-hand side of Equation (2.3) will be referred to as the *normalized profit function* and denoted by Π^*, so that

$$\Pi^*(q) = F(D(q)) - qD(q). \tag{2.4}$$

$\Pi^*(q)$ has a number of remarkable properties. First if Equation (2.4) is differentiated with respect to q,

$$\frac{d\Pi^*(q)}{dq} = \frac{dF}{dX}\frac{dD\,(q)}{dq} - D(q) - q\frac{dD\,(q)}{dq}. \tag{2.5}$$

But $\dfrac{dF}{dX} = q$ by virtue of the assumption of profit maximization. Thus $-\dfrac{d\Pi^*(q)}{dq} = D(q)$.

In other words, the negative of the derivative of the normalized profit function is the demand function. This result is sometimes referred to as the Hotelling-Shephard Lemma. Two aspects of the plausibility of this result might be noted. First, $D(q)$ must be positive and intuition suggests that as the price of an input increases, profit should fall, which implies that $d\Pi^*/dq$ is negative. Second, if profit is relatively insensitive to input price, that is, $d\Pi^*/dq$ is small, then it is plausible that input demand cannot be large. This result generalizes to the case of multiple variable inputs, in which the negative of the vector of partial derivatives of the normalized profit function is the vector of demand functions for the variable inputs.

No arbitrary function $\Pi^*(q)$ can be admissible as a normalized profit function. It must be nonnegative monotonically decreasing, and convex in the normalized price. It can be proven that, under mild regularity conditions, there is a one-to-one correspondence between production functions on the one hand and normalized profit functions on the other. Thus given a production function, the normalized profit function is uniquely determined and vice versa. This one-to-one correspondence implies that if the assumption of profit maximization is maintained, the analysis can just as well start with a normalized profit function as a production function, because there must exist a production function which gives rise to the normalized profit function. The advantage of starting with a normalized profit function lies in the fact that the demand function can be obtained by simple differentiation. If one starts with a production function, the demand function can only be obtained by solving an optimization problem as, for example, in Equation (2.2).

Having obtained the demand function from the profit function, the supply function can be readily derived. Revenue is given by the product of the price of output, p_0, and supply, V. Profit, on the other hand, is given by revenue minus cost, so that nonnormalized profit is equal to $p_0\Pi^*(q) = p_0V(q) - p_0qD(q)$, which by dividing through by p_0 and solving for $V(q)$ yields

$$\begin{aligned} V(q) &= \Pi^*(q) + q \cdot D(q) \\ &= \Pi^*(q) - q \cdot \frac{d\Pi^*(q)}{dq}. \end{aligned} \tag{2.6}$$

Thus, if one specifies a normalized profit function, $\Pi^*(q)$, one can obtain the demand and supply functions immediately by Equations (2.5) and (2.6), i.e., as functions of q above. Equation (2.6) also generalizes to the case of multiple variable inputs as

$$V(q) = \Pi^*(q) - \sum_{i=1}^{m} q_i \frac{\partial \Pi^*(q)}{\partial q_i}. \tag{2.7}$$

TEST OF PROFIT MAXIMIZATION

The normalized profit function is useful not only in the modeling of profit-maximizing farms. It also provides an analytical framework within which the hypothesis of profit maximization can be tested statistically. This idea is illustrated again with reference to the one-output, one-variable-input case. Suppose that the normalized profit and the input demand of a farm are observed at different normalized prices and that the normalized profit function takes the form

$$\Pi^*(q) = Aq^{\alpha}, \quad \alpha < 0. \tag{2.8}$$

Then demand is given by Equation (2.5) as

$$D(q) = -\frac{d\Pi^*}{dq} = -A\alpha q^{(\alpha-1)},$$

which implies that

$$-q\frac{D(q)}{\Pi^*} = \alpha \quad . \tag{2.9}$$

By taking natural logarithms of Equation (2.8),

$$ln\, \Pi^* = ln\, A + \alpha\, ln\, q. \tag{2.10}$$

Equations (2.9) and (2.10) form a pair. Given observations of normalized profits and input demands at different normalized prices, one can estimate the parameters of these equations. But there are two possible estimates for α, one from Equation (2.9), the factor demand function, and one from Equation (2.10), the normalized profit function. For any particular sample of observations the two estimates are not necessarily identical. However, if indeed the farm maximizes profit, then the parameter α in the two equations must be identical. Thus, the hypothesis of profit maximization can be tested statistically.

More generally, let the normalized profit function be

$$\Pi^*(q) = G(q), \tag{2.11}$$

where $G(q)$ is nonnegative, monotonically decreasing, and convex in q. Then the input demand function is given by

$$D(q) = -\frac{dG(q)}{dq} \tag{2.12}$$

Since $D(q)$ is minus the derivative of $G(q)$, its parameters must be a subset of the parameters of $\Pi^*(q)$, which is equal to $G(q)$. Again, given an algebraic form for $G(q)$ and observations of normalized profits and input demands at different normalized prices, one can estimate the parameters of $G(q)$. A subset of such parameters will appear in both Equations (2.11) and (2.12) and hence can be estimated in two different ways—one from Equation (2.11) and the other from Equation (2.12). If indeed the farm maximizes profit, then the two estimates should coincide. This then provides the basis for a test of the hypothesis of profit maximization in general. The same consideration for the multiple-variable-input case leads to an analogous conclusion, with $\Pi^*(q) = G(q)$, and

$$D_i(q) = -\frac{\partial G(q)}{\partial q_i}, \quad i = 1, \ldots, m.$$

TECHNICAL EFFICIENCY

The normalized profit function can be used also for the purpose of measurinq economic efficiency. As suggested in Chapter 1, two components of economic efficiency are distinguished: technical efficiency and price efficiency.

Technical efficiency is considered in terms of differences between farms in the levels of technology incorporated in their respective normalized profit functions. The differences in the technological levels are assumed to be neutral. The production functions of the two farms are then given by $V_1 = A_1F(X)$; $V_2 = A_2F(X)$, where the only difference lies in the scalar factor A_i.

The normalized profit functions of the two farms are given respectively by

$$\Pi_i^*(q) = \underset{X}{\text{Max}} \; \{A_iF(X) - qX\}, i = 1, 2.$$

Let $G(q) \equiv \max_{X} \{F(X) - qX\}$, that is, the normalized profit function of a farm with a production function $V = F(X)$. Then it follows that the normalized profit function of a farm with a production function $V = A_i F(X)$ is given by

$$\Pi_i^*(q) = A_i \max_{X} \left\{F(X) - \frac{q}{A_i} X\right\}. \tag{2.13}$$

But $\max_{X} \left\{F(X) - \frac{q}{A_i} X\right\}$ is precisely the same as the maximized normalized profit of a farm with production function $V = F(X)$ and facing normalized price equal to $\frac{q}{A_i}$, that is, $G\left(\frac{q}{A_i}\right)$. Thus, $\Pi_i^*(q) = A_i \overset{G}{\cancel{F}}\left(\frac{q}{A_i}\right), i = 1, 2.$

What is the effect of changes in the level of technology on the normalized profit function? It may be noted that

$$\frac{d\Pi_i^*(q)}{dA_i} = G(q/A_i) - \frac{q}{A_i}\frac{dG}{dq}(q/A_i).$$

Since A_i is nonnegative, $G(q)$ is nonnegative and monotonically decreasing, the effect of an increase in the technological level parameter is to increase normalized profit. It may be concluded that the farm with a higher technological level parameter will have a higher normalized profit function, that is, will have higher normalized profit for all possible normalized prices. This farm may be said to be dominant from the point of view of technical efficiency.

PRICE EFFICIENCY

Farms may, however, fail to maximize profit perfectly. A farm is said to be *price-efficient* if it maximizes profit, that is, equates its marginal product of every variable input to its corresponding opportunity cost. A farm which fails to do so is said to be *price-inefficient*. The normalized profit function can also be used to assess relative price efficiency.

Again let there be two farms whose production functions are identical up to a multiplicative technological level parameter. Instead of equating the marginal product of the variable input to the normalized price of that input, it is assumed that each of the farms equates the marginal product to a constant, not necessarily equal to one, times the normalized price, that is,

$$\frac{dV_1}{dX_1} = A_1 \frac{dF(X_1)}{dX_1} = k_1 q; \frac{dV_2}{dX_2} = A_2 \frac{dF(X_2)}{dX_2} = k_2 q. \tag{2.14}$$

The parameters k_1 and k_2 will be referred to as price efficiency parameters. Under profit maximization

$$k_1 = k_2 = 1. \tag{2.15}$$

From Equation (2.13) one can solve for the demand functions of the variable inputs of the two firms under mild regularity conditions. In particular, since the production functions are identical up to a constant multiplicative technological-level parameter, the marginal conditions are given by

$$\frac{dF(X_1)}{dX} = \frac{k_1 q}{A_1}; \frac{dF(X_2)}{dX} = \frac{k_2 q}{A_2},$$

which implies that farms one and two equate the marginal product of the variable input to $\frac{k_1 q}{A_1}$ and $\frac{k_2 q}{A_2}$, respectively. Farms one and two act as if they maximize profit, taking as given $\frac{k_1 q}{A_1}$ and $\frac{k_2 q}{A_2}$ as their respective normalized prices. Let $D(q)$ be the demand function of a profit-maximizing farm with production function $F(X)$ and facing normalized price q, then the demand functions for the variable inputs for farms one and two are given by

$$D_1(q) = D(k_1 q/A_1); D_2(q) = D(k_2 q/A_2). \tag{2.16}$$

It is possible that $k_1/A_1 = k_2/A_2$, in which case the demand functions of the two farms will be identical, but that will be purely fortuitous. In Equation (2.5), $D(q) = -\frac{d\Pi^*(q)}{dq} = -\frac{dG(q)}{dq}$, where $G(q)$ is the normalized profit function corresponding to the production function, $V = F(X)$.

The output supply function for a profit-maximizing farm with a normalized profit function $\Pi^*(q)$ is given in Equation (2.6) as function of q. The output supply functions of two farms with different levels of technical and price efficiency, as in (2.15), may be written as

$$V_1(q) = A_1 F(X_1^*) \qquad V_2(q) = A_2 F(X_2^*)$$
$$= A_1 F(D(k_1 q/A_1)); \qquad = A_2 F(D(k_2 q/A_1)).$$

where X_1^* and X_2^* are the quantities of the variable input employed at normalized price q by farms one and two, respectively. But, by definition, from Equation (2.6),

$$F(D(q)) = \Pi^*(q) - q\frac{d\Pi^*}{dq}(q).$$

Thus

$$F(D(k_i q/A_i)) = \Pi^*(k_i q/A_i) - \frac{k_i q}{A_i}\frac{d\Pi^*}{dq}(k_i q/A_i), \quad i = 1, 2.$$

which leads to

$$V_i(q) = A_i \Pi^*(k_i q/A_i) - k_i q\frac{d\Pi^*}{dq}(k_i q/A_i), \quad i = 1, 2. \tag{2.17}$$

Actual normalized profit is given by

$$\begin{aligned}\Pi_i^*(q) &= V_i(q) - qD_i(q) \qquad (2.18)\\ &= A_i\Pi^*(k_iq/A_i) - k_iq\frac{d\Pi^*}{dq}(k_iq/A_i) + q\frac{d\Pi^*}{dq}(k_iq/A_i)\\ &= A_i\Pi^*(k_iq/A_i) + (1-k_i)q\frac{d\Pi^*}{dq}(k_iq/A_i), i = 1,2.\end{aligned}$$

Note that this, in general, is not equal to $A_i\Pi^*(k_iq/A_i)$.

If $k_i = 1$, that is, the i^{th} farm is price-efficient, then actual normalized profit becomes $\Pi_i^*(q) = A_i\Pi^*(q/A_i)$ as before.

What is the effect of changes in the level of technology on the actual normalized profit function? Differentiating Equation (2.18) with respect to A_i,

$$\begin{aligned}\frac{d\Pi_i^*(q)}{dA_i} &= \Pi^*(k_iq/A_i) - \frac{d\Pi^*}{dq}(k_iq/A_i)\frac{k_iq}{A_i}\\ &\quad - (1-k_i)q\frac{d^2\Pi^*}{dq^2}(k_iq/A_i)\frac{k_iq}{A_i^2},\end{aligned}$$

which by Equation (2.17) may be rewritten as

$$= V_i(q)/A_i - (1-k_i)q\frac{d^2\Pi^*}{dq^2}(k_iq/A_i)\frac{k_iq}{A_i^2},$$

which is indefinite in sign. However, if $k_i \geqq 1$, then an increase in the level of technology increases the actual normalized profit function.

If the additional assumption is made that $\Pi^*(q)$ has the form $\Pi^*(q) = q^\alpha$, $\alpha < 0$, then the demand functions may be derived as

$$\begin{aligned}D_i(q) &= -\frac{d\Pi^*}{dq}(k_iq/A_i)\\ &= -\alpha\left(\frac{k_iq}{A_i}\right)^{\alpha-1}, \quad i = 1,2.\end{aligned}$$

where $\frac{d\Pi^*}{dq}(\cdot)$ is to be understood as the first derivative function of $\Pi^*(\ )$.

The actual normalized profit functions may be derived as

$$\begin{aligned}\Pi_i^*(q) &= A_i\left(\frac{k_i q}{A_i}\right)^{\alpha} + (1 - k_i)\alpha q\left(\frac{k_i q}{A_i}\right)^{\alpha - 1}\\ &= \left[A_i \frac{k_i^{\alpha}}{A_i^{\alpha}} + (1 - k_i)\frac{k_i^{\alpha - 1}\alpha}{A_i^{\alpha - 1}}\right] q^{\alpha}\\ &= \left(\frac{k_i}{A_i}\right)^{\alpha - 1}[k_i + (1 - k_i)\alpha]q^{\alpha}\\ &\equiv A_i^* q^{\alpha}, \quad i = 1, 2,\end{aligned}$$

and, finally, the ratio of expenditure on the variable input to profit as

$$\frac{qD_i(q)}{\Pi_i^*(q)} = \frac{-\alpha}{[k_i + (1 - k_i)\alpha]} \equiv -\alpha_i^*, \quad i = 1, 2.$$

By combining these results, one obtains

$$\ln \Pi_i^*(q) = \ln A_i^* + \alpha \ln q, \tag{2.19}$$

and

$$-\frac{qD_i(q)}{\Pi_i^*(q)} = \alpha_i^*, \quad i = 1, 2. \tag{2.20}$$

Observe that $A_1^* = A_2^*$ implies equal relative economic efficiency. $A_1 = A_2$ and $k_1 = k_2$ if and only if $A_1^* = A_2^*$ and $\alpha_1^* = \alpha_2^* \cdot k_i = 1$, that is, perfect price efficiency obtains, if and only if $\alpha_i^* = \alpha$. These results and their analogs for the multiple-variable-inputs case then form the basis of the tests of relative efficiency between two farms.

THE CASE OF THE COBB-DOUGLAS PRODUCTION FUNCTION

In the empirical applications several variable inputs and fixed inputs are distinguished. The production function is assumed to be Cobb-Douglas in form,

$$V = A \prod_{i=1}^{m} X_i^{\alpha_i} \prod_{j=1}^{n} Z_j^{\beta_j},$$

where $\alpha_i > 0, \beta_j > 0, \forall, i, j$, and $\sum_{i=1}^{m} \alpha_i < 1$; and where the X_i's are the quantities of the variable inputs and the Z_j's are the quantities of the fixed inputs.

As Lau (1978) has shown, the normalized restricted profit function corresponding to the Cobb-Douglas production function takes the form

$$\Pi^*(q, Z) = G(q, Z) = V^* - \sum_{i=1}^{m} q_i X_i^* \tag{2.21}$$

$$= A^{(1-\mu)^{-1}}(1 - \mu) \prod_{i=1}^{m} \left(\frac{q_i}{\alpha_i}\right)^{-\frac{\alpha_i}{(1-\mu)}} \prod_{j=1}^{n} Z_j^{\frac{\beta_j}{(1-\mu)}},$$

where q is the vector of normalized prices of the variable inputs and Z is the vector of the quantities of the fixed inputs, and $\mu \equiv \sum_i \alpha_i$.

Given the functional form of $G(q, Z)$, one can derive the actual normalized profit functions and the demand functions for a farm with technical efficiency parameter A_i and vector of price efficiency parameter k_i as

$$\Pi_i^{*a} = A_i^{(1-\mu)^{-1}} \left(1 - \sum_{j=1}^{m} \alpha_j / k_{ij}\right) \left[\prod_{j=1}^{m} k_{ij}^{-\alpha_j(1-\mu)^{-1}}\right] \left[\prod_{j=1}^{m} \alpha_j^{\alpha_j(1-\mu)^{-1}}\right]$$

$$\left[\prod_{j=1}^{m} q_{ij}^{-\alpha_j(1-\mu)^{-1}}\right] \left[\prod_{j=1}^{n} Z_{ij}^{\beta_j(1-\mu)^{-1}}\right], \quad i = 1, 2, \tag{2.22}$$

$$X_{ij} = A_i^{(1-\mu)^{-1}} (\alpha_j / k_{ij} q_{ij}) \left[\prod_{j=1}^{m} k_{ij}^{-\alpha_j(1-\mu)^{-1}}\right] \left[\prod_{j=1}^{m} \alpha_j^{\alpha_j(1-\mu)^{-1}}\right]$$

$$\left[\prod_{j=1}^{m} q_{ij}^{-\alpha_j(1-\mu)^{-1}}\right] \left[\prod_{j=1}^{n} Z_{ij}^{\beta_j(1-\mu)^{-1}}\right], \quad i = 1, 2; j = 1, \ldots, m. \tag{2.23}$$

From these two equations, one can derive the factor share functions

$$\frac{q_{ij} X_{ij}}{\Pi_i^{*a}} = \frac{\alpha_j / k_{ij}}{\left(1 - \sum_{j=1}^{m} \alpha_j / k_{ij}\right)}, \quad i = 1, 2; j = 1, \ldots, m, \tag{2.24}$$

so that the ratio of expenditure on the j^{th} input to the actual restricted profit is a constant. Moreover, this constant depends only on the vector of price efficiency parameters k_i and the elasticities of production of the variable inputs (and in particular is independent of A_i).

Taking natural logarithms of the actual normalized restricted profit function,

$$\ln \Pi_i^{*a} = \ln A_i^* + \sum_{j=1}^{m} \alpha_j^* \ln q_{ij} + \sum_{j=1}^{n} \beta_j^* \ln Z_{ij} \tag{2.25}$$

where

$$
\begin{aligned}
\ln A_i^* &= (1-\mu)^{-1}\ln A_i + \ln\left(1-\sum_{j=1}^{m}\alpha_j/k_{ij}\right) \\
&\quad - \sum_{j=1}^{m}\alpha_j(1-\mu)^{-1}\ln k_{ij} + \sum_{j=1}^{m}\alpha_j(1-\mu)^{-1}\ln \alpha_j, \\
\alpha_j^* &\equiv -\alpha_j(1-\mu)^{-1}, j = 1,\ldots,m, \\
\beta_j^* &\equiv \beta_j(1-\mu)^{-1}, j = 1,\ldots,m,
\end{aligned}
$$

so that the actual normalized restricted profit function of two farms differ only by a multiplicative constant A_i^*. The i^{th} farm is said to be relatively more efficient than the j^{th} farm if the i^{th} actual normalized restricted profit function is greater than the j^{th} actual normalized restricted profit function. In the present Cobb-Douglas case, this implies $A_i^* > A_j^*$, which is also sufficient for the i^{th} farm to be globally (for all normalized prices and fixed inputs) relatively more efficient than the j^{th} farm. It may be noted further that for the Cobb-Douglas case, $\partial\Pi_i^{*\alpha}/\partial A_i > 0$, $\forall\, i$, so that an increase in the technological level of the i^{th} farm always increases the actual normalized restricted profit function of the i^{th} farm.

The ratio of expenditures on the j^{th} input to profits may be written as

$$
-\frac{q_{ij}X_{ij}}{\Pi_i^{*\alpha}} \equiv \alpha_{ij}^{**}, \quad i = 1, 2; j = 1, \ldots, m, \tag{2.26}
$$

where

$$
\alpha_{ij}^{**} \equiv \frac{-\alpha_j/k_{ij}}{\left(1-\sum_{i=1}^{m}\alpha_i/k_{ij}\right)}, \quad i = 1, 2; j = 1, \ldots, m.
$$

It may then be observed, that, first, two farms are equally price (in)efficient $(k_1 = k_2)$ if and only if $\alpha_{1j}^{**} = \alpha_{2j}^{**}, j = 1, \ldots, m$; second, a farm is price efficient $(k_i = 1)$ if and only if $\alpha_{ij}^{**} = \alpha_j^*, j = 1, \ldots, m$; third, two farms are of equal relative economic efficiency if and only if $\ln A_1^* = \ln A_2^*$; and, finally, two farms are equal in technical efficiency and in price efficiency if and only if $\ln A_1^* = \ln A_2^*$ and $\alpha_{1j}^{**} = \alpha_{2j}^{**}, j = 1, \ldots, m$. These last four observations form the basis of the empirical tests of relative efficiency between different sets of firms.

Finally, if $\ln A_1^*$ is greater than $\ln A_2^*$ then the marginal product of the actual normalized restricted profit function with respect to the k^{th} fixed input will be greater in the first farm than in the second farm, holdinq the normalized prices and the fixed inputs constant. To the extent that the latter variables are different, the marginal products, or quasi-rents, will be different. By the Shephard-Hotelling Lemma, the marginal product of the profit function with respect to the k^{th} fixed input is precisely the marginal product of the production function with respect to the k^{th} fixed input. One may therefore obtain a comparison of the marginal products of the fixed inputs by comparing the partial derivatives of the actual normalized restricted profit functions with respect to the fixed inputs. Such a comparison may have important implications on the relative desirability of alternative distributions of the fixed inputs among the farms.

COMPUTATION OF THE INDIRECT ESTIMATES OF THE PRODUCTION-FUNCTION PARAMETERS

Given the parameter estimates of the actual normalized restricted profit function, α_j^*, $(j = 1, \dots, m)$ and β_j^*. 1, $(j = 1, \dots, n)$, one can compute the implicit estimates of the parameters of the production function through the identities

$$\alpha_j^* = -\alpha_j(1 - \mu)^{-1}, j = 1, \dots, m,$$
$$\beta_j^* = \beta_j(1 - \mu)^{-1}, j = 1, \dots, n,$$

where

$$\mu \equiv \sum_{j=1}^{m} \alpha_j.$$

Summing the first identity across the variable inputs, one obtains:

$$\sum_{j=1}^{m} \alpha_j^* = -\mu(1 - \mu)^{-1}.$$

Let

$$\mu^* \equiv \sum_{j=1}^{m} \alpha_j^*,$$

then

$$\mu^* = -\mu(1 - \mu)^{-1},$$

which leads to

$$(1 - \mu)\mu^* = -\mu,$$

or

$$\mu = -\mu^*(1 - \mu^*)^{-1}, \quad (1 - \mu) = (1 - \mu^*)^{-1}.$$

Thus

$$\alpha_j = -\alpha_j^*(1 - \mu^*)^{-1}, \quad j = 1, \dots, m, \tag{2.27}$$
$$\beta_j = \beta_j^*(1 - \mu^*)^{-1}, \quad j = 1, \dots, n. \tag{2.28}$$

Since $(1 - \mu) > 0$, by local strong concavity, and $\mu > 0$ by monotonicity, the value $(1 - \mu^*)$ lies strictly between zero and one. It follows that the value of $(1 - \mu^*)$ must be strictly greater than one, or that μ^* must be strictly negative. Further the production elasticities α_j and β_j are always smaller in magnitude than the corresponding profit elasticities with respect to the normalized prices, α_j^*'s and the fixed inputs, β_j^*'s.

These implicit estimates of the production-function parameters computed from the estimates of the profit-function parameters are referred to as indirect estimates to distinguish them from the direct estimates obtained from the direct estimation of the production function. The indirect estimates are consistent only if the estimator of the profit-function parameters is consistent.

THE APPLICATION OF THE METHODOLOGY

The chapters that follow are devoted to the analysis of production in specific countries under the hypothesis that the production function and hence the normalized restricted profit function is Cobb-Douglas in form. The basic estimating equations are therefore Equation (2.24), the actual normalized restricted profit function, and Equation (2.25), the factor-share functions. Comparison of the values of the estimated coefficients from these two equations, as noted above, constitutes the test of profit maximization. It also throws light on economic efficiency and its components, technical and price efficiency, and relative efficiency between groups of farms.

Given the estimates of the normalized restricted profit function and the factor-share functions, the own- and cross-price elasticities for the output supply (from Equation (2.16)) and factor demands (from Equation (2.22)) or its transform (2.23) may be computed. Finally, the indirect estimates of the production-function elasticities may be derived by applying Equations (2.26) and (2.27).

CHAPTER III.

EFFICIENCY AND TECHNOLOGICAL CHANGE IN TAIWAN'S AGRICULTURE

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This chapter applies the profit-function methodology to cross-sectional data on farm households in Taiwan. The existence of two successive cross-sections of data allows the extension of the basic framework in this volume to include a test of the stability of the estimated production-function parameters across 1967 and 1968. If in fact the parameters estimated from one year's data do not differ significantly from the parameters estimated from another year's data, more confidence can be placed in the methodology and its results.

THE MODEL

The Cobb-Douglas normalized restricted profit function with four variable inputs—labor, mechanical input, animal input, and fertilizer—and two fixed inputs—land and capital assets—is written as

$$\begin{aligned} ln\,\Pi^* = {} & ln\,A^* + \alpha_L^*\,ln\,q_L + \alpha_A^*\,ln\,q_A + \alpha_M^*\,ln\,q_M + \alpha_F^*\,ln\,q_F \\ & + \beta_K^*\,ln\,Y_K + \beta_T^*\,ln\,Y_T + \sum_{i=1}^{7} \delta_i D_i, \end{aligned} \qquad (3.1)$$

where Π^* is restricted profit (current revenue less current variable costs) per farm normalized by the price of output; q_L is the money wage per day normalized by the price of output; q_A is the money animal-input-price per day normalized by the price of output; q_M is the money mechanical-input-price per hour normalized by the price of output; q_F is the money price of fertilizer per kilogram normalized by the price of output; Y_K is the quantity of fixed farm assets, in New Taiwan dollars;[1] Y_T is the farm area in hectares; and D_i's are dummy variables corresponding to agricultural regions.

The demand for each variable factor of production is given by

$$X_i = \frac{-\partial\Pi}{\partial q_i}, \quad i = L, A, M, F,$$

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[1] The exchange rate for the year of the study was NT$40 to US$1.

Food Research Studies, Vol. XVII, No. 1, 1979

which implies the following factor-share functions:

$$\frac{-q_L X_L}{\Pi^*} = \alpha_L^* \tag{3.2}$$

$$\frac{-q_A X_A}{\Pi^*} = \alpha_A^* \tag{3.3}$$

$$\frac{-q_M X_M}{\Pi^*} = \alpha_M^* \tag{3.4}$$

$$\frac{-q_F X_F}{\Pi^*} = \alpha_F^*, \tag{3.5}$$

where X_L is total labor days; X_A is total animal input in days; X_M is total hours of mechanical input; and X_F is total quantity of fertilizer in kilograms.

From the definition of normalized profit the output supply function is obtained:

$$V = \Pi^*(q_i, Y_i) - \sum_{i=1}^{4} \frac{\partial \Pi^*(q_i, Y_i)}{\partial q_i} q_i. \tag{3.6}$$

Given any five of the Equations (3.1) through (3.6), the sixth may be derived from the normalized profits identity, $\Pi^* = V + \sum_{i=1}^{4} q_i X_i$. Hence, without loss of generality, one of the six equations may be dropped. One concentrates therefore on Equations (3.1) to (3.5).

Estimates of all the parameters can be obtained from Equation (3.1). Alternatively, the parameters of the variable factors of production may be estimated by fitting Equations (3.2) to (3.5). However, the four parameters associated with the variable factors appear both in Equation (3.1) and in the set of Equations (3.2) to (3.5). Under the hypothesis of profit-maximizing and price-taking behavior on the part of the farms, the parameters in Equations (3.2) through (3.5) must be equal to the corresponding parameters in Equation (3.1). This equality provides the basis for a test of the hypothesis of profit maximization. Alternatively, it may be desirable to maintain the hypothesis of profit maximization as part of the specification. In that case, the efficiency of the estimators of the parameters may be increased by imposing the constraints implied by profit maximization, namely, that the α_i^*'s in the factor-share functions and in the normalized profit functions are equal. In this study, the hypothesis of profit maximization is tested explicitly. If the hypothesis of profit maximization is not rejected, two subsidiary hypotheses are then tested conditionally: constant returns to scale in production and stability of parameters.

Constant returns to scale implies that $\beta_K^* + \beta_T^* = 1$. Stability of parameters implies that the estimated parameters of the normalized profit function are not significantly different between the 1967 and the 1968 cross sections. To test the hypothesis of stability of parameters, a generalization of the Chow test is employed (Chow, 1960).[2]

Before proceeding to a discussion of statistical methods and the presentation of the empirical results, a brief description of the Taiwan data is in order.

THE DATA

Many of the data for this research were derived from official sources of the Government of Taiwan.[3] More specific information about the construction of variables appears in the Appendix to this chapter.

The basic data source provides information on household averages of about 400 farm households grouped according to five sizes of operation (from below 0.5 hectares to 2.0 hectares and above by 0.5 hectare steps) and eight agricultural regions. The number of observations available, therefore, is about 40 for each year.

The first task is to determine the expenditures on and the prices of the variable factors of production. The quantity of labor and the wage rate are computed directly from the *Report of Farm Record-Keeping Families in Taiwan* (Provincial Government of Taiwan, 1967-68a). Family labor is valued, on the margin, at the same rate as hired-in or hired-out labor. Labor input is measured in terms of homogenized 10-hour labor-days. The wage rate is measured in New Taiwan dollars per labor-day.

The quantities of animal input and mechanical input are also obtained from the *Report*. The former is measured in days and the latter in hours. The corresponding animal input and mechanical input prices are computed from subsidiary sources. The *Report* gives fertilizer expenses in cash and in kind. The computation of fertilizer price is complex and is detailed in the Appendix. On the assumption that cash expenditures refer to chemical fertilizers and the in-kind expenditures to organic fertilizers, a geometrically weighted average of overall fertilizer price is constructed for each observation in the sample by using weights from each observation and price data from subsidiary sources.

The second task is to obtain a measurement of the price of output and hence normalized profits and prices. The *Report* reports only the price of rice, and not the prices of the other outputs. Hence it is necessary to construct an output price index for each observation taking into account the differential composition of output using subsidiary data at the *hsien* (county) level. Such an output price index is constructed as the geometrically weighted average of the prices of the different kinds of outputs at the level of the agricultural regions using the value

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[2] The Chow test is not directly applicable because there are five stochastic equations in each period and the errors are not assumed to be homoscedastic.

[3] The main source is Provincial Government of Taiwan (1967-68b), Department of Agriculture and Forestry, *Report of Farm Record-Keeping Families in Taiwan*, *1967 and 1968*, Taipei. This source was supplemented with data from Provincial Government of Taiwan (1967-68a), Department of Agriculture and Forestry, *A Report on Cost Survey of Agricultural Products*, *1967 and 1968*, Taipei and Provincial Government of Taiwan (1967-68c), *Taiwan Agriculture Yearbook*, *1967 and 1968*, Taipei.

shares of the respective outputs at the level of the farm size and regional groups as weights. The average total values of output and the expenditures on production are available for each farm size and regional group. Given the price index of agricultural output derived as above, the normalized profits may be derived for each observation by subtracting from total normalized revenue the total normalized expenditures on each of the variable factors of production—labor, animal input, mechanical input, and fertilizer.

The final task is to obtain measurements of the quantities of fixed factors of production—fixed assets and land. Fixed farm assets are reported in New Taiwan dollars and include investment in plant and live capital. From these two components it is possible to estimate the value of plant and other improvements used for consumption purposes (including, for example, the proportion of plant used for residential purposes) and the value of live capital represented as a variable input in this analysis in terms of animal labor. The remainder of plant and live capital constitutes the fixed input component of farm assets. Cultivated land is reported separately for paddy land and dry land in hectares. All land area is homogenized into paddy-land equivalent by scaling the dry land by the ratio of dry-land yields to paddy-land yields.

STATISTICAL METHOD

Given the assumptions of profit-maximizing and price-taking behavior on the part of the farm households, the local strong concavity of the production functions in the variable inputs and the short run fixity of the quantities of fixed assets and land, the farm's decision variables are the quantity of output and the quantities of the four variable inputs—labor, animal input, mechanical input, and fertilizer. The price of output and the prices of the variable inputs as well as the quantities of the fixed inputs are predetermined and not subject to change by the action of any one farm in the short run. Consequently, output, labor, animal input, mechanical input, and fertilizer are jointly dependent variables, and the prices of output and variable inputs and the quantities of fixed inputs are the predetermined variables in the model. Because of the profit identity, namely, that profit is equal to current revenue less current variable costs, an alternative set of five jointly dependent variables consists of profits and expenditures on each of the four variable factors of production. It is clear that, given the predetermined variables, there is a one-to-one correspondence between profits and expenditures on each variable factor of production, and the quantities of output and of each of the variable factors of production. Thus, in Equations (3.1) and (3.2) to (3.5), the variables on the left-hand side are the jointly dependent variables and those on the right-hand side include only the predetermined variables.

Under these conditions, ordinary least squares applied to each of the Equations (3.1) to (3.5) separately will be consistent. However, these estimates in general will be inefficient because the restriction that the same α_i^* appears in Equation (3.1) and in one of the Equations (3.2) to (3.5) has not been taken into account. A natural and more efficient approach is to estimate Equations (3.1) and (3.2) to (3.5) jointly, imposing the condition that the two estimates of each α_i^* are equal.

Alternatively the test of equality may be used to validate or refute the hypothesis of profit maximization.

Little is known about how stochastic disturbance terms in general should be introduced into economic relationships, although Hoch (1958), Mundlak and Hoch (1965), and subsequently Zellner, Kmenta, and Drèze (1966) have proposed one assumption that is compatible with the Cobb-Douglas case. Here, an additive error with zero expectation and finite variance is assumed for each of the Equations (3.1) and (3.2) to (3.5). Nerlove, in his pioneering study of cost functions, derives an additive error to the natural logarithm of the cost function (1960). The same can be done here for the profit function, using similar assumptions—namely, that farms maximize profits subject to unknown exogenous disturbances. The additive error in the factor-share equations may arise from differential abilities to maximize profits or divergence between expected and realized prices. A similar stochastic specification is employed by Arrow, Chenery, Minhas, and Solow in their equation for estimating the elasticity of substitution (1961). Here it is assumed that for the same farm the covariance of the errors of any two of the five equations is permitted to be non-zero. However, the covariances of the errors of any two equations corresponding to different farms are assumed to be identically zero. Given this specification of errors, Zellner's (1962) method of imposing known constraints on the coefficients in the equations provides an asymptotically efficient method of estimation, and this is the method employed here .

EMPIRICAL RESULTS

Tests of Profit Maximization and Constant Returns

To test the validity of the restrictions implied by the hypotheses of profit maximization—constant returns and stability of parameters—test statistics based on F-ratios are employed. These hypotheses do not form a nested sequence. In order to control the overall level of significance of this series of tests, that is, to control the probability of falsely rejecting one of this series of tests, it is necessary to reduce the level of significance assigned to each individual test. To illustrate this idea, suppose there are two hypotheses of interest. Moreover, suppose the test statistics corresponding to the two hypotheses are independently distributed. Let the level of significance of each individual test be set at α. Then the probability of falsely rejecting each individual hypothesis when it is true is α. The probability of falsely rejecting one of the two hypotheses when both are true, however, is given by: $1-(1-\alpha)(1-\alpha) \simeq 2\alpha$, for small α, where $(1-\alpha)$ is by definition the probability of accepting the individual hypothesis when it is true, and $(1-\alpha)(1-\alpha)$ is the probability of accepting both hypotheses when both are true. A similar result holds even in the case where the test statistics are not independently distributed.

If the number of hypotheses of interest is large, then it is clear from the above consideration that the probability of falsely rejecting one of a series of tests is going to become quite substantial. One way to avoid this type of error is to select an overall level of significance for the whole series of tests and then allocate the levels of significance among the individual tests. It turns out that the true overall level of significance is bounded by the sum of levels of significance assigned to the individual tests, that is, $\alpha \leq \Sigma_i \alpha_i$. Thus, if $\Sigma_i \alpha_i$ is fixed ab initio, it provides an upper bound for the true overall level of significance regardless of whether the test statistics are independently distributed and how the levels of significance are allocated amongst the individual tests.

Thus, to control the overall level of significance of this series of tests, the overall level of significance is set at .05. This implies that the probability of rejecting a true hypothesis in the series of tests is at most .05. A level of significance of .01 is first assigned each to the test of the equality restriction implied by profit maximization in 1967 and 1968, respectively. A level of significance of .03 is then assigned to the tests on the structure of the technology, that is, the test of constant returns to scale in 1967 and 1968 and the test of stability of parameters, all conditional on the validity of the hypothesis of profit maximization. These two sets of tests are "nested" under the null hypothesis that the sum of levels of significance of the two sets of tests provides a close approximation to the level of significance for both sets of tests simultaneously. A level of significance of .01 is assigned to each of the three hypotheses of constant returns in 1967, constant returns in 1968, and stability of parameters. The test procedure is presented schematically in Chart 1.

The first hypothesis to be tested is that of profit maximization. Operationally, this implies testing the null hypothesis to determine that the α_i^*'s from the normalized profit and factor share equations are indeed equal:

$$\begin{aligned} H_O:\ & \alpha_L^* = \alpha_L^* \text{ and} \\ & \alpha_A^* = \alpha_A^* \text{ and} \\ & \alpha_M^* = \alpha_M^* \text{ and} \\ & \alpha_F^* = \alpha_F^*, \end{aligned}$$

separately for 1967 and 1968.

Conditional on the validity of the equality hypothesis, the hypothesis of constant returns to scale is tested, that is,

$$H_O:\ \beta_K^* + \beta_T^* = 1,$$

again separately for 1967 and 1968.

The test statistics are presented in Table 3.1. At a level of significance of .01 each, the hypothesis cannot be rejected that the restrictions implied by profit maximization are valid for 1967 and 1968. Proceeding conditionally on the validity of the hypothesis of profit maximization at a level of significance of .01, the hypothesis of constant returns to scale cannot be rejected either. Critical values for the test statistics for levels of significance equal to .01 and .05 are also presented in Table 3.1 so that the reader may evaluate the results of the tests for alternative allocations of the overall levels of significance among stages of the test procedure. Thus, the empirical evidence provides support for price efficiency of Taiwan farmers. In addition, it also provides support for the hypothesis of constant returns to scale.

CHART 1.—TEST PROCEDURE

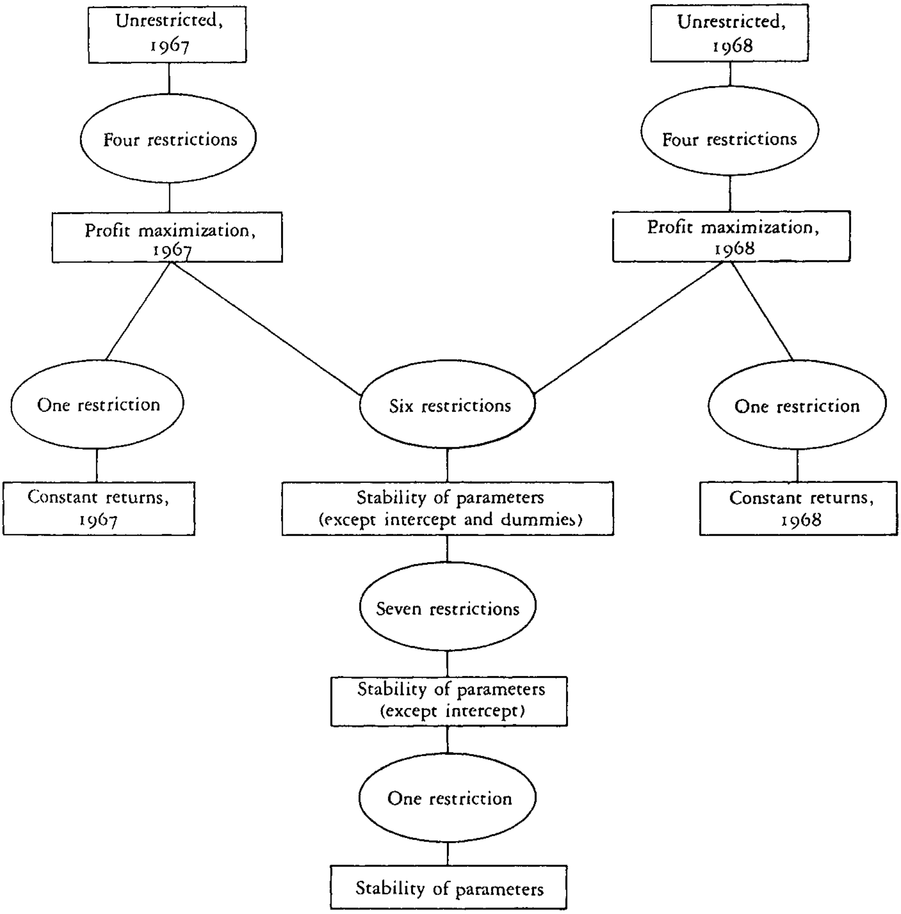

TABLE 3.1.—F-RATIOS FOR TESTS OF PROFIT MAXIMIZATION AND CONSTANT RETURNS TO SCALE, 1967 and 1968

Year	Degrees of freedom	Profit maximization restrictions[a]	Constant returns to scale restrictions[b]	Critical values of F-ratios, levels of significance 0.01	0.05
1967	4,177	2.075		3.42	2.42
	1,181		0.302	6.77	3.90
1968	4,182	1.790		3.42	2.42
	1,186		0.712	6.77	3.90

[a] There are four restrictions implied by the hypothesis of profit maximization, $\alpha_L^* = \alpha_L^*$, $\alpha_A^* = \alpha_A^*$ and $\alpha_M^* = \alpha_M^*$, $\alpha_F^* = \alpha_F^*$.

[b] The hypothesis of constant returns to scale is conditional on profit maximization; it implies one restriction, $\beta_K^* + \beta_T^* = 1$.

Parameter Estimates, 1967 and 1968

The parameter estimates for 1967 and 1968 are presented separately in Tables 3.2 and 3.3. In the first column the coefficients estimated from ordinary least-squares applied equation by equation are reported. These estimators are consistent, but inefficient, under the stochastic specification. In the second column the coefficients estimated from Zellner's method (1962) without restrictions are presented. These estimators are more efficient than the single-equation ordinary least-square estimators. Their efficiency, however, may be further improved, if the hypothesis of profit maximization is maintained by imposing the linear constraints implied by profit maximization. In the third column such restricted estimates are given. Finally, in the fourth column coefficients estimated from Zellner's method imposing the linear constraints implied by profit maximization and constant returns to scale are reported. On the basis of these results, which signify that the observed data are consistent with profit maximization and constant returns to scale, the estimates reported in the fourth column are adopted as the final set of estimates for further analysis. The coefficient estimates of the normalized profit function reported in the fourth column satisfy the additional conditions of monotonicity (decreasing) and convexity of the normalized profit function in the normalized prices and monotonicity (increasing) and quasiconcavity in the quantities of the fixed factors. These conditions must be satisfied by a normalized restricted profit function if restricted profit is truly maximized (Lau, 1978).

Tests of Stability of Parameters

Since two cross sections are available for 1967 and 1968, it was decided to test for the stability of parameters, that is, whether the parameters of the normalized restricted profit function are the same in 1967 and 1968. This test is of economic interest not so much because of the possibility of technical progress, since the two years are consecutive, but because the stability of the parameters of the normalized restricted profit function estimated from cross sectional data would add confidence in the procedure.

To test the hypothesis of stability of parameters, test statistics based on F-ratios are employed. These test statistics are derived in a manner similar to that of the Chow test (1960) for structural change. They essentially generalize the Chow test to the case in which there is more than one stochastic equation and the variance-covariance matrix of the system as a whole is not homoscedastic.

Specifically, if the assumption of profit maximization is maintained, the system of equations consisting of the natural logarithm of normalized profits and the four factor share equations may be considered as one single univariate equation with a heteroscedastic variance-covariance matrix of errors. The test of stability of parameters is equivalent to a test of whether the coefficients estimated from such a system for 1967 is the same as those estimated for 1968. To apply the Chow test, both the dependent and the independent variables of the system of five equations are transformed by premultiplying a suitable matrix P, with the result that the error of the system of equations is changed into a homoscedastic disturbance. This matrix P has the property of $P \Sigma P' = 1$, $P'P = \Sigma^{-1}$, where Σ is the variance-covariance matrix of the error of a typical observation of the five-equation system. Given a consistent estimator of Σ, a consistent estimator of P, say $\hat{P}$, may be obtained by direct computation. Using this $\hat{P}$, the 1967 and 1968 problems may be transformed into an equivalent univariate problem with a homoscedastic variance-covariance matrix. The Chow test procedure is then carried out for 1967 and 1968 with the transformed problem.

Stability of parameters between 1967 and 1968 is tested conditional on the validity of the hypothesis of profit maximization in 1967 and 1968. As previously mentioned, a level of significance of .01 is assigned to the test of stability of parameters. The test is composed of three sequential stages: (1) stability of the parameters of the normalized profit function between 1967 and 1968, except for the intercept term and the dummy variables; (2) stability of all parameters except for the intercept; and (3) stability of all parameters. Under (3), the two normalized profit functions for 1967 and 1968 are identical in every respect. A level of significance equal to .0033 is allocated to each of the three stages of the test of the stability of parameters. These three tests are "nested"; thus, under the null hypothesis the sum of levels of significance of the three tests provides a close approximation to the level of significance for the three tests simultaneously. The test statistics are presented in Table 3.4. At a level of significance of .0033 none of the three stages of the test of stability of parameters can be rejected. It can thus be concluded that the technology is stable between 1967 and 1968. Critical values for the test statistics for levels of significance equal to .01 and .005 are presented in Table 3.4 so that the reader may evaluate the results of these tests for alternative allocations of the overall levels of significance among stages of the test procedure.

TABLE 3.2.—JOINT ESTIMATION OF THE NORMALIZED PROFIT-FUNCTION AND FACTOR-SHARE EQUATIONS FOR VARIABLE INPUTS, 1967

		Estimated coefficients[a]			
		Restricted			
Variable	Parameter	Single equation OLS	No restrictions	Profit maximization[b]	Profit maximization and constant returns[c]
Profit function					
Constant	$ln A^*$	9.793	9.487	10.350	9.979
		(4.858)	(4.153)	(1.973)	(1.538)
Labor	α_L^*	-2.116	-1.268	-0.325	-0.818
		(0.481)	(0.411)	(0.132)	(0.131)
Animal input	α_A^*	0.450	0.378	-0.041	-0.041
		(0.201)	(0.172)	(0.008)	(0.008)
Mechanical input	α_M^*	0.429	0.003	-0.019	-0.019
		(1.350)	(1.154)	(0.005)	(0.005)
Fertilizer	α_F^*	-1.190	-0.841	-0.225	-0.224
		(0.379)	(0.324)	(0.020)	(0.019)
Fixed assets	β_K^*	0.153	0.130	0.076	0.110
		(0.232)	(0.198)	(0.182)	(0.137)
Land	β_T^*	1.060	0.970	0.913	0.890
		(0.216)	(0.184)	(0.148)	(0.137)

Dummy variables[d]	δ_i				
Factor equations					
Labor	α_L^*	-0.883 (0.143)	-0.883 (0.143)	-0.825 (0.132)	-0.818 (0.131)
Animal input	α_A^*	-0.044 (0.008)	-0.044 (0.008)	-0.041 (0.007)	-0.041 (0.008)
Mechanical input	α_M^*	-0.020 (0.005)	-0.020 (0.005)	-0.019 (0.005)	-0.019 (0.005)
Fertilizer	α_F^*	-0.238 (0.021)	-0.232 (0.021)	-0.225 (0.010)	-0.224 (0.019)

---

[a] Numbers in parentheses are asymptotic standard errors.

[b] There are four restrictions implied by the hypothesis of profit maximization, $\alpha_L^* = \alpha_L^*$, $\alpha_A^* = \alpha_A^*$, $\alpha_M^* = \alpha_M^*$, $\alpha_F^* = \alpha_F^*$

[c] Conditional on profit maximization, there is one additional restriction implied by constant returns: $\beta_K^* + \beta_T^* = 1$.

[d] To save space the coefficients of the dummy variables are not reported.

TABLE 3.3.—JOINT ESTIMATION OF THE NORMALIZED PROFIT FUNCTION AND FACTOR SHARE EQUATIONS FOR VARIABLE INPUTS, 1968

		Estimated coefficients[a]			
				Restricted	
	Parameter	Single equation OLS	No restrictions	Profit maximization[b]	Constant returns and profit maximization[c]
Profit function					
Constant	$ln A^*$	9.085	6.007	11.870	11.540
		(4.080)	(3.271)	(1.415)	(1.277)
Labor	α_L^*	-1.370	-0.785	-0.975	-0.981
		(0.501)	(0.402)	(0.127)	(0.127)
Animal input	α_A^*	-0.272	-0.124	-0.055	-0.055
		(0.194)	(0.156)	(0.006)	(0.006)
Mechanical input	α_M^*	0.763	1.259	-0.024	-0.024
		(1.270)	(1.018)	(0.005)	(0.005)
Fertilizer	α_F^*	0.183	-0.140	-0.237	-0.238
		(0.462)	(0.371)	(0.019)	(0.019)
Fixed assets	β_K^*	0.151	0.093	-0.009	0.024
		(0.178)	(0.143)	(0.131)	(0.117)
Land	β_T^*	0.737	0.781	0.971	0.976
		(0.176)	(0.141)	(0.117)	(0.117)

Dummy variables[d]	δ_i				
Factor equations					
Labor	α_L^*	-1.086	-1.086	-0.975	-0.988
		(0.138)	(0.138)	(0.127)	(0.127)
Animal input	α_A^*	-0.057	-0.057	-0.055	-0.055
		(0.006)	(0.006)	(0.006)	(0.006)
Mechanical input	α_M^*	-0.024	-0.024	-0.024	-0.024
		(0.005)	(0.005)	(0.005)	(0.005)
Fertilizer	α_F^*	-0.251	-0.251	-0.237	-0.238
		(0.020)	(0.020)	(0.019)	(0.019)

---

[a] Numbers in parentheses are asymptotic standard errors.

[b] There are four restrictions implied by the hypothesis of profit maximization, $\alpha_L^* = \alpha_L^*$, $\alpha_A^* = \alpha_A^*$, $\alpha_M^* = \alpha_M^*$, $\alpha_F^* = \alpha_F^*$

[c] Conditional on profit maximization, there is one additional restriction implied by constant returns: $\beta_K^* + \beta_T^* = 1$.

[d] To save space the coefficients of the dummy variables are not reported.

TABLE 3.4.—F-RATIOS FOR TESTS OF STRUCTURAL CHANGE, 1967-68

Degrees of freedom	Hypothesis 1[a]	Hypothesis 2[b]	Hypothesis 3[c]	Critical values of F-ratios, levels of significance 0.005	Critical values of F-ratios, levels of significance 0.01
6,369	F = 1.693			3.09	2.86
7,375		F = 2.004		2.30	2.20
1,382			F = 0.376	2.24	2.13

[a] The hypothesis implies six restrictions, $\alpha_L^* = \alpha_L^*$, $\alpha_A^* = \alpha_A^*$, $\alpha_M^* = \alpha_M^*$, α_F^*, $= \alpha_F^*$, $\beta_K^* = \beta_K^*$, $\beta_T^* = \beta_T^*$.
[b] The hypothesis is conditional on hypothesis 1 and implies the additional restrictions $\delta_i = \delta_i$, $i = 1, 2, \ldots, 7$.
[c] The hypothesis is conditional on hypotheses 1 and 2 and implies the additional restriction, $ln\ A^* = ln\ A^*$.

Parameter Estimates, 1967 and 1968 Pooled

On the basis of the results of the test of stability of parameters, which indicates no significant difference for each of the three stages of the test, the two cross sections of data are combined. The parameters of the normalized profit function also are reestimated, imposing the constraint that the parameters of 1967 and 1968 are the same, as well as the constraints implied by profit maximization and constant returns to scale, hypotheses which have found to be consistent with the empirical data. These parameter estimates are reported in Table 3.5. In the first column coefficients estimated without the equality restrictions on either the intercept or the dummy variables are presented, in the second column the coefficients estimated without the equality restriction on the intercept, in the third column the coefficients estimated with all the equality restrictions imposed, and in the fourth column the coefficients with all the equality restrictions and constant returns imposed. For further discussion and analysis the estimates reported in the fourth column are adopted in view of the results of hypothesis testing. The coefficient estimates of the normalized profit function for 1967 and 1968 pooled satisfy also the conditions of monotonicity and convexity.

Output Supply and Factor Demand Functions

Using the estimates from the fourth column of Table 5, the output supply and factor demand own- and cross-price elasticities can be computed as well as elasticities with respect to the fixed factors of production. First, normalized profits in terms of money prices of output and variable factors of production are written

$$\begin{aligned} \ln \Pi^* = {} & \ln A^* + \alpha_L^* \ln q_L' + \alpha_A^* \ln q_A' + \alpha_M^* \ln q_M' + \alpha_F^* \ln q_F' \\ & - (\alpha_L^* + \alpha_A^* + \alpha_M^* + \alpha_F^*) \ln p_A + \beta_K^* \ln Y_K + \beta_T^* \ln Y_T \\ & + \sum_{i=1}^{7} \delta_i D_i, \end{aligned} \tag{3.7}$$

where prime denotes money values in New Taiwan dollars and p_A is the money price of output.

From (3.6) the output supply function is written

$$V_S = \Pi^*(1 - (\alpha_L^* + \alpha_A^* + \alpha_M^* + \alpha_F^*)).$$

Thus

$$\begin{aligned} \ln V_S = {} & \left[\ln\left(1 - \sum_{i=1}^{4} \alpha_i^*\right) + \ln A^* \right] + \alpha_L^* \ln q_L' + \alpha_A^* \ln q_A' + \alpha_M^* \ln q_M' \\ & + \alpha_F^* \ln q_F' - (\alpha_L^* + \alpha_A^* + \alpha_M^* + \alpha_F^*) \ln p_A + \beta_K^* \ln Y_K \\ & + \beta_T^* \ln Y_T + \sum_{i=1}^{7} \delta_i D_i. \end{aligned} \tag{3.8}$$

TABLE 3.5.—JOINT ESTIMATION OF THE NORMALIZED PROFIT-FUNCTION AND FACTOR-SHARE EQUATIONS FOR VARIABLE INPUTS, 1967 AND 1968 POOLED

	Variables and parameters[c]	Estimated coefficients,[a] Zellner's method with restrictions[b]			
		(1) six restrictions	(2) thirteen restrictions	(3) fourteen restrictions	(4) fifteen restrictions
Profit function					
Constant	lnA^*			11.110	10.690
				(1.835)	(1.628)
Constant	lnA_1^*	11.250	10.840		
		(2.005)	(1.916)		
Constant	lnA_2^*	11.400	10.890		
		(1.943)	(1.887)		
Labor	α_L^*	-0.982	-0.982	-0.980	-0.980
		(0.482)	(0.048)	(0.048)	(0.048)
Animal input	α_A^*	-0.048	-0.037	-0.035	-0.036
		(0.041)	(0.041)	(0.041)	(0.041)
Mechanical input	α_M^*	-0.020	0.000	-0.001	-0.002
		(0.047)	(0.071)	(0.046)	(0.046)
Fertilizer	α_F^*	-0.239	-0.230	-0.230	-0.231
		(0.044)	(0.044)	(0.044)	(0.044)
Fixed assets	β_K^*	0.019	0.053	0.029	0.070
		(0.187)	(0.181)	(0.173)	(0.153)
Land	β_T^*	0.947	0.910	0.927	0.930
		(0.161)	(0.157)	(0.153)	(0.152)

Factor equations

Labor	$-\frac{q_L X_L}{\Pi} = \alpha_L^*$	-0.985	-0.982	-0.980	-0.980
		(0.048)	(0.048)	(0.048)	(0.048)
Animal input	$-\frac{q_A X_A}{\Pi} = \alpha_A^*$	-0.048	-0.037	-0.035	-0.036
		(0.041)	(0.041)	(0.041)	(0.041)
Mechanical input	$-\frac{q_M X_M}{\Pi} = \alpha_M^*$	-0.020	0.000	-0.001	-0.002
		(0.047)	(0.071)	(0.046)	(0.046)
Fertilizer	$-\frac{q_F X_F}{\Pi} = \alpha_F^*$	-0.239	-0.230	-0.230	-0.231
		(0.044)	(0.044)	(0.044)	(0.044)
	$\beta_K^* + \beta_T^*$	0.966	0.963	0.956	1.000

---

[a] Coefficients corresponding to the dummy variables are omitted to save space.

[b] Numbers in parentheses are estimates of asymptotic standard errors, except for the dummy variables where they are the computed t-statistics.

[c] Subscripts 1 and 2 of the constant refer to 1967 and 1968, respectively.

TABLE 3.6.—OWN- AND CROSS-PRICE ELASTICITIES AND ELASTICITIES WITH RESPECT TO THE FIXED INPUTS, 1967 AND 1968 POOLED

	P_A	q_L	q_A	q_M	q_F	Y_K	Y_T
V_S	1.248	-0.980	-0.036	-0.002	-0.231	0.070	0.930
X_L	2.248	-1.980	-0.036	-0.002	-0.231	0.070	0.930
X_A	2.248	-0.980	-1.036	-0.002	-0.231	0.070	0.930
X_M	2.248	-0.980	-0.036	-1.002	-0.231	0.070	0.930
X_F	2.248	-0.980	-0.036	-0.002	-1.231	0.070	0.930

TABLE 3.7.—COMPARISON OF ALTERNATIVE ESTIMATES OF THE PRODUCTION ELASTICITIES*

	Indirect estimates	Direct estimates				
	This study, cross section, 1966-68	This study, cross section, 1967-68	Wang, cross section, 1957	Wang, cross section, 1957	Chen, cross section, 1963	Ho, time series, 1903-60
Labor	0.44	0.26	0.25	0.33	0.07	0.45
Animal input	0.02	0.03	0.34	0.31	0.51	
Mechanical	0.00	0.02				0.19
Fertilizer	0.10	0.54				
Fixed assets	0.03	0.01			0.16	0.11
Land	0.41	0.06	0.36	0.44	0.23	0.25
Sum of elasticities	1.00	0.94	0.95	1.08	0.97	1.00

*Data are from Y. Wang in E. O. Heady and J. L. Dillon (1961), *Agricultural Production Functions*, Iowa University Press, Ames; H. Y. Chen (1968), *Structure and Productivity of Capital in the Agriculture of Taiwan and Their Policy Implications to Agricultural Finance*, Sino-American Joint Commission on Rural Reconstruction, Taipei; and Y. M. Ho (1966), *Agricultural Development of Taiwan, 1903-1960*, Vanderbilt University Press, Nashville, Tennessee.

Similarly, from Equations (3.2) to (3.5) the typical factor demand equation, for example, the demand for labor, is written

$$\begin{aligned} ln\, L_D = {} & [ln(-\alpha_L^*) + ln\, A^*] + (\alpha_L^* - 1) ln\, q_L' + \alpha_A^*\, ln\, q_A' \\ & + \alpha_M^*\, ln\, q_M' + \alpha_F^*\, ln\, q_F' + \left(1 - \sum_{i=1}^{4} \alpha_i^*\right) ln\, p_A + \beta_K^*\, ln\, Y_K \\ & + \beta_T^*\, ln\, Y_T + \sum_{i=1}^{7} \delta_i D_i. \end{aligned} \tag{3.9}$$

By differentiating Equations (3.8) and (3.9) with respect to the prices of output and variable inputs and the quantities of fixed inputs, a matrix of elasticities is obtained, which is presented in Table 3.6.

First, it should be noted that the own-price elasticities of output and variable inputs are all greater than one in absolute value, indicating a rather elastic response of factor utilization. The cross-price elasticities, on the other hand, are rather low, with the exception of the price of output and the price of labor. The cross-price elasticites between the variable inputs are all negative, indicating that all the variable inputs are more complements than substitutes. The output supply and factor demand appear to be highly sensitive to changes in output price, especially the latter.

The elasticities of output supply and factor demands with respect to the fixed factors of production show that there is almost unitary elasticity with respect to land, that is, a 1 percent increase in land is likely to bring about a 1 percent increase in output and factor demands. However, the elasticities with respect to fixed assets appear to be negligible. It should be pointed out that fixed-input elasticities measure the response of price-taking, profit-maximizing farms with respect to an exogenous change in the fixed factors, holding the prices of output and variable inputs constant. Thus, the elasticities reflect the mutatis mutandis effect of a change in the quantity of a fixed input, allowing the farm to adjust its output and variable inputs optimally. Hence, the elasticities are not comparable to the production-function elasticities, which reflect the ceteris paribus effects of a change in the quantity of a fixed input, holding the quantities of the variable inputs constant. The mutatis mutandis effect is much greater than the ceteris paribus effect, as expected. For purposes of prediction and policy analysis, these mutatis mutandis elasticities frequently are the more relevant.

Comparison with Other Studies

Using the parameter estimates of the normalized restricted profit function reported in Table 3.5, the indirect estimates of the production elasticities of the Cobb-Douglas production function may be derived which underlie the Cobb-Douglas normalized restricted profit function. These estimates are consistent estimates of the production-function elasticities and are called indirect estimates to distinguish them from the direct estimates, which are obtained by estimating the production function directly.

Both the indirect and the direct production-function elasticities are reported for 1967 and 1968 pooled data in Table 3.7, as are production-function elasticities obtained by other studies of Taiwan agriculture. It should be emphasized that the indirect estimates of the production elasticities are not strictly comparable to the directly estimated production elasticities. The former estimates are statistically consistent and asymptotically efficient given the stochastic assumptions. The latter estimates are generally inconsistent due to simultaneous equation bias. In addition, the estimates obtained from other studies may also be different owing to differences in the type of data (cross section or times series), the time period, the type of output, and the degree of disaggregation of the inputs. Specifically, Wang defines operating capital as the sum of fertilizer, purchased feed, building, machinery and livestock services (in Heady and Dillon, 1961). Chen (1968), who uses the same *Farm Report* data for 1963, defines land and labor similarly to this study. His definitions of operating capital and fixed assets, however, are different. His operating capital includes cash, receivables, inventory of farm products, livestock and poultry, farming materials and equipment, and so forth. Chen's fixed assets is a stock concept including land, buildings, household furnishings, orchards and trees, and farm machinery. In this study service flows in physical units are the variables of animal input, mechanical input, and fertilizer, and the production component only of the stock of fixed farm assets has been measured. Finally, Ho's elasticities are factor shares in the total cost of production (1966). The production elasticities are also estimated for pooled 1967 and 1968 cross sections directly by a regression of the quantity of outputs on the quantity of inputs. The results are presented in Table 3.7.

The differences among the alternative estimates are striking, as are the differences between indirect estimates and direct estimates of the same parameters. The land elasticity obtained from the direct estimation of the production function appears to be too low. The labor elasticity also appears to be low in view of the significant labor share (40 percent) in total cost. These biases in the directly estimated elasticities are attributed to the existence of simultaneous-equations bias in the direct estimation of the production function. However, in a model with five stochastic equations it is difficult to isolate a priori the precise cause of the direction and magnitude of these biases.

The magnitudes of the indirect estimates of the production elasticities appear to be quite reasonable in comparison to Ho's factor share estimates and are consistent with the a priori expectations of economic theory. Labor and land are by far the two most important factor inputs. Fertilizer is next in importance with an elasticity of approximately .10. Animal and mechanical labor inputs do not figure prominently in 1967 and 1968. Fixed assets also have a low elasticity. These findings are consistent with the observation that while Taiwan agriculture has undergone substantial technological progess in the past quarter of a century, most of the innovations have been labor-intensive. Thus, labor remains the most important variable input of production.

SUMMARY AND CONCLUSIONS

In this paper short run output-supply and factor demand functions are estimated for agriculture in Taiwan for 1967 and 1968. The framework of normalized restricted profit function is employed and jointly estimated. The profit function and the four variable input demand functions are labor, animal labor, mechanical labor, and fertilizer. The hypothesis of profit maximization is tested and confirmed. Conditional on the validity of the profit-maximization hypothesis, the hypotheses of constant returns to scale and structural change are also tested and confirmed. The latter finding implies that the estimates of the parameters of the normalized profit function using this method are rather stable over time.

A previous study for India done by Lau and Yotopoulos (1972) allowed for only one variable input. It appears that in situations in which the direct production-function estimation yields unreasonable estimates, as in the present case, the normalized profit-function and factor-demand function approach gives "reasonable" estimates for the parameters of the production function.

What are the policy implications of these findings? First, they show that Taiwan farmers respond to price changes in an efficient manner. Thus, price instruments are likely to be quite effective. Second, both the supply of output and the demand for fertilizers are quite elastic. This has obvious implications on the determination of the level of government price support for agricultural output as well as the subsidy for chemical fertilizers. Finally, the tests of stability of parameters indicate that the behavior of the farm households is quite regular and predictable. This should increase confidence in the use of policy instruments which rely on the intermediation of the market process relative to policy instruments which rely on direct administrative control.

APPENDIX

DATA

The Geographical and Farm Household Sample

The bulk of the data for this research was derived from Provincial Government of Taiwan, Department of Agriculture and Forestry, *Report of Farm Record-Keeping Families in Taiwan* (1967-68b) (henceforth, the *Report*) for the years 1967-68. The Report presents summary statistics for a sample of about 400 farm households with previous experience in record keeping that are selected each year to participate in the project.

The sample covers the same townships (28 in 1967 and 38 in 1968) that represent 11 percent of the total number of 311 townships in Taiwan. These townships are classified in eight agricultural regions: northern rice, middle rice, southern rice, tea, southwestern mixed farming, western sugarcane and rotation, banana and pineapple, and eastern mixed farming. In order to control for geographical and climatic variables dummy variables are used for each of the eight regions. The eastern mixed farming region takes the value of zero and other dummies are measured as deviations from this region. Appendix Table A.1 shows the regions and the dummy variables defined. Part of the data needed for this project—such as price of output, fertilizer price, and mechanical wage rates—is obtained from other sources (to be specifically mentioned below) where they are reported not in terms of the eight regions but rather in terms of 15 *hsiens* (counties). The correspondence between the eight regions and the hsiens, as well as the number of families reported in the *Report* for each year and region, are also presented in Table A.1.

The raw data consist of accounting records of farm income, farm family earnings, and farm operation and household expenses. All the data, however, are reported only in terms of averages of farms of a given size for each region. The farm sizes distinguished consist of five cells: farms under 0.5 hectares, from 0.5 to 1.0, 1.0 to 1.5, 1.5 to 2.0, and over 2.0 hectares. The total sample, therefore, consists of 40 observations for each year.

TABLE A.1.—THE GEOGRAPHICAL AND FARM HOUSEHOLD SAMPLE*

Region	Hsien (county)	Number farm households in *Report*	
		1967	1968
Northern rice	Taipei Yilan Taoyuan	31	47
Middle rice	Miaoli Taichung Changhwa Yunlin	49	75
Southern rice	Kaohsiung Pingtung	37	32
Tea	Taoyuan Sinchu	46	38
Southwestern mixed farming	Chiayi Pingtung Hwalien	50	50
Southwestern sugarcane and rotation	Yunlin Chiayi Tainan Kaohsiung	107	95
Banana and pineapple	Nantou Kaohsiung	48	41
Eastern mixed farming	Taitung Hwalien	34	37
		402	415

*Data are from the Provincial Government of Taiwan (1967-68b), Department of Agriculture and Forestry, *Report of Farm Record-Keeping Families in Taiwan*, Taipei.

Price and Quantity of Output

The *Report* gives output in terms of total value for each farm size cell in each region. One exception is rice which is reported both in value and quantity terms. The *Report* distinguishes between crop and livestock receipts and the values of cash cropping and subsistence cropping are given separately.

The problem that arises is how to compute an average output price to associate with the value of output reported for each region. The original data do not provide the price of rice. However, two subsidiary sources, *A Report on Cost Survey of Agricultural Products* (henceforth *CS*) (in Chinese) for 1967-68 (Provincial Government of Taiwan, 1967-68a) and *Taiwan Agricultural Yearbook* (henceforth *TAY*) for 1967-68 (Provincial Government of Taiwan, 1967-68c) report by hsien prices and quantities for 45 crop products and three livestock products, which account for about 90 percent of the total value of Taiwan agricultural production. It is assumed that the price of each agricultural product is the same at the hsien and the regional level. From the price of each crop (except rice) and livestock product reported at the hsien level, a weighted average price is derived for non-rice output, p_{NR}, at the regional level. The weighting formula employs the ratio of value of crop i in total value of agricultural production (rice excepted) as a geometric weight:

$$p_{NR} = \prod_{i=1}^{47} p_i^{V_i/V_{NR}}, \tag{A.1}$$

where p_i is price of i crop, V_i and V_{NR} are, respectively, the values of i crop and the total value of non-rice output for each region, and the product sum is over the 47 non-rice crops.

The hsien price of rice is utilized at the regional level with the data from the *Report* on quantity of rice production to yield the value of rice produced by each farm cell in the sample. Finally, the overall average price of agricultural output for each region, p_A, is derived by using value geometric weights and the price of rice and non-rice, i.e.,

$$p_A = \prod p_{NR}^{V_{NR}/V} p_R^{V_R/V}, \tag{A.2}$$

where the subscripts NR and R represent non-rice and rice, respectively, and the exponents are the value share of non-rice and rice output.

Having derived the average price of agricultural output for each region, the total value of output for the region can be divided by P_A to derive the "homogenized quantity" of agricultural output.

Price and Quantity of Labor, Animal Labor, and Mechanical Labor

The *Report* presents for each region and by farm size homogenized family labor and hired labor in terms of 10-hour days as well as the total wage bill for hired-in labor. From these data region and farm size farm labor, X_L, and labor wage rate, q_L, are computed.

The *Report* also presents for each region and by farm size animal labor input in days, $X_{.A}$, and mechanical labor input in hours, $X_{.M}$. The respective prices, $q_{.A}$ and $q_{.M}$, are obtained again by geometric weighting from the *CS* that reports by selected hsien wage rates for animals and mechanical equipment owned by the farm family or hired, separately.

Price and Quantity of Fertilizer

The computation of fertilizer price and quantity is complex. The *Report* presents fertilizer expenses in New Taiwan dollars paid in cash and in kind for each farm size cell in each region. The *CS* reports by five crop categories (which are made up of 40 crops) and by hsien, quantity and value of four kinds of organic fertilizer and seven kinds of chemical fertilizer. It is assumed that the fertilizer expense reported in kind in the *Report* refers to organic fertilizer that consists of by-products of the family farm operation, while the expense reported in cash consists of chemical fertilizer purchased.

An average price and quantity of all types of fertilizer is then obtained for both organic and chemical categories, used by each farm cell in each region. The detailed calculations follow.

Data on Fertilizer at the Hsien Level

The sources for fertilizer data at the hsien level are *CS* and *TAY*. The information on fertilizer that exists at the hsien level gives the ratio of fertilizer kilogram per hectare to crop yield kilogram per hectare for each crop group j. The latter ratio is defined as U_{ijk}:

$$U_{ijk} = \frac{F_{ijk} \text{ in kilogram per hectare}}{Y_{jk} \text{ in kilogram per hectare}}, \tag{A.3}$$

where F_{ijk} is fertilizer of type i in kilogram per hectare; Y_{jk} is yield of crop group j in kilograms per hectare; k is prefecture, $k = 1, \ldots 15$; j is crop group on which fertilizer is applied, $j = 1, \ldots, 9$; and i is type of fertilizer, for four organic, $i = 1, \ldots, 4$ (i.e., composite, "night soil," soybean cake, and astragalus) and seven chemical varieties, $i = 5, \ldots, 11$ (i.e., ammonium sulphate, urea, calcium superphosphate, potassium chloride, calcium ammonium nitrate, calcium cyanamide, and others).

At the hsien level information also exists on the price of i type of fertilizer for hsien k, Q_{ik}, and on the price of each crop, P_l. From this information the total requirements are derived of fertilizer type i for each prefecture and the weighted price of all fertilizer used in the hsien, q_k:

$$W_j = \sum_{l \epsilon j} V_{lk}, \text{ and} \tag{A.4}$$

$$P_j = \prod_{l \epsilon j} P_l^{V_{lk}/\sum_{l \epsilon j} V_{lk}}, \tag{A.5}$$

where P_j is the weighted price of output of crop group j; V_{lk} is the value of output of crop categories that form each group j in hsien k; P_j is the price of output; and l is crop category, $l = 1, \ldots, 45$. The geometric weighting in Equation (A.5) employs the value share of product as weight in the value of output of group j.

The total quantity of fertilizer i used for crop group j is estimated,

$$\phi_{ijk} = W_{jk} \frac{1}{P_{jk}} \frac{1}{Y_{jk}} F_{ijk}, \qquad \text{(A.6)}$$

where the two terms outside the parentheses on the right-hand side represent the quantity of output of crop group j and the term in parentheses represents the information available on fertilizer utilization from Equation (A.3), fertilizer of type i in kilograms per yield of crop group j in kilograms. The average price for the fertilizer type *mix* used in hsien k is obtained from Equation (A.6) and the price of fertilizer type i in hsien k, Q_{ik}, separately for organic and chemical fertilizers:

$$q_k = \prod_i Q_{ik}^{FE_i/\sum_i FE_i}, \; i = 1, \ldots, 4 \text{ for organic and}$$
$$i = 5, \ldots, 11 \text{ for chemical fertilizers,} \qquad \text{(A.7)}$$

where FE_i is the total expense for fertilizer type i. The weighting exponent in Equation (A.7) is the expense for fertilizer type i as a percent of the total fertilizer expense. This weight is obtained by multiplying ϕ_{ijk} in Equation (A.6) by p_{jk} to get fertilizer expense, separate for organic and chemical types.

Two fertilizer mix prices have thus been derived for each hsien. One, for organic fertilizer used in the hsien, represents an average of prices of organic fertilizer, $i = 1, \ldots, 4$, weighted by the value of crops that the hsien produces and the ratio of fertilizer kilograms per hectare to crop yield per hectare. The other fertilizer mix price is for chemical fertilizer used in the hsien, and it represents an average of prices of chemical fertilizer, $i = 5, \ldots, 11$, weighted in a similar manner.

Data on Fertilizer at the Regional Level

As used for input in this study, the data of the *Report* distinguish eight regions with farms classified in five size cells within each region. Thus

m = regions in this study, m = 1, ..., 8
n = farm-size cells within each region, n = 1, ..., 5.

The available information in this classification is value of output for each farm-size cell and quantity of rice separately reported. Also, previously the average price of output relevant to each farm-size observation has been derived. In order to proceed from the hsien to the regional level, it is assumed that the ratio of fertilizer per hectare to yield per hectare as defined in Equation (A.3) holds also after the 15 hsiens were aggregated into eight regions. However, the mix between organic and chemical fertilizer may vary according to region but also

TABLE A.2.—REGIONAL FERTILIZER PRICES*

(New Taiwan dollars per kilogram)

Year	Fertilizer	Region							
		1	2	3	4	5	6	7	8
1967	Chemical	3.63	4.27	4.67	3.85	4.25	3.65	4.15	3.15
	Organic	0.13	0.17	0.21	0.15	0.27	0.31	0.96	0.12
1968	Chemical	3.77	3.88	4.77	4.08	4.69	3.89	3.89	3.48
	Organic	0.18	0.23	0.21	0.20	0.20	0.20	0.28	0.22

*Data are computed from Provincial Government of Taiwan (1967-68a), Department of Agriculture and Forestry, *A Report on Cost Survey of Agricultural Products*, Taipei.

among farm-size cells within each region. For, depending on fertilizer price, the farmer is likely to substitute one fertilizer type for another. In this way the weighted fertilizer price would vary from farm to farm even though the market price of fertilizer type *i* may be fixed and thus identical for all farm households. The weighting scheme again utilizes the value of organic and chemical fertilizer in total fertilizer expense as

$$q_{Fnm} = \prod_{i=1}^{4} q_k^{FE_i/FE} \prod_{i=5}^{11} q_k^{FE_i/FE}, \tag{A.8}$$

where $FE = \sum_{i=1}^{11} FE_i$.

The first product sum denotes the prefecture-average price of organic fertilizer, as computed in Equation (A.7), weighted by information from the *Report* on value share of organic fertilizer (fertilizer expenditure "in cash") to total fertilizer expenditure for the farm-size cell *n*. The second product sum term represents, correspondingly, the hsien-average price of chemical fertilizer, with the appropriate value share weights from the *Report*.

Table A.2 presents regional average price for chemical and organic fertilizers.

Farm Area

Two kinds of land are distinguished in the *Report* data—paddy land and dry land. The latter is relatively small for the sample, accounting on the average for one quarter of total farm area. All land area is homogenized into paddy land equivalent by weighting the dry land by the ratio of dry land yields to paddy land yields. The resulting homogenized paddy land equivalent is expressed in hectares. The data also provide a double-cropping index. This index was not used in the analysis on the hypothesis that the intensity of land use is determined endogenously.

Fixed Assets

The fixed variable for capital is defined as fixed farm assets and is expressed in New Taiwan dollars. Fixed farm assets include investments in plant and live capital. The former consists of the value of the farmhouse, barns, storage facilities, fences, and other land improvements. Live capital denotes investment in animals and trees. For the purposes of the production analysis fixed farm assets are considered only to the extent that they provide inputs in the production process. Therefore, the value of the farmhouse must be subtracted from the proportion used for consumption purposes, such as family abode. The converse is the case with live capital. The animal component of live capital that is used for production purposes is already accounted for by including the animal wage rate as a variable factor in the profit function. The value of orchards and animals that produce output for own-family consumption or for sale—such as poultry, cows or pigs—is therefore left for inclusion with the fixed farm assets.

To estimate the component of the household assets in buildings that is used for production purposes, the value of buildings is regressed from the *Report* data, on the household expenditures and the farm receipts, also from *Report* data. The regression equation is

$$Y = a_1X_1 + a_2X_2, \qquad (A.9)$$

where Y is the reported value of building asset; X_1 is the household consumption expenditure per capita; and X_2 is the total farm receipts.

The regression coefficients for Equation (A.9) are given in Table A.3. From these coefficients the production component of the building asset is estimated in the following manner. First, the consumption component of the building assets is estimated by multiplying the estimated coefficient, a_1, by the household consumption expenditure per capita. By subtracting the estimated consumption component of the building asset from the reported value of building asset, Y, the production component of the building asset was obtained.

To estimate the live capital assets component of the fixed farm assets the following procedure was used. From data in the *TAY* the ratio of the value of working animals to total value of animals by region was calculated. Then by multiplying this ratio with the reported value of livestock asset in the *Report* the livestock attributed to working animal asset was obtained. Finally the fixed assets variable was determined by summing the three components—the values of fixed assets used in production; the residual value of the farmhouse after the consumption component was netted out; and the value of livestock net of the component of working animals.

TABLE A.3.—REGRESSION COEFFICIENTS OF VALUE OF BUILDING ASSET ON HOUSEHOLD CONSUMPTION EXPENDITURES AND FARM RECEIPTS[a]

Year	Household consumption expenditure (per capita)	Total farm receipts
1967	2.33 (1.18)	1.80 (0.22)
1968	2.14 (0.96)	1.44 (0.19)

[a] Numbers in parentheses are standard errors.

CHAPTER IV.

TECHNOLOGICAL CHANGE IN DRYLAND WHEAT PRODUCTION IN TURKEY*

KUTLU SOMEL

Wheat is a salient part of Turkish agriculture and of Turkish diets. Wheat production in Turkey has always depended critically on weather conditions. Periodic shortfalls in wheat production have often imposed a burden on the economy by fanning inflationary pressures and draining scarce foreign exchange reserves.

The government has shown particular interest in the various dimensions of wheat production in Turkey and both supports the price of wheat and controls the price and weight of bread (Forker, 1971). Government supported research and development efforts have been directed toward increasing wheat production. The policies to disseminate the high yielding variety (HYV) seeds and the related package of techniques have met with enthusiastic response by Turkish farmers in the coastal areas with fertile soils and high rainfall (USAID, 1969; Demir, 1976). However, these coastal areas, where commercialization of agriculture is relatively high and the possibility of alternative crops, such as cotton, is always present, are not areas of stable wheat supply for Turkey as changes in relative prices alter the area devoted to wheat.

The granary of Turkey is the Central Anatolian Plateau (CAP) which accounts for more than one-third of total wheat production (Table 4.1). Wheat is produced in CAP under dry tillage conditions with half the land lying in fallow each year. Since the limiting factor is moisture, the fallow system is designed to accumulate moisture and to reestablish nutrients in the soil. Due to water resource limitations, irrigation is not an economically feasible alternative at present.

A new technology for wheat production in CAP has been proposed with the purpose of changing tillage practices to increase soil moisture retention. This technology draws on the experience of wheat production under dry tillage conditions in the Pacific Northwest of the United States. After study of the soil properties and precipitation of the CAP region, the Wheat Research and Training

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Project (Turkey, 1974) and the U.S. Agency of International Development (USAID)/Oregon State University Team (1975) have suggested modifications of the alternative technology to fit Turkish equipment and agricultural characteristics. The extension and demonstration of the technology has been the responsibility of the Wheat Research Center in Ankara, the Rockefeller Foundation; and the General and Provincial Directorates of Technical Agriculture of the Ministry of Agriculture.

The purpose of this study is to conduct an economic evaluation of the new technology. It must be emphasized that in this context no analysis of the diffusion of the new technology is intended due to data limitations. The analysis is based on data from a field survey of 65 farms in the southern part of Ankara conducted during the summer and fall of 1976.

Initially a brief review of the improvements in dryland wheat technology in CAP will be combined with a discussion of farmer behavior in CAP. Within this framework research hypotheses will be developed and tested. The analysis, implications, and qualifications of these hypotheses will follow.

IMPROVED DRYLAND WHEAT TECHNOLOGY VIS-A-VIS FARMER BEHAVIOR IN CAP

Since the limiting factor in CAP is water, technological change focuses on increasing the level of moisture conserved in fallow lands. The increased moisture in the soil is combined with other inputs. Technical research has been directed toward packages of techniques and inputs that will increase yields (USAID/Oregon State University Team, 1975; Turkey, 1974).

The basic characteristics of the improved dryland wheat technology can be summarized as follows[1]:

1. The first tillage of the fallow takes place in March and April rather than May and June as is the case in traditional technology. As a result, water consumption by weeds and remnant seeds that germinate during the spring is eliminated. Further operations on the fallow, especially tillage with the sweep, are recommended. This eliminates further growth of weeds and also promotes the development of a protective mulch cover over the soil which prevents evaporation.

The earlier tillage of the fallow as the most significant dimension of the improved technology. As fallow lands are generally treated as commons for the grazing of livestock, the elimination of weeds is expected to have an adverse effect on the herds. However, the costs of early tillage, as far as wheat production is concerned, are the same as late tillage.

2. The tillage operations on the fallow are directed toward the preparation of a suitable seed bed. The seeding operations take place in September and October. The use of improved or HYV seeds, seed drills, and phosphorus and nitrogen fertilizers are recommended.

3. After the dormant winter season the wheat plant grows during the spring.

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[1] More detailed discussion of the technology can be found in U.S. Agency for International Development/Oregon State University Team (1975) and Somel (1977, pp. 9-17).

TABLE 4.1.—WHEAT IN TURKEY AND IN THE CENTRAL ANATOLIAN PLATEAU (CAP), 1973*

	Turkey	CAP	Percent of CAP in Turkey
Total area harvested *(hectares)*	15,248,218	5,512,865	36.2
Cereals area harvested *(hectares)*	12,687,975	5,205,922	41.0
Wheat area harvested *(hectares)*	8,400,000	3,582,343	42.6
Wheat production *(tons)*	10,000,000	3,969,059	39.7
Wheat yields *(kilograms / hectare)*	1,190	1,108	—

*Data are from Turkey (1975), State Institute of Statistics, *Agricultural Structure and Production*, Ankara.

During this growth period more nitrogen fertilizer can be applied as well as herbicides to remove the competition of weeds for water.

4. The wheat crop is then harvested between July and September. The harvested land will then be in fallow till spring.

The basic purpose of the improved dryland wheat technology is to increase yields. Given that the limits of cultivable lands have been reached in Turkey in general and for wheat in CAP in particular, an increase in yields is a reasonable macroeconomic policy. However, Turkish farmers are increasingly operating in a commercialized, market-oriented environment with high levels of purchased input use.[2] Between 1950 and 1974 agricultural land increased by 74 percent,[3] the number of tractors increased 12-fold and consumption of fertilizers increased 75-fold (Turkey, 1976, 1968). Under these circumstances, technologies that are developed to increase yields per se need not be adopted by farmers. Farmers are not interested in increasing yields but in increasing profits. As a result it is not uncommon for technical developments to be rejected totally at the farm level due to high costs. Fortunately, this is not the case in CAP, where awareness among farmers is quite high and diffusion of new techniques has been substantial in a short period of time due to the efforts of the extension personnel of the Ministry of Agriculture.

In general technological improvements are transferred to the farmer as package recommendations. These packages are fairly well defined in terms of sets of mutually dependent and indispensable input levels, implements, and techniques. However, from an economic point of view, this approach is justifiable only if the production process is characterized by fixed proportions. In a world where possibilities of substitution exist, the package approach may be constrained by on-farm conditions which may be different from the controlled

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[2] The transformation of agriculture within the economy has been discussed in Birtek and Keyder (1975), and the transformations within agriculture have been discussed in Tekeli (1977, pp. 11-45).

[3] The corresponding increases are 60 percent in cereal area and 95 percent in wheat area.

experimental situation in which the package was developed. Under experimental conditions, the evaluated technology can often be interpreted as a technical engineering phenomenon.

Farms are units of economic activity. They can be viewed as approaching the implementation of improved dryland wheat technology as a comprehensive economic phenomenon. Under farming conditions the technological package is tampered with and often diluted by economic considerations. Components of the package are not as readily available to farmers as they are to experiment stations. For example, the shortage of herbicides in 1975 and fertilizer in 1976 in Turkey and the consequent black market prices hardly affected the experimenters, but had substantial impact on the farmers. Even when there are no shortages, the farmer, responding to relative prices, may decide not to use some inputs or to use them at other than levels "recommended" by the package. Similarly, farmers may not find it profitable to invest immediately in some equipment considered to be part of the package.

This argument suggests that farmers, motivated by economic criteria, may adopt packages not as a whole but in subsets of their components. This result is consistent with specific studies of the adoption process which find farmers adopting technologies in clusters of components, usually beginning with practices that have high benefit-cost ratios and low risk. It is futile under these circumstances to insist on the implementation of a "package." It also is not justifiable to view the package as the only way to define a technology. Clearly, an approach to the problem of distinguishing between technologies based on economic criteria should not focus on only one set of components, but on combinations of various components as revealed by a priori or ex ante irreversible choices that define the intent to implement a technology.

This cryptic guideline will become clear with a simple economic description of a farmer's productive activities. A farmer controls the levels of factors utilized in production. The decisions are whether to use certain factors of production as well at what level. In the short run, some of these factors are fixed (for example, land), but others can be varied (for example, amount of fertilizer and so forth). The variation in the levels of the variable factors of production occurs in response to prices as well as to technological considerations.

In other words, in the decision-making system of a farmer the levels of utilization of factors of production are endogenous since they are under his control, as opposed to prices which are exogenous variables. Under these circumstances the farmer will attempt to achieve his objective, such as profit maximization, by varying the levels of the factors of production in response to variations in their prices. The emphasis here is that the levels of use of factors of production are determined by the farmers's evaluation of prices vis-à-vis his objective. Then the package will be adopted as a whole if the prices are just right. In a stochastic world such fortuitous coincidences are quite rare.

A technology then is composed of various input-output possibilities. The variations of these possibilities correspond to movements on the production surface of the particular technology. An input-output possibility is a specific process of production utilizing a unique mix of factors of production. The choice of a process is a function of the prices of output and of factors of production.

There remains, however, a problem of distinguishing between technologies. In cases where a priori criteria can be found to make this distinction, the problem becomes easy. If there are ex ante choices by the farmer (separate from the ex post choices of the levels of input and factors of production utilization that can be explained by prices) which indicate an unambiguous irreversible intent to use one or another technology, then these choices are the criteria of distinction.

In the case of the dryland wheat production in CAP, the key difference between traditional and improved technologies is the timing of the first tillage. Whether a farmer performs early or late tillage on the fallow represents an irreversible decision to implement one technology or the other. The variations observed later in the use of inputs and factors of production correspond to movements on the production surfaces of the respective technologies.

The timing of the first tillage constitutes the actual criterion of distinction between the improved and traditional dryland wheat technologies in this study. Specifically, improved technology is defined by the choice of early tillage, i.e., when the first tillage operations on the fallow are completed prior to the first week in May. Traditional technology is defined by the choice of late tillage on the fallow, i.e., when the first tillage operations on the fallow are completed after the first week in May. The timing-of-the-tillage criterion is actually a better decision rule than one based on the rigid package definition of the improved technology.

THE MODEL SPECIFICATION

A comparative economic evaluation of the improved and traditional technologies can be made utilizing profit-function analysis. The specific method would be to utilize tests of relative technical, price, and economic efficiency. Given the results of these tests, it is also possible to test for absolute efficiency, i.e., profit maximization.

The Cobb-Douglas specification is adopted to describe the nature of wheat production in CAP. Specifically, the production function is

$$Q = AL^{\alpha_L}K^{\alpha_K}I^{\alpha_I}T^{\alpha_T}, \tag{4.1}$$

where Q is output of wheat and by-products in wheat equivalents; L is labor services in hours; K is capital services in hours; I is composite seed-fertilizer-herbicide input in kilograms; and T is land input in decares (1 decare = 0.1 hectare).

The variables L, K, and I are the variable factors of production and T is the fixed factor of production. This specification approximates closely the nature of activities in wheat production in CAP. In a single production season, the levels of labor services, capital services, and seed-fertilizer-herbicide input can be varied, whereas land is fixed at sowing time.

All variables are in homogenized units. All but the land variable, T, and output, Q, were homogenized by the following procedure: the average price of each variable was calculated by a weighted geometric average, the weights being the share of the expenditure for components in the total expenditures for the specific aggregate variable. Total expenditure for the aggregate was then divided by the average price to derive the homogenized variable. Land is measured directly. Output is equivalent to the weight of wheat plus a third of the weight of hay. The price of hay was rarely observed and therefore it was imputed at one-third of the price of wheat. This conversation rate was uniformly applied to all farms. Detailed discussion of the variables can be found in Somel (1977).

The profit function that corresponds to the production function in Equation (4.1) and the relevant factor share equations are as follows:

$$ln\,\Pi = ln\,A^* + \alpha_L^* ln\,P_L + \alpha_K^* ln\,P_K + \alpha_I^* ln\,P_I + \alpha_T^* ln\,T + \sum_j \delta_j D_j + \epsilon_1, \tag{4.2}$$

$$-\frac{P_L L}{\Pi} = \alpha_L^{*\prime} + \epsilon_2, \tag{4.3}$$

$$-\frac{P_K K}{\Pi} = \alpha_K^{*\prime} + \epsilon_3, \tag{4.4}$$

$$-\frac{P_I I}{\Pi} = \alpha_I^{*\prime} + \epsilon_4, \tag{4.5}$$

where P_L is the farm-specific price of L, normalized by the farm specific price of wheat, P_Q; P_K is the farm-specific price of K, normalized farm specific price of wheat, P_Q; P_I is the farm-specific price of the composite seed-fertilizer-herbicide input, normalized by the farm-specific price of wheat, P_Q; and D_j is the dummy variable for each village that accounts for differences in soil quality, topography, and so forth.

Equations (4.2) to (4.5) comprise the basic structure of the model. In the comparison of tillage practices they are fitted separately for early and late tillage farms. The results of the estimation of the model are presented in Table 4.2.

TESTS OF HYPOTHESES

Various tests are conducted within the framework of profit-function analysis and the results of these tests are presented in Table 4.3. The overall level significance for this series of tests is set at 0.05. Since the tests are not all nested, 0.01 level of significance has been allocated to each of the tests of nonneutral difference in technology, profit maximization, and equal relative economic efficiency. The hypotheses of constant returns to scale have been allocated 0.02 level of significance.

1. The first test is designed to determine if the technology of production, as applied by the early and late tillage farms, displays factor-biased differences. The results are negative. The only technological difference that might exist is factor-neutral.

2. The test of profit maximization is conducted for early and late tillage farms separately. For both early and late tillage, farmers appear to be maximizers.

TABLE 4.2.—JOINT ESTIMATION OF THE NORMALIZED PROFIT FUNCTION AND FACTOR SHARE EQUATIONS FOR VARIABLE INPUTS, ALL FIELDS ($n = 89$)

		Estimated coefficients[a]		
Variable	Parameter	Single equation OLS	No restrictions	Profit maximization restrictions[b]
Profit function				
Constant	A^*	5.07 (0.61)	5.45 (0.42)	6.17 (0.19)
Labor	α_L^*	0.17 (0.13)	0.08 (0.07)	-0.03 (0.01)
Capital services	α_K^*	-0.04 (0.15)	-0.06 (0.10)	-0.22 (0.01)
Seed-fertilizer	α_I^*	-0.20 (0.30)	0.17 (0.21)	-0.27 (0.02)
Land	β_T^*	0.84 (0.06)	0.87 (0.04)	0.88 (0.04)
Factor equations				
Labor	$\alpha_L^{*\prime}$	-0.04 (0.01)	-0.04 (0.01)	-0.03 (0.01)
Capital services	$\alpha_K^{*\prime}$	-0.22 (0.01)	-0.22 (0.01)	-0.22 (0.01)
Seed-fertilizer	$\alpha_I^{*\prime}$	-0.27 (0.02)	-0.27 (0.02)	-0.27 (0.02)

[a] Figures in parentheses are asymptotic standard errors.

[b] There are three restrictions implied by the hypothesis of profit maximization: $\alpha_L^* = \alpha_L^{*\prime}$, $\alpha_K^* = \alpha_K^{*\prime}$, and $\alpha_I^* = \alpha_I^{*\prime}$

3. The hypothesis of constant returns to scale is tested separately for early and late tillage farms. The evidence points to decreasing returns to scale for both groups separately and when pooled.

4. Conditional on the hypothesis that there are no biased technological differences between early and late tillage farms, tests of relative efficiency are conducted. They indicate that farms are equally price and economically efficient.

5. Further exploration of the early and late tillage technologies is pursued, although the results are not reported in Tables 4.2 and 4.3. More specifically, the survey found equally efficient farmers using owned tractors and others using tractor services on a custom rental basis.

The following question arises. Given the choice of technology, i.e., early or late tillage, are there differences in technical, price, and economic efficiency between the fields tilled by owned tractors and those where custom services are

TABLE 4.3.—TESTS OF HYPOTHESES

Test number	Maintained hypothesis	Tested hypothesis	Computed F	Critical $F_{0.01}$
1		No non-neutral difference in technology	F(4,323) = 1.28	F(4,323) = 3.40
2a		Profit maximization of early tillage farms	F(3,153) = 1.96	F(3,153) = 3.90
2b		Profit maximization of late tillage farms	F(3,170) = 1.39	F(3,170) = 3.90
3a		Constant returns to scale (early tillage farms)	F(1,153) = 8.82	F(1,153) = 6.80
3b		Constant returns to scale (late tillage farms)	F(1,170) = 8.36	F(1,170) = 6.80
3c	No non-neutral difference in technology	Constant returns to scale (all farms)	F(1,338) = 11.51	F(1,338) = 6.72
4a	No non-neutral difference in technology	Equal price efficiency	F(3,334) = 1.32	F(3,334) = 3.85
4b	No non-neutral difference in technology	Equal relative economic efficiency	F(4,334) = 0.99	F(3,334) = 3.38

TABLE 4.4.—DIRECT AND INDIRECT ESTIMATES OF PRODUCTION-FUNCTION ELASTICITIES

Variable	Direct estimates[a]	Indirect estimates[b]
Labor	-0.0222 (0.0314)	0.0218
Capital services	0.2142 (0.0753)	0.1455
Seed-fertilizer	0.0250 (0.1205)	0.1754
Land	0.6671 (0.1357)	0.5796
Sum of elasticities	0.8840	0.9223

[a] Numbers in parentheses are standard errors.

[b] Based on restricted estimates. The figures in parentheses are the standard errors of the direct estimates from a Cobb-Douglas specification with village dummies.

utilized? The results indicate that irrespective of whether the choice of early or late tillage is made, there are no significant differences in technical efficiency, price efficiency, and economic efficiency between the users of owned tractors or of custom services.

DERIVED ESTIMATES

From the restricted estimates in column 3, Table 4.2, indirect production function estimates and estimates of output supply and factor demand functions can be derived.

Indirect Production-Function Elasticities

The indirect production-function elasticities, based on the restricted estimates of the profit function, are presented in Table 4.4 along with elasticities from the direct estimates of the production function. The cross elasticities in the factor-demand functions indicate that the factors of production are complements. There are problems of multicollinearity with the direct production-function estimates, and the indirect estimates are much more in conformity with a priori expectations.

Output Supply Elasticities

It is possible to observe the output supply elasticities with respect to price of output and prices of the factors as well as the quantity of the fixed factor, land. These elasticities are given in Table 4.5 for the whole sample.

Input Demand Elasticities

In the factor demand functions, own-price elasticities, cross-price elasticities,

TABLE 4.5.—OUTPUT SUPPLY, FACTOR DEMAND, AND FIXED INPUT ELASTICITIES FOR ALL FIELDS[a]

	P_Q	P_L'	P_K'	P_I'	T
Output supply	0.5213	-0.0331	-0.2213	-0.2669	0.8818
Labor demand	1.5213	-1.0331	-0.2213	-0.2669	0.8818
Demand for capital services	1.5213	-0.0331	-1.2213	-0.2669	0.8818
Demand for seed-fertilizer	1.5213	-0.0331	-0.2213	-1.2669	0.8818

[a] Based on restricted estimates.

output-price elasticities, and elasticities with respect to the quantity of the fixed input, land, can be observed directly. The values of these elasticities, based on restricted estimates, are presented in Table 4.5 for the sample as a whole.

Policy Implications

The macroeconomic objective of the development of the improved technology was to increase production through increasing yields. This study refers to the micro-level and indicates that farmers who adopted the improved technology had no significant efficiency advantage over those who did not. The implication is that farmers would have no incentive to adopt the improved technology and as a result the macroeconomic objectives sought by its introduction could not be achieved. This study takes as exogenous the price regime and the allocation of the fixed factors that existed in 1976. It follows that the macroeconomic objectives could be pursued only if further incentives were offered to the adopters of the improved technology by changing these exogenous factors. Microeconomic profitability should always be used as a beacon in pursuing macroeconomic policies.

A further result of the study indicates that there are no differences in efficiency between using owned tractors or custom services. Hence it is interesting to observe that custom operations can offer a pressure valve in the demand for tractors without any efficiency losses in wheat production. Detailed studies of various forms of custom operations such as Gençağa, Kapil, Duman, and Mann (1973) would provide interesting insights.

Output supply and factor demand functions are significant products of the profit-function approach. Analysis of the elasticities presented in Table 4.4 can cast important light on certain fundamental questions of economic policy.

Output supply exhibits fairly low sensitivity to changes in the price of wheat and to changes in factor prices. The insensitivity to factor prices is interesting because there appears to be one fairly universal direction in these prices: up. That wheat supply does not exhibit extreme sensitivity to these prices is encouraging from the national viewpoint. However, this insensitivity does imply necessarily that manipulation of factor prices is not an effective policy tool—only that comparatively higher percentage reductions are necessary to stimulate a given percentage increase in wheat supply.

Wheat supply response to wheat prices also exhibits inelasticity. However, wheat price appears to be a more suitable tool for policy purposes. First, traditionally wheat prices are controlled and supported by the government through the Soil Products Office. Second, price increases of only double the desired percentage increase in supply are necessary to stimulate the wheat supply: for example, a 10 percent increase in wheat price is necessary to induce an approximately 5 percent increase in wheat supply.

Cross elasticities of factor-demand functions imply that they are complements, but this relationship is fairly weak as indicated by the low values of these cross elasticities. Responses to own-price changes are elastic but only slightly above one. Changes in the price of wheat appear to provide the most significant stimulus for factor demands. A given percentage increase in wheat price will cause an increase in factor demands one-and-a-half times that percentage increase.

One way to increase wheat supply is to allocate more land to wheat. Most of this land would have to come from other crops. A 10 percent increase in wheat land would result in nearly a 9 percent increase in wheat supply. However, most of the new lands for wheat would be relatively less fertile lands or lands less suitable for wheat. The complementary input requirements of such lands would be relatively higher. The fairly low level of labor services has alarming implications for unemployment. The integration of agricultural policies into policies for overall economic development appears to be of crucial importance. Tekeli (1977) discusses some of the buffer mechanisms in agriculture and in metropolitan areas which absorb the impact of displacement of agricultural labor. However, how much pressure these buffers can bear is a problem that merits scrutiny.

An interesting observation arises relating to profits. On the average current profits, i.e., current revenues less direct or imputed expenditures on variable factors of production, comprise nearly 65 percent of total revenues. This is nearly a 200 percent return on current expenditures. Part of the profits are the rent of land. The rent of land is estimated to be 318.25 Turkish liras per decare (TL/da).[4] Looking again at the averages derived from the sample, a yield of 210.88 kg/da at 2.64 TL/kg implies total revenues of 556.72 TL/da and profits of 365.77 TL. Of this, 318.25 TL is the rent of land, leaving 47.52 TL of pure profits per decare. This is equivalent to a share of pure profits in total revenues of 8.5 percent. The phenomenal rents which accrue to landowners reflect how significant are the welfare dimensions of problems such as land reform and income distribution.

COMPARISON WITH OTHER STUDIES

The key results of the study can now be summarized:

1. There are neither technological differences nor differences of efficiency between the traditional practices as characterized by early tillage and the improved practices as characterized by late tillage—at least for the year in which the survey was conducted.
2. The farmers studied are profit maximizers.
3. The data indicate the existence of decreasing returns to scale.
4. Given the choice of technology, there appear to be no differences in efficiency between the use of owned tractors and custom services.
5. The indirect estimates of the production function indicate very low elasticity with respect to labor services, and relatively higher elasticity with respect to land.
6. Finally, the output supply and factor demand functions indicate that there is substantial insensitivity to input prices and relatively higher sensitivity to output price.

These results can be contrasted with the findings of some other studies. The results for the production year 1974-75, reported by the Wheat Research and Training Project (Turkey, 1975) compare demonstration farmers (new technology) with cooperating control farmers (traditional technology). The evaluation, based on differences in yields, indicates an average net benefit of 203 TL

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[4] The rate of exchange for 1976 was 16.6 TL/US$1.

(approximately US$15 at the 1975 exchange rate) per decare (equal to 0.01 hectare) in favor of the demonstration farmers. The average ratio of increased benefits to increased costs for that group is 5.3:1, and it varies between 1.1:1 and 10.5:1. Interesting though it might have been, it is not entirely appropriate to compare the demonstrator farmers of the Wheat Research and Training Project with the farmers in actual field conditions of the CAP study. While the criterion of the CAP comparison—the timing of first tillage—is probably a necessary condition for a farmer to be in the demonstrator group, it is not a sufficient condition also. Demonstrator farmers also practiced the other components of the package, such as application of certain quantities of fertilizer and of other inputs. Moreover, it is doubtful that the performance of demonstrator farmers could ever be replicated by farmers in actual field conditions.

Further, the indirect estimates of the production-function elasticities can be compared with the findings of two other studies: First, Törüner and Karakaya (1974) estimate Cobb-Douglas production functions for the Turkish agricultural sector for 1967, 1970, and for all the years between 1967 and 1970 pooled together. The data are on a provincial basis. The dependent variable is the value of agricultural output. The independent variables are labor in number of male adult equivalents, a composite seed-fertilizer-chemical input, crop area, area for fruits and vegetables, value of modern equipment, and value of traditional equipment. All but the seed-fertilizer-chemical variable are stock variables. Regional and year dummy variables are also utilized.

The use of stock variables, the use of value of output rather than physical output, and the fact that the estimates are for agricultural output rather than wheat make comparison difficult. The only comparable elasticity appears to be the seed-fertilizer-pesticide elasticity. The two estimates are quite close, 0.1754 in this study and 0.2080 in Törüner and Karakaya . The crop area elasticity of 0.1951 is quite low as compared with the land elasticity of 0.6671 in this study. This particular elasticity is 0.3784 for 1967 in Törüner and Karakaya, but drops for 1970 and the pooled estimates. The reasons for this result are not provided.

The most significant contrast between the Törüner and Karakaya study and this study is that the former claims inefficiencies in the allocation of resources. The basis for this result is comparison of the ratio of value of marginal products to the prices of factors. Although not stated, mean values of the variables are apparently used, and the prices of factors are the same for all the provinces. The resulting ratios indicate overutilization of labor and modern equipment, and underutilization of the seed-fertilizer-herbicide composite. The ratio for crop area varies, indicating overutilization in some estimates and underutilization in others. No ratios are provided for traditional equipment, which has a negative elasticity, and for fruit and vegetable areas.

These results do not conform with those of this study, where statistical tests indicate that hypotheses of profit maximization and hence efficient allocation of resources cannot be rejected. Besides the differences that exist in the specification of variables, the difference in methodologies used can probably account for the diverging results. Törüner and Karakaya utilize variables aggregated to the provincial level to derive efficiency implications in a microeconomic frame. They further aggravate the problem by using a single set of average prices to analyze efficiency criteria, disregarding interprovince variations in prices. When the problem is analyzed in a considerably more microeconomic setting as in this study, the results are considerably different. These results illustrate that a study of efficiency based on firm (farm) level data will provide considerably more meaningful information.

Second, Demir, Ugur, and Saygideger (1971) estimate Cobb-Douglas production functions for wheat in a study aimed mainly at analyzing the effects of fertilizers. The variables are province-level values of cultivated land area, commercial nitrogen fertilizer, commercial phosphorus fertilizer, and tractors in horsepower units. Output is wheat production in physical units. Although a labor variable is not used, these results are quite close to the estimates in the present study. The land elasticities of 0.783 and 0.691 are slightly higher than the estimate of 0.58 for all fields in this study. The sums of the fertilizer elasticities of 0.234 and 0.174 are quite close to the elasticity of the seed-fertilizer-herbicide composite input of 0.17 in this study. The same can be said of the tractor elasticity and capital services elasticity values, which are 0.12 and 0.15, respectively. However, the former elasticity is based on a stock concept, whereas the estimate in this study reflects flows of services.

QUALIFICATIONS OF THE STUDY

The results of this study should be taken with several caveats. The area studied is a relatively more advanced part of CAP. The farmers of Ankara are among the avant garde of progressive farmers in CAP. Whether such a sample can represent conditions in the rest of CAP is debatable. However, it may provide a picture of what might occur as conditions which characterize the Ankara farmers extend to other farmers in CAP as well.

The weather conditions for the production years 1974-75 and 1975-76 have been extremely favorable. Plentiful and timely rainfall has characterized the latter year covered by this study. Clearly, such plentiful availability of moisture would diminish the effects of a technology aimed at moisture conservation. It is not unreasonable to attribute the lack of differences between traditional and improved technologies partially to the favorable weather conditions.

The traditional and improved practices need to be evaluated under different weather conditions. The results in this study imply that no net benefits can be associated with improved practices in wheat production in favorable weather years. There are also indications that the improved system does not have much effect on moisture conservation during extremely dry years (Turkey, 1974, pp. 7, 8, and 43). Under those circumstances, the improved system can be recommended if it is more efficient under normal weather conditions and if the probability of such weather conditions is sufficiently high to make adoption worthwhile in the long run. Further research is necessary to evaluate all these aspects.

This analysis of wheat production is also partial in two respects. First, on the production side only activities involving the production of wheat are analyzed, while production of other products is neglected. In one respect this can be justified by the relative importance of wheat. On the other hand, some products which are possibly competitive with wheat were unjustifiably omitted due to lack of data. One particular activity, that of raising sheep and cattle on the fallow, is significant, especially with respect to the early tillage practice. One approach would have been to compare the net benefits of early tillage with the possible net losses that could be associated with the removal of the herds from fallow grazing due to the elimination of weeds. Since no net benefits are associated with early tillage in the analysis, one inference could be that late tillage, where herds take advantage of weed growth for grazing, may appear to be a superior alternative. However, as the conclusions with regard to the lack of net benefits of early tillage are not without qualifications, the shortcomings that have resulted from those qualifications must be kept in mind. A frame of analysis which considers competitive production activities would provide a deeper insight, particularly to the problem of early tillage vis-à-vis fallow grazing.

Second, on the consumption side, household behavior, with respect to consumption decisions, work-leisure choices, and labor supply, is totally omitted. As Jorgenson and Lau (1969) have indicated, if there are markets for the farm output and the factors of production, the production behavior of a farm household can be decomposed from consumption behavior and analyzed separately (Lau, Lin, and Yotopoulos, 1978).

Further studies on agricultural production and household behavior in CAP should provide more meaningful information about the agricultural economy as well as the social and cultural characteristics of the farmers of CAP. This study has focused on the economic analysis of technological change. The socioeconomic impact of technological change still remains on the agenda for future research.

CHAPTER V.

PRODUCTION BEHAVIOR OF THE JAPANESE FARM HOUSEHOLD IN THE MID-1960s*

YOSHIMI KURODA

The rapid growth of the Japanese economy after World War II, and especially after 1960, had an important impact on agricultural employment and mechanization. A rapid increase in the demand for labor in the nonagricultural sectors encouraged a substantial migration of labor off the farms. Migration and the increase of wage rates, relative to the price of capital, contributed to the rapid pace of mechanization of agriculture of the 1960s.

The objective of this study is first, to analyze the farm household behavior in production under the rapidly changing economic conditions of the mid-1960s. Using the framework outlined in Chapter 2, the study specifies four variable inputs—labor, fertilizer, feed, and agrichemicals—and four fixed inputs—machinery, plants, animals, and farmland. The increasing importance of the nonlabor variable inputs makes it mandatory that these inputs be taken into account explicitly in the analysis of production. It is also important to define a broad set of fixed inputs, such a machinery, plants, and animals. Second, it is of great interest to examine whether or not farm households follow the marginal principles of production under rapidly changing economic conditions. The theory of the firm for a sample of farm households is therefore tested, examining the hypothesis of profit maximization with regard to the levels of utilization of the variable inputs. Third, the hypothesis of constant returns to scale in agricultural production is tested. Fourth, in order to examine farmer response to prices in the supply of farm products and in the demand for the variable inputs, the output supply and the four factor demand functions are derived. These functions include the prices of output and the four variable inputs as well as the quantities of the four fixed inputs. The elasticities estimated from these functions provide important information for the analysis of agricultural policy, especially with regard to the appropriate level of the agricultural price supports.

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THE MODEL[1]

The model used is almost identical to that introduced in Chapter 3, with the exceptions that four variable inputs—labor, fertilizer, feed, and agrichemicals—and four fixed inputs—machinery, plant, animals, and land—are distinguished. Eleven regional dummy variables, denoting the agricultural regions of Japan, are included.

As in Chapter 3, the natural logarithm of the normalized profit function and the four variable factor share functions are estimated as a single system. The hypotheses of profit maximization and constant returns to scale are tested in this study, the latter both unconditionally and conditional on the validity of the hypothesis of profit maximization.

SPECIFICATION OF THE VARIABLES

The main source of data used in this study is the 1965 *Nōka Keizai Chōsa Hōkoku (NKCH)* (Report on the Economic Survey of Farm Households) published annually by the Japanese Ministry of Agriculture and Forestry (Japan, 1965b). The computation of prices of output and of the variable inputs specific to farm firms is of critical importance to the model. Data from the Ministry's *Nōka Butsuzai Tōkei (NBT)* (Statistical Survey on Commodities of Farm Households) (Japan, 1965b) were used to compute the farm-specific variable input prices. For the farm firm-specific output price the estimates made by Torii were employed (1969).

The sample consists of the "average farms" in each of the six size classes[2] for the 12 regions of the country (excluding Hokkaidō).[3] The details of specifications of the variables in the model are given in order.

Profit and Quantity and Price of Output

The money profit, denoted by P', of the farm firm is given by

$$P' = P_A Y - \sum_{i=1}^{4} q_i' x_i, \tag{5.1}$$

where $P_A Y$ is the value added in 1,000 yen,[4] i.e., total output less variable costs other than labor, fertilizer, feed, and agrichemicals; x_1 is the quantity of farm labor in man-days; q_1' is the money price of farm labor in 1,000 yen per man-day; x_2, x_3, x_4 are the quantities of fertilizer, feed, and agrichemicals in kilograms; and q_2', q_3', and q_4' are the money prices of fertilizer, feed, and agrichemicals in 1,000 yen per kilogram, respectively.

The model requires profit normalized by the output price, that is, $\pi^* \equiv (P'/P_A)$. A number of operations are necessary for this purpose. First of all, the output price should be farm specific. The fact that farms sell outputs at different times and in different markets should be considered and different average prices are

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[1] For the construction of a model suitable for our specific analysis, the author has drawn heavily on Lau and Yotopoulos (1971), Yotopoulos and Lau (1973), and Yotopoulos and Nugent (1976).

[2] The six size classes are 0.1 to 0.3, 0.3 to 0.5, 0.5 to 1.0, 1.0 to 1.5, and 2.0 hectares and over.

[3] The 12 regions are Tōhoku, Hokuriku, Kita-Kantō, Minami-Kantō, Tōzan, Tōkai, Kinki, San-in, San-yō, Shikoku, Kita-Kyūshū, and Minami-Kyūshū.

[4] The exchange rate for the mid-1960s was 360 yen/US$1.

therefore obtained, even in a regime where there are perfect markets. All of these individual prices obtained thus must be weighted to determine the average price of output of each farm. A geometrically weighted average price is employed with the value share of each product in the total production of a farm firm, as weights.

Torii (1966) estimated the geometrically weighted average price of the farm products of an average farm firm in each size class in each region for the period 1954-67. His estimates for 1965 are used here.

Before computing the normalized profit, the quantities and prices of the variable factors of production are specified in the following sections.

Quantity and Price of Farm Labor.

The amount of labor spent on the farm (x_l) is defined as the sum of family labor (x_{lf}) and hired labor (x_{lh}). Hired labor consists of temporary and permanent hired labor. It is assumed that the quality of labor in the two categories is homogenous. Furthermore, family labor and hired labor are composed of male and female labor which may be different in quality. Therefore, the two different qualities of labor must be homogenized to justify the underlying assumption. Since *NKCH* reports the numbers of days per year spent on the farm for male and female workers separately, the female labor days are converted to man-days by multiplying by 0.8. The conversion coefficient, 0.8, is simply an average ratio of farm-wage rate of female labor to that of male labor for the period 1963-67 (Japan, 1965c).

Next, the farm-specific price of labor is computed in the following manner. The total wage bill paid to both the permanent and temporary hired labor expressed in terms of 1,000 yen per year is divided by the total man-days of the hired labor. The necessary data are taken from *NKCH*. This price of labor, denoted by q'_1, is imputed to the price of family labor in order to compute the total labor costs, $q'_1 x_1$. Finally, the normalized wage rate, q_1, is obtained by dividing the money wage rate, q'_1, by the output price, P_A.

Quantities and Prices of Fertilizer, Feed, and Agrichemicals

The 1965 *NBT* reports the total quantities of and expenditures on 17, 8, and 10 different kinds of fertilizer, feed, and agrichemicals, respectively, per average farm firm in each size class in each region (Japan, 1965). The quantities are given in kilograms and the expenditures in yen per year. The rest of the procedure of computing the average prices of these three variables follows the case of the output price. The prices are geometrically weighted average prices. The prices of fertilizer, feed, and agrichemicals, q'_2, q'_3, and q'_4, respectively, are expressed in terms of 1,000 yen per kilogram. These prices were normalized by the output price to obtain q_2, q_3, and q_4, respectively, which are farm specific.

Theoretically, the sums of the expenditures on fertilizer, feed, and agrichemicals given in *NBT* should be equal to those given in *NKCH* for each corresponding farm firm. However, the sums in *NBT* are usually smaller. This result occurs because *NBT* does not always cover every item for these variable inputs. Therefore, the total expenditures on fertilizer, feed, and agrichemicals reported in *NKCH* are employed to compute the money profit (P') given in Equation (5.1). Finally, P' was deflated by the output price, P_A, to obtain the actual normalized profit, Π^*.

Machinery, Plants, and Animals

The flows of machinery, plants, and animals, denoted by K_1, K_2, and K_3, respectively, are computed by the following formulae:

$$
\begin{aligned}
K_1 &= M_m + D_m + 0.06K_m, \\
K_2 &= D_p + 0.06K_p, \\
K_3 &= M_a + D_a + 0.06K_a,
\end{aligned}
$$

where K_m, K_p, and K_a are the stocks of these capital assets at the beginning of the 1965 crop year; M_m and M_a are the costs of repairs and maintenance for machinery and the costs of insemination charges and maintenance for animals, respectively; and D_m, D_p, and D_a are the depreciation of machinery, plants, and animals, respectively.

The necessary data are all reported in *NKCH* per average farm firm in each size class for each region. Finally, the interest rate of 6 percent is applied to the expenditures on these items, which was the average interest rate for one-year time deposits in commercial banks during the 1963-67 period (Japan, 1963). These service flows so obtained are farm-firm specific and are expressed in 1,000 yen.

Farmland

One hectare of farmland in Tōhoku region may not be homogeneous with one hectare of farmland in Shikoku region. The former can only be used for single-cropping while the latter is suitable for double- or triple-cropping. Differences in land quality among regions must therefore be homogenized.

It is assumed that the price of farmland reflects land quality. The price of land in this context is the rent in cash or in kind per unit of farmland. The farmland area multiplied by the rent per unit of land is defined as the service flow of the farmland. The rent of farmland for each farm firm is therefore necessary for the analysis. *NKCH* reports the total rent and the planted area of rented land per average farm firm in each size class for each region. Thus, the farm rent per unit of planted area of rented land is obtained by dividing the total rent paid by the total area of planted area of rented land per average farm firm in each size class for each region. The service flow of farmland, denoted by K_4, is then computed for each farm firm in each size class for each region by multiplying the total planted area by the farm rent per unit of planted area. K_4 is expressed in 1,000 yen per year.

STOCHASTIC SPECIFICATION

For the stochastic specification of the model used in the statistical estimation, an additive error is assumed with zero expectation and non-zero finite variance for each of the five equations. The additive error in the four factor share equations may arise from differential abilities to maximize profit or divergence between expected and realized prices. Non-zero covariances of the errors in the five equations are assumed for the same farm firm. However, the covariances of the errors of each equation corresponding to different farm firms are assumed to be zero. With this specification of errors, Zellner's method of estimation is used (Zellner, 1962).

EMPIRICAL RESULTS

In the present study, the estimation of the profit and factor share functions precedes the estimation of the output supply function. The former five functions first are estimated by Zellner's efficient method with no restrictions on parameters. The estimates are reported in the third column of Table 5.1. Then, the hypothesis of profit maximization and constant returns to scale is tested. Based on the results the profit and factor share functions are reestimated with restrictions on parameters.

TESTS OF HYPOTHESES

First, the null hypothesis of profit maximization is tested. As seen in Table 5.2, none of these hypotheses can be rejected at the 1 percent level of statistical significance. This implies that the observations are consistent with the farm-firm maximizing its profit with respect to the variable inputs.

Next, the null hypothesis of constant returns to scale in agricultural production of farm firms is tested by determining whether the sum of the coefficients of the fixed inputs, i.e. $\sum_{j=1}^{4} \beta_j^*$, is equal to one. The value $\sum_{j=1}^{4} \beta_j^*$ is 1.11 in the case of Zellner's efficient estimation with no restriction (Table 5.1). Two cases of the same test are executed: one is unconditional, and the other is conditional on the validity of the equality hypothesis. The former is rather straightforward as a test. In the latter case, the hypothesis of constant returns to scale is tested conditional on the validity of the hypothesis of profit maximization.

As can be observed in Table 5.2, the null hypothesis of constant returns to scale is rejected for both cases at the 1 percent level of statistical significance. Since $\sum_{j=1}^{4} \beta_j^*$ is estimated to be 1.11, the results of the hypothesis testing indicate the existence of increasing returns to scale. A 99 percent confidence interval for $\sum_{j=1}^{4} \beta_j^*$ may be computed.[5] The computed confidence interval is given as

$$1.1079 \leqq \sum_{j=1}^{4} \beta_j^* \leqq 1.1129.$$

It may therefore be included that increasing returns to scale exist in agricultural production with probability 0.99.

Based on the results of tests the profit and factor-share functions were reestimated with only profit-maximization restrictions. The estimates are presented in the last column of Table 5.1. The statistical significance of the estimated coefficients is drastically increased. This is the final specification of the profit and factor-share functions in the study and is used for further analysis.

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[5] This method is suggested by Nerlove (1960).

TABLE 5.1.—COBB-DOUGLAS PROFIT AND FACTOR-DEMAND FUNCTIONS

		Estimated coefficients[a]	
Variable	Parameter	No restrictions	Profit maximization restrictions[b]
Profit function			
Constant	$\ln A^*$	1.15*	1.44*
		(2.48)	(6.99)
Labor	α_1^*	-0.14	-0.55*
		(-0.70)	(-22.30)
Fertilizer	α_2^*	-0.09	-0.13*
		(-1.17)	(-29.80)
Feed	α_3^*	-0.10	-0.27*
		(-0.45)	(-11.11)
Agrichemicals	α_4^*	-0.00	-0.04*
		(-0.04)	(-20.93)
Machinery	β_1^*	0.09	0.28*
		(1.03)	(7.01)
Plants	β_2^*	0.07*	0.10*
		(2.57)	(3.09)
Animals	β_3^*	0.05	0.03
		(1.67)	(0.81)
Land	β_4^*	0.90*	0.73*
		(7.41)	(26.22)
Sum of β_j^*	δ_i	1.11	1.14
Factor equations			
Labor demand	α_1^*	-0.58*	-0.55*
		(-22.75)	(-22.30)
Fertilizer demand	α_2^*	-0.13*	-0.13*
		(-32.14)	(-29.80)
Feed demand	α_3^*	-0.29*	-0.27*
		(-11.87)	(-11.11)
Agrichemical demand	α_4^*	-0.04*	-0.04*
		(-28.16)	(-20.93)

[a] Coefficients with * are statistically significant at the 5 percent level; figures in parentheses are compute t-ratios.

[b] There are fourt restrictions implied by the hypothesis of profit maximization: $\alpha_1^* = \alpha_1^*$, $\alpha_2^* = \alpha_2^*$, $\alpha_3^* = \alpha_3^*$, and $\alpha_4^* = \alpha_4^*$.

[c] To save space the estimates of the coefficients of the dummy variables are not reported.

TABLE 5.2.—STATISTICAL HYPOTHESES TESTED

Maintained hypothesis	Tested hypothesis H_0	Computed F	Critical $F_{0.01}$
	Profit maximization	$F_{(4,336)} = 2.68$	$F_{(4,336)} = 3.32$
	Constant returns	$F_{(1,336)} = 8.17$	$F_{(1,336)} = 6.63$
Profit maximization	Constant returns	$F_{(1,340)} = 59.05$	$F_{(1,340)} = 6.63$

[a] There are four restrictions implied by the hypothesis of profit maximization: $\alpha_1^* = \alpha_1^*$, $\alpha_2^* = \alpha_2^*$, $\alpha_3^* = \alpha_3^*$, and $\alpha_4^* = \alpha_4^*$.

[b] One restriction is implied by the hypothesis of constant returns: $\beta_1^* + \beta_2^* + \beta_3^* + \beta_4^* = 1$.

TABLE 5.3.—INDIRECT ESTIMATES OF PRODUCTION ELASTICITIES, 1965

Variable	Parameter	Estimated elasticity[a]	
Labor, $ln\ x_1$	α_1	0.277	
Fertilizer, $ln\ x_2$	α_2	0.063	
Feed, $ln\ x_3$	α_3	0.134	0.218
Agrichemical, $ln\ x_4$	α_4	0.021	
Machinery, $ln\ K_1$	β_1	0.141	
Plants, $ln\ K_2$	β_2	0.066	0.221
Animals, $ln\ K_3$	β_3	0.014	
Land, $ln\ K_4$	β_4	0.369	
Sum of α_i's and β_j's		1.086	

[a] The indirect estimates of the production elasticities were computed by using the estimates of the profit and factor demand functions given in the last column in Table 5.1.

PRODUCTION-FUNCTION ELASTICITIES

Using the parameter estimates of the profit function reported in the last column of Table 5.1, the indirect estimates may be derived of the Cobb-Douglas production function that underlies the fitted Cobb-Douglas profit function. Reported in Table 5.3, these indirect estimates are consistent estimates of the production-function elasticities. The elasticities can of course be estimated directly by fitting conventional Cobb-Douglas production functions. In Table 5.4 direct estimates of production elasticities from previous studies are presented which are more or less comparable with the indirect estimates since they refer to cross-sectional data for years close to 1965.

TABLE 5.4.—DIRECT ESTIMATES OF THE PRODUCTION ELASTICITIES FROM OTHER STUDIES, 1960s*[a]

	Torii	Yuize		Akino		
Variable	1961	1960	1962	1960	1965	1960-65
Labor	0.220[b]	0.268	0.222	0.287	0.250	0.277
Working capital	0.576[c]	0.460	0.456	0.243	0.274	0.260
Fixed capital	0.181[d]	0.072	0.077	0.284	0.357	0.305
Land	0.033	0.337	0.378	0.186	0.119	0.158
Sum of elasticities	1.011	1.136	1.142	1.000	1.000	1.000

*Data are from Y. Torri (1969), "Nōson Bukka Shisū no Sokutei (Estimation of Index)," *Mita Gakkai Zasshi*, Vol. 62, No. 8, pp. 120-38; Y. Yuize (1965), "Nōgyō Seisan ni-okeru Kakaku Hannō (Price Responsiveness in Agricultural Production)," *Nōgyō Sogo Kenkyū (Quarterly Journal of Agricultural Economics)*, Vol. 19, No. 1, pp. 107-42; and M. Akino (1973), "Shiken-Kenkyū, Kyōiku to Nōgyo Seichō (Experiment, Research and Education in Agricultural Growth)," *Nōgyō Sogo Kenkyū*, Vol. 27, No. 1, pp. 43-78.

[a] The dependent variable in each case is the gross farm output. The definitions of the independent variables vary in the estimations by the three researchers. The estimation is based on regional cross-section data in his estimation.

[b] The sum of the elasticities of male and female labor.

[c] The sum of the elasticities of fertilizer, feed, and agrichemicals.

[d] The sum of the elasticities of machinery, animals, and farm buildings and structures.

TABLE 5.5.—COMPUTED ELASTICITIES OF OUTPUT SUPPLY AND FACTOR DEMAND, 1965*

Variable	Endogenous variables Output supply ($\ln Y$)	Labor demand ($\ln x_1$)	Fertilizer demand ($\ln x_2$)	Feed demand ($\ln x_3$)	Agrichemical demand ($\ln x_4$)
Labor, q_1	-0.549	-1.549	-0.549	-0.549	-0.549
Fertilizer, q_2	-0.125	-0.125	-1.125	-0.125	-0.125
Feed, q_3	-0.266	-0.266	-0.266	-1.266	-0.266
Agrichemical, q_4	-0.042	-0.042	-0.042	-0.042	-1.042
Price of output, P_A	0.982	1.982	1.982	1.982	1.982
Machinery, K_1	0.281	0.281	0.281	0.281	0.281
Plants, K_2	0.104	0.104	0.104	0.104	0.104
Animals, K_3	0.028	0.028	0.028	0.028	0.028
Land, K_4	0.732	0.732	0.732	0.732	0.732

*Elasticities were computed using the estimates reported in the last column in Table 1. For the procedure of the estimation of elasticities, see Lawrence J. Lau and Pan A. Yotopoulos (1972), "Profit, Supply and Factor Demand Functions," *American Journal of Agricultural Economics*, Vol. 54, pp. 11-18.

When comparing the indirect and direct estimates of the elasticities of the production function, an important difference between these two types of estimates must be considered. The direct estimates reported in Table 5.3 are obtained by the single equation ordinary least squares method. As a result, the direct estimates are subject to simultaneous equations bias to the extent that it is present in the agricultural production of the farm firm. The indirect estimates, on the other hand, are free of such bias since they are obtained through the simultaneous solution of the profit and factor-demand functions. In addition, the stochastic specification for the estimation of the production and profit functions are different. Another important point is the inescapable differences in the definition of the variables in the models in different studies.

The production elasticities range in the two tables from 0.22 to 0.29 with respect to labor as estimated by Torii (1969), Yuize (1965), and Akino (1973). This range is very close to that of the indirect estimate of the labor-production elasticity in this study, 0.28. This similarity, however, must be regarded as a pure coincidence, as the remaining parameter estimates are not comparable in magnitude across studies at all.

The production elasticities with respect to working capital estimated by Torii, Yuize, and Akino vary widely. Fertilizer, feed, and agrichemicals were summed up for the indirect estimates as well as for the direct estimates by Torii, so that the numerical values of the working capital-production elasticity may be compared with those estimated by Yuize and Akino. The direct estimates of the elasticity by Torii, Yuize, and Akino provide the range 0.24-0.58. The indirect estimate of the elasticity in the present study is 0.22. The lower bound of the range for the direct estimates (0.24) is very close to the indirect estimate of the elasticity.

Comparison of the direct and indirect estimates of the production elasticities to fixed capital is more difficult because of the different degrees of aggregation of fixed capital from one study to another. Torii originally estimated the production elasticities separately for machinery, plants, and farm buildings and structures in the production function. The three elasticities are summed up here to yield an estimate of the fixed captial-production elasticity. Yuize defined the fixed capital in the production function as the sum of machinery, plants, animals, and farm buildings and structures. Akino employed only machinery as a proxy for the fixed capital. In the studies by Yuize and Akino, the estimates of the production elasticity with regard to the fixed capital so defined may directly be considered as estimates of the fixed capital-production elasticity. In the case of the indirect estimation in the present study, the production elasticities with respect to machinery, plants, and animals were summed up to yield an estimate of the fixed capital-production elasticity. By comparing these estimates of the fixed capital-production elasticities in Tables 3 and 4, it may be observed that the estimates by Torii (0.18 in 1961) and Akino (0.28 in 1960) are fairly close to the indirect estimate which is approximately 0.22 for 1965.

Excluding the estimate by Torii, the direct estimates of the land-production elasticity range from 0.12 to 0.38. The indirect estimate of the elasticity in the present study, on the other hand, is 0.37 for 1965 which is close to Yuize's estimates (0.34 in 1960 and 0.38 in 1962).

The sum of the production elasticities through Cobb-Douglas production functions indicates whether the production faces constant, increasing, or decreasing returns to scale. Akino, however, assumed constant returns to scale, and he constrained the sum of coefficients to unity in the estimation of the production function. Torii found that the sum of the production elasticities was barely greater than one. However, Yuize's results indicate the existence of increasing returns to scale since the sums of the production elasticities, about 1.14 both in 1960 and in 1962, are greater than one. Although he did not test statistically for economies of scale, Yuize's results seem to be consistent with the results in the present study where a rigorous statistical test was carried out to test for increasing returns to scale in the agricultural production during the mid-1960s.

Output Supply and Factor Demand Elasticities

By using the estimates of the last column of Table 5.1, the elasticities of output supply and factor demand with respect to the prices of output and variable inputs, and to the quantities of fixed inputs can be computed. The estimates of elasticities are reported in Table 5.5.

First, the elasticities of output supply are examined. As expected a priori from the theory of the profit and factor-demand functions, the supply elasticities with respect to input prices are negative; the elasticities with respect to the output price and the fixed inputs are positive. In general, the results show the farm responsiveness in output supply to changes in prices. The results also indicate the importance of an increase in area farmed for an increased supply of farm output. Furthermore, a 10 percent increase in the price of farm labor (wage rate) will decrease the output supply of the farm by 5 percent. Thus, the rapid increase in farm wage rates during the 1960s had a relatively serious negative effect on the supply of output.

Above all, the most interesting elasticity is the own-price elasticity. It is around unity, indicating that the farm behaved rather elastically during the mid-1960s to changes in output prices.

Next, the elasticities of demand for labor, fertilizer, feed, and agrichemicals are presented in columns 2, 3, 4, and 5, respectively, in Table 5.5. The results are as expected from theory. The elasticities of demand of the firm for the variable factors are negative with respect to own prices. The elasticity of output with respect to price is positive; and so is its elasticity with respect to quantities of fixed inputs.

It is significant that the elasticities of the demand for the variable inputs with respect to their own prices are all greater than one. This indicates that the farm firm responds elastically to changes in the input prices in the demand for the variable inputs of labor, fertilizer, feed, and agrichemicals. Second, the elasticities of demand for these variable inputs with respect to the output price are around 2.0, indicating that the demand for the variable inputs by the farm firm is strongly influenced by changes in the output price. Finally, an increase in farmland increases the demand for these variable inputs fairly elastically.

SUMMARY AND CONCLUSIONS

The empirical findings of this study can be summarized as follows:

1. Farms maximize their profit with respect to the prices they face in the markets for labor, fertilizer, feed, and agrichemical inputs.

2. There are increasing returns to scale in Japanese agricultural production. This finding is consistent with the trend of an increasing number of larger scale farm households and a decreasing number of smaller scale farm households during the postwar years in Japan. This finding also lends support to a removal of legal limitations on the size of farms. This will invariably involve the consolidation of a number of small farms. The political and social implications of this potential development deserve further study.

3. The supply elasticity output with respect to its own price is about one. This finding indicates that there is no "rigidity of farm output supply" at the microeconomic level in postwar Japanese agriculture. It also has implications on the agricultural price support policy.

4. The farm firm's demands for labor, fertilizer, feed, and agrichemicals are elastic with respect to their own prices. Also, the farms are highly responsive to changes in the price of output. They increase their demands for the variable inputs in response to an increase in the output price. This finding is evidence of the substantial market orientation of the Japanese farms.

5. An increase in land area at the farm level increases the supply of output and the demand for the variable inputs by the farm, as indicated by the relatively large elasticities, 0.73 for all cases.

CHAPTER VI.

A MICROECONOMIC ANALYSIS OF THE AGRICULTURE OF THAILAND

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This study of the production behavior of the agricultural household in Thailand is an application of the profit-function methodology. Like the other studies in this volume, the present research has the following features. First, four variable inputs are specified—labor, animal input, mechanical input, and seed fertilizers. The increasing importance of the nonlabor variable inputs makes it mandatory that these inputs be taken into account explicitly in the analysis of production if realistic policy implications are to be reached. Second, the functions for output supply and for the demand of each of the variable factors of production are derived. The resulting system of the five simultaneous equations gives solutions for the values of the endogenous variables in terms of variables that are exogenous in the short run operations of the agricultural household. These variables are the price of output and of the four variable factors of production and the quantities of the fixed factors of production which are fixed assets and land. The elasticities that are estimated in this manner give important information that cannot be obtained from the standard production-function analysis. Third, the hypothesis of profit maximization is explicitly tested with respect to all four of the variable inputs. Fourth, the hypothesis of constant returns to scale is also explicitly tested.

The absence of reliable data on the production activities of agricultural households has been a limiting factor of recent attempts to analyze the behavior of farmers in Thailand. A special field survey was therefore conducted in 1973 to provide the data for this study. The survey was organized by Kamphol Adulavidhaya of Kasetsart University in collaboration with Pan A. Yotopoulos and Lawrence J. Lau of Stanford University and covered six provinces in the Central Plain and the Northeast of Thailand, namely, Suphan Buri, Phichit, Lop Buri, Nakhon Sawan, Saraburi, and Nakhon Ratchasima.

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THE MODEL

The normalized restricted profit function with four variable and two fixed inputs of production is specified identically as in Equation (3.1) of Chapter 3:

$$ln\,\Pi^* = ln\,A^* + \alpha_L^*\,ln\,q_L + \alpha_A^*\,ln\,q_A + \alpha_M^*\,ln\,q_M + \alpha_F^*\,ln\,q_F + \beta_K^*\,ln\,Y_K + \beta_T^*\,ln\,Y_T + \sum_m^5 \delta_m D_m$$

where Π^* is restricted profit (current revenue less current variable costs), per farm, normalized by the price of output; q_L is the money wage per day normalized by the price of output; q_A is the money animal input price per day normalized by the price of output; q_M is the money mechanical input price per hour normalized by the price of output; q_F is the money price of a composite input that includes seed, fertilizer, and chemicals, per kilogram, normalized by the price of output; Y_K is the quantity of fixed farm assets, in Thai *bahts*;[1] Y_T is the farm area in *rai* (one rai is equal to .16 of a hectare); and D_i's are dummy variables corresponding to the five different villages included in the study.

Following the derivations in Chapters 2 and 3, the demand for each variable factor of production and the supply of output are defined as in Equations (3.2) and (3.6). Moreover, the tests of the relevant hypotheses are identical to those presented in Chapter 3, with the exception of the test for structural change which is inapplicable to the Thai data.

THE DATA

The data for this study were collected from six provinces. The first province, Suphan Buri, is located in the Lower Central Plain where rice is grown almost exclusively and mostly under irrigated conditions. The second province, Phichit, is located in the Upper Central Plain where rice is grown with some corn. The balance of the provinces grow mostly corn and other crops.

One *amphur* (district) was selected from each province and within each amphur the *tambons* (communes) were classified into two categories on the basis of their distance from the amphur seat. From each category one tambon was randomly chosen and two *mubans* (villages) were selected from the tambon also on the basis of their distance from the center. The list of farmers within each muban was stratified on the basis of size of holding (less than 20 rai, 20-40 rai, 40-60 rai, 60-80 rai, 80-100 rai, and over 100 rai). A random sample of 18-20 farms was drawn from each muban, distributed proportionally to the number of farms in each size of holding.

The survey was carried out in 1973 and covers the crop year 1972 to March 1973. This was a year of unusual drought that affected the whole country, and most severely the Central Plain and the Northeast where the production of the first crop season was almost entirely destroyed. As a result only 47 percent of the area reported as planted in the sample was also harvested. Only where irrigation was available, as in the case of the Lower Central Plain that was represented in the survey by the province of Suphan Buri, was the damage less severe. As a result a

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[1] The exchange rate in 1973 was 20 bahts/US$1.

number of farms in the sample had negative profits or zero observations for certain inputs and therefore could not be included in the analysis.

First the expenditures on the variable factors of production and their prices are determined. The quantity of labor is given in terms of homogenized ten-hour man-days. It is assumed that family labor is valued on the margin at the same rate as hired-in or hired-out labor for which there is information in the survey. The quantity of animal input is given in the survey in days and its price is that observed for draft animals hired. Hired tractors represented the bulk of the mechanical inputs used and are expressed in hours. The seed-chemical variable includes chemical fertilizers purchased, organic fertilizers produced on the farm, chemicals, and also purchased seeds which were mostly of improved varieties. All these components of the fertilizer variable are homogenized in kilograms and the price of the variable is obtained by geometric weighting of the prices of its individual components.

The second task is to measure the price of output and hence normalized profits. For this purpose an output price index is constructed by geometrically weighting the prices of different kinds of outputs produced on each farm, using the value shares of these outputs divided by total farm production as the weights. Since the total value of output is available for each farm, and given the price index of agricultural output derived as above, the normalized profits are obtained for each observation by subtracting from total normalized revenue the total normalized expenditures on each of the variable factors of production.

The final task is to obtain measurements of the quantities of fixed factors of production—fixed assets and land. Fixed farm assets are reported in the questionnaire in terms of initial acquisition value and estimated present value, with information also on the age of the asset. After apportioning some assets (such as farmhouses) partly to consumption and partly to production purposes, the mean value of initial and present value is taken as a rough estimate of the production contribution of the asset. Fixed assets are expressed in bahts. Finally, the land input is planted area in rai.

EMPIRICAL RESULTS

The parameter estimates of the coefficients are presented in Table 6.1, starting from the ordinary least squares estimators and imposing seriatim the linear constraints implied by profit maximization and constant returns to scale. The discussion of the results is based on the final column of Table 6.1.

Following the procedure outlined in previous chapters the validity of the restrictions implied by the hypothesis of profit maximization and constant returns to scale is tested by employing test statistics based on F-ratios. The test statistics are reported in Table 6.2 for the levels of significance of 0.05 and also of 0.01. The null hypothesis of profit maximization cannot be rejected. Proceeding conditionally on the validity of the hypothesis of profit maximization, the hypothesis of constant returns to scale is then tested. It also cannot be rejected at either level of significance.

Using the parameter estimates of the normalized restricted profit function reported in Table 6.1, the indirect estimates of the parameters of the Cobb-

TABLE 6.1.—JOINT ESTIMATION OF THE NORMALIZED PROFIT FUNCTION AND FACTOR SHARE EQUATIONS FOR VARIABLE INPUTS

		Estimated coefficients[a]			
				Restricted	
Variable	Parameter	Single equation OLS	No restrictions	Profit maximization restrictions[b]	Profit maximization and constant returns[c]
Profit function					
Constant	$\ln A^*$	-0.216	-1.158	0.859	0.136
		(-0.100)	0.704)	(0.591)	(0.109)
Labor	α_L^*	-0.548	-0.237	-0.562	-0.574
		(-0.571)	(-0.325)	(-1.357)	(-1.380)
Animal input	α_A^*	0.902	0.336	-0.086	-0.088
		(0.829)	(0.406)	(-1.382)	(-1.420)
Mechanical input	α_M^*	0.597	0.290	-0.119	-0.123
		(1.834)	(1.170)	(-2.725)	(-3.081)
Seed-fertilizer	α_F^*	-0.622	-0.135	-0.110	-0.112
		(-1.776)	(-0.506)	(-1.195)	(-1.220)
Fixed assets	β_K^*	0.648	0.422	0.472	0.459
		(2.266)	(1.941)	(2.000)	(1.930)
Land	β_T^*	-0.220	0.247	0.310	0.541
		(-0.646)	(0.956)	(0.983)	(2.273)

Dummy variables[d]	δ_i				
Factor equations					
Labor	α_L^*	-1.999 (-2.554)	-1.999 (-2.554)	-0.562 (-1.357)	-0.574 (-1.380)
Animal input	α_A^*	-0.278 (-2.586)	-0.278 (-2.586)	-0.086 (-1.382)	-0.088 (-1.420)
Mechanical input	α_M^*	-0.141 (-4.617)	-0.141 (-4.617)	-0.119 (-2.725)	-0.123 (-3.081)
Seed-fertilizer	α_F^*	-0.407 (-2.451)	-0.407 (-2.451)	-0.110 (-1.195)	-0.112 (-1.220)

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[a] Numbers in parentheses are asymptotic standard errors.

[b] There are four restrictions implied by the hypothesis of profit maximization: $\alpha_L^* = \alpha_L^*$, $\alpha_A^* = \alpha_A^*$, $\alpha_M^* = \alpha_M^*$, and $\alpha_F^* = \alpha_F^*$.

[c] Conditional on profit maximization, there is one additional restriction implied by constant returns: $\beta_K^* + \beta_T^* = 1$.

[d] The estimates of the coefficients of the dummy variables have been omitted in order to save space.

TABLE 6.2.—STATISTICAL HYPOTHESES TESTED

Tested hypothesis H_0	Computed F	Critical $F_{0.05}$	Critical $F_{0.01}$
Profit maximization[a]	F(4,139) = 2.21	F(4,139) = 2.44	F(4,139) = 3.49
Constant returns conditional on profit maximization[b]	F(1,143) = 1.50	F(1,143) = 3.91	F(1,143) = 6.81

[a] The hypothesis of profit maximization implies four restrictions, $\alpha_L^* = \alpha_L^*$, $\alpha_A^* = \alpha_A^*$, $\alpha_M^* = \alpha_M^*$, and $\alpha_F^* = \alpha_F^*$.

[b] Conditional on profit maximization, there is one additional restriction implied by constant returns, $\beta_K^* + \beta_T^* = 1$.

Douglas production function which underlies the fitted Cobb-Douglas profit function are derived. These estimates, which are reported in Table 6.3, are consistent estimates of the production-function elasticities. Finally, by differentiating the output supply and input demand functions with respect to price and to the quantities of the fixed inputs, the matrix of elasticities, which is presented in Table 6.4, is obtained.

No studies of Thai agriculture provide production elasticities which are readily comparable with the results of Table 6.3. Some previous studies, based on direct estimation of the production function, have consistently produced statistically insignificant estimates for the labor elasticity, and excessively high estimates for land elasticity, sometimes approaching unity.[2] It may well be that the lack of simultaneous equation bias in this approach, a common problem in the direct estimation of the production function, has contributed to obtaining reasonable estimates.

There is broad agreement in the literature that variations in Thai rice yields are mostly due to "environmental factors," such as soil, water, and weather differentials, including the expansion of land under cultivation, and not to factors related to the use of other variable inputs (Hsieh and Ruttan, 1967; Behrman, 1968b). In these estimates, instead, labor is an important factor of production, and the coefficient of land is similar to that of capital. The other inputs have coefficients that are decidedly lower.

There has been general agreement in the literature that Thai agriculture product and factor markets transmit price information quite efficiently (Pantum, 1963; Usher, 1967; Behrman, 1968a,b). The estimates of marginal productivities of the factors of production in Table 6.3, which are uniformly close to factor prices, as well as the confirmation of the hypothesis of profit maximization, provide further evidence of the allocative efficiency of Thai agriculture. The producers in the sample were not discouraged from using optimal quantities of factors, especially fertilizer, because of the unfavorable rice to fertilizer price ratio. On the contrary, the low use of fertilizer reported for Thailand is economically optimal under the existing price regime (Yotopoulos and Adulavidhaya, 1977).

[2] For examples, see Behrman (1968b) and Mellor and Stevens (1956).

Although the producers in the sample seem to have adjusted successfully to the economic conditions they face, changes in some government policies, specifically price policies, can play an important role in increasing output. Table 6.4 suggests that the output supply and the factor demands in particular are highly sensitive to changes in output price. Furthermore, the own-price elasticities of output and variable inputs are all greater than one, indicating a rather elastic response of factor utilization. The cross-price elasticities on the other hand are generally low, with the exception of those for output and labor. Moreover, the negative cross-price elasticities between all the variable inputs indicate that these inputs are complements rather than substitutes.

The elasticities of output supply and factor demand with respect to the fixed factors of production measure the mutatis mutandis effect of a change in the quantity of a fixed input, allowing the farm to adjust its output and variable inputs optimally, while the prices are held constant. Such optimal adjustment will lead to an increase in output supply and input demands of .54 with an increase in the quantity of land and of .46 with an increase in the quantity of capital, as shown in Table 6.4. These coefficients are much higher and also more meaningful than the production coefficients reported in Table 6.3, which show the effect of a change in one factor when other factors are held constant and no optimal adjustment is allowed.

SUMMARY AND CONCLUSIONS

In this paper short run output supply and factor-demand functions are estimated for a sample of Thai farms. The framework of the normalized restricted profit function is employed, and the profit function and the four variable input demand functions—labor, animal input, mechanical input, and seed-fertilizer—are jointly estimated. The hypothesis of profit maximization is tested and cannot be rejected. Conditional on the validity of the profit maximization hypothesis, the hypothesis of constant returns to scale is also tested and accepted.

The indirect estimates of the coefficients of the production function which are implied by the estimated normalized profit function are reasonable and emphasize the importance of labor in Thai agriculture. In terms of the magnitude of the estimated coefficients, at least, land and fixed assets are the next most important factors of production. The own- and cross-price elasticities of outputs and inputs reveal some interesting patterns. The price elasticity of output supply is close to unity. Since this refers to all output produced, whether for own consumption or marketed, the price elasticity of the latter is probably higher. This hypothesis will be tested specifically in the next step of the analysis of the Thailand data that also combines the consumption side of the agricultural household. Own-price elasticities of demand for the factors of production are uniformly above unity, with labor at 1.57. On the other hand, the cross elasticities are relatively small for all inputs. While the farmers in the sample have successfully adjusted to higher prices, there appears to be substantial room for increasing food supplies in Thailand by judicious use of government price policies.

TABLE 6.3.—INDIRECT ESTIMATES OF INPUT ELASTICITIES AND RELATED STASTICS, THAILAND

	Production coefficient	Mean value	Price (*baht*)	Marginal revenue product
Value of output (*baht*)	—	17,335.00	12.69	—
Labor (*days*)	0.30	473.64	12.63	11.05
Animal input (*days*)	0.05	74.56	9.79	10.93
Mechanical input (*hours*)	0.07	16.60	43.97	67.88
Seed-fertilizer (*kg*)	0.06	52.53	20.18	19.47
Fixed assets (*baht*)	0.24	8,925.50	—	0.47
Land (*rai*)	0.29	50.08	—	98.65

TABLE 6.4.—OWN- AND CROSS-PRICE ELASTICITIES AND ELASTICITIES WITH RESPECT TO THE FIXED INPUTS, THAILAND

	P_A	q_L	q_A	q_M	q_F	Y_K	Y_T
Output, V_S	0.898	-0.574	-0.088	-0.123	-0.112	0.459	0.541
Labor, X_L	1.898	-1.574	-0.088	-0.123	-0.112	0.459	0.541
Animal input, X_A	1.898	-0.574	-1.088	-0.123	-0.112	0.459	0.541
Mechanical input, X_M	1.898	-0.574	-0.088	-1.123	-0.112	0.459	0.541
Seed-fertilizer, X_F	1.898	-0.574	-0.088	-0.123	-1.112	0.459	0.541

CHAPTER VII.

MICROECONOMIC ANALYSIS OF PRODUCTION BEHAVIOR OF MALAYSIAN FARMS: LESSONS FROM MUDA*

MOKHTAR TAMIN

From the colonial era until recently, West Malaysia has relied heavily on rice imports. Thus, by 1957 when West Malaysia attained her independence from the United Kingdom, 44 percent of domestic requirements were imports. Within the framework of the post-independence policy of rice self-sufficiency, the new administration implemented a program which included: (1) heavy infrastructure investment, (2) manipulation of input and output prices, (3) research, and (4) agricultural extension and institution-building. The objective of the program was three-fold: to increase the welfare of the Malay rice farmers, to save foreign, exchange, and to reduce the risk attached to overdependence on foreign sources of rice.

The program resulted in a remarkable increase in the rate of self-sufficiency in rice from 56 percent in 1955-56 to an all-time high of 93 percent in 1974-75. This change was made possible mainly by a dramatic increase in off-season production, which now accounts for 40 percent of the total.

Under these changing conditions, the rice sector of West Malaysian agriculture has taken on a increasingly important role economically, socially, and politically. The success or failure of government intervention in increasing production and farmers' welfare must necessarily depend on the response of economic agents, be they farm households or enterprises in the private sector. At the very least, any government intervention policy in these areas must be concerned with farmer responses to input and output price changes. More specifically, the Malaysian government instituted a guaranteed minimum paddy-price policy as well as a fertilizer-subsidy program to promote the domestic production of rice. The guaranteed minimum paddy price fluctuated between 12 and 17 Malaysian dollars (M$)[1] 1 per *pikul* (1 pikul = 133 lbs.) during the period 1949-76. The fertilizer subsidy rate fluctuated between 10 and 50 percent during the period 1961-76. The determination of a combination of guaranteed minimum price and the fertilizer-subsidy rate requires a knowledge of output supply and input demand responses of farmers to own as well as cross prices.

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* This article is based on the author's Ph.D. dissertation, Food Research Institute, Stanford University, 1978. The author would like to express thanks to the members of his committee, and especially to Professors Yotopoulos and Lau, for their help.

[1] The exchange rate for 1973 was M$2.54/US$1.

One of the implicit objectives of the rice self-sufficiency program is to improve the welfare of poor rice farmers. The income transfer that the policy entails has seldom been explicitly expounded, but tenants and small farmers have been singled out for special consideration. Thus, past credit and input subsidy programs tended to favor these groups. As Goldman (1975) pointed out, 33 percent of the farmers own about 60 percent of the land, and about 47 percent are either pure tenants or rent a major part of the land they cultivate. Furthermore, about 40 percent of the farmers belong to the small farm category, that is, operate less than 3 acres. Programs designed to help such disadvantaged farmers have often been alleged to favor income equity at the expense of productivity. Whether this is true depends on, among other things, the relative technical and price efficiency between different groups of farms.

In this chapter, both issues of price response and relative efficiency between owner and tenant farms are investigated within the framework of profit functions.

THE MODEL AND THE DATA

The production behavior of the farm houshold is central to the two policy issues discussed above. In this chapter, it is studied by applying the profit-function approach to cross-sectional survey data. Various other methodological approaches were considered including the often used production-function approach, the Nerlovian supply-response approach, and the linear programming method of obtaining the normative output supply and input demand curves. Lau and Yotopoulos's profit function approach was chosen (Lau and Yotopoulos, 1971, 1972; Yotopoulos and Lau, 1973). The choice has a number of distinct advantages, which have been fully considered elsewhere in this volume.

The data were obtained from a cross-sectional survey of farm households in the Muda Irrigation Region in February and April 1973. Paddy cultivation is the main occupation of over 50,000 households in the area which accounts for about 30 percent of the paddy land in West Malaysia and for almost 50 percent of the total paddy output. A standard cross-section sampling procedure was adopted using the FAO/IBRD/MUDA sampling frame.[2] Essentially a three-stage sampling procedure was followed: (1) the selection of survey districts, (2) the selection of villages, and (3) the selection of farm households. The sample breakdown is shown in Table 7.1, wherein a farmer is classified as an owner if he owns more than 50 percent of the land he cultivates. On this basis, 54 percent of farm households may be classified as owner households and 46 percent as tenant households.

EMPIRICAL SPECIFICATION

The Cobb-Douglas form of the normalized restricted profit function in four

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[2] The FAO/IBRD/MUDA, a joint project of the Food and Agriculture Organization of the United Nations, the World Bank, and Muda Agricultural Development Authority, survey of 534 double-cropping farm households carried out during the 1972-73 crop year involved weekly farm visits to obtain both farm management and household consumption data.

variable inputs, two fixed inputs, and seven dummy variables is given in a form analogous to Equation (3.1):

$$ln\,\Pi^* = ln\,A^* + \alpha_1^*\,ln\,w_1 + \alpha_2^*\,ln\,w_2 + \alpha_3^*\,ln\,w_3 + \alpha_4^*\,ln\,w_4 + \beta_1^*\,ln\,Z_1 + \beta_2^*\,ln\,Z_2 + \sum_{i=1}^{7} d_i^* D_i, \tag{7.1}$$

where Π^* is normalized restricted profit; A^* is intercept; w_1 is normalized labor wage rates in Malaysian dollars (M$) per man-day; w_2 is normalized animal input price in M$ per eight-hour day; w_3 is normalized mechanical input price in M$ per hour; w_4 is normalized price of fertilizer in Malaysian cents per pound of nutrients; Z_1 is quantity of land in acres; Z_2 is quantity of fixed assets in M$; D_1 is tenurial dummy with owner operators taking on the value of one and others zero; D_2 is tenurial dummy with tenants taking on the value of one and all others zero; D_3 is soil type dummy with nonacid soil taking the value of one and all others zero; D_4 is district dummy with farms in district 0213 taking the value of one and all others zero; D_5 is district dummy with farms in district 0205 taking the value of one and all others zero; D_6 is district dummy with farms in district 0208 taking the value of one and all others zero; and D_7 is dummy variable with farms reporting the use of agrichemicals such as insecticides and weedicides taking the value of one and all others zero.

The four variable factors share equations are as follows:

$$-\frac{w_1X_1}{\Pi^*} = \alpha_1^{**}, \tag{7.2}$$

$$-\frac{w_2X_2}{\Pi^*} = \alpha_2^{**}, \tag{7.3}$$

$$-\frac{w_3X_3}{\Pi^*} = \alpha_3^{**}, \tag{7.4}$$

and

$$-\frac{w_4X_4}{\Pi^*} = \alpha_4^{**}, \tag{7.5}$$

where X_1 is total labor days; X_2 is total animal days; X_3 is total hours of mechanical input; and X_4 is total quantity of fertilizer nutrients in pounds. Equation (7.1), which is the normalized restricted profit function, and Equations (7.2) through (7.5), which are the factor-share equations, are jointly estimated.

The hypothesis that farmers maximize profit can be tested by comparing, as in preceding chapters, the variable factor coefficients from the normalized restricted profit function (7.1) with their respective conterparts in the factor-demand Equations (7.2) through (7.5), denoted by α_i^* and α_i^{**} $= 1, \ldots, 4$. The statistical estimation procedure comprises two stages, namely the unrestricted stage, whose parameters will be used for the tests of profit maximization and

TABLE 7.1.—SAMPLE BREAKDOWN BY FARM SIZE AND TENURE*
(Number of farm households)

	Tenure		
Farm size	Owner	Tenant	Total
Small $\leqq$ 3.00 acres	72	68	140
Large $>$ 3.00 acres	112	98	210
Total	184	166	350

*Mokhtar Tamin (1978), "Rice Self-Sufficiency in West Microeconomic Implications," Ph.D Dissertation, Stanford University, Stanford.

constant returns to scale, and the restricted stage in which both the profit-maximization restrictions, $\alpha_i^* = \alpha_i^{**}$, and the constant-returns-to-scale restriction, $\beta_1^* + \beta_2^* = 1$, are imposed if found to be valid.

ESTIMATION OF THE PROFIT AND FACTOR-DEMAND FUNCTIONS AND HYPOTHESIS TESTING

The results of the Zellner's unrestricted efficient parametric estimates are presented in column (3) of Table 7.2. The null hypotheses of profit maximization and constant returns to scale are then tested and the results are presented in Table 7.3. Both hypotheses cannot be rejected at a 0.01 level of significance. The restrictions implied by these two hypotheses are then imposed on the estimation procedure, resulting in estimates which are presented in columns (4) and (5) of Table 7.2.

In order to study price response the output supply and variable factor-demand functions have to be derived first. They are given by:

$$\begin{aligned} ln\, Y_s^* = {} & ln\left(1 - \sum_{i=1}^{4} \alpha_i^*\right) + ln\, A^* + \alpha_1^*\, ln\, w_1' + \alpha_2^*\, ln\, w_2' + \alpha_3^*\, ln\, w_3' \\ & + \alpha_4^*\, ln\, w_4' + \beta_1^*\, ln\, Z_1 + \beta_2^*\, ln\, Z_2 - \sum_{i=1}^{4} \alpha^*\, ln\, p_o; \end{aligned} \tag{7.7}$$

$$\begin{aligned} ln\, X_1^* = {} & ln(-\alpha_1^*) + ln\, A^* + (\alpha_1^* - 1) ln\, w_1' + \alpha_2^*\, ln\, w_2' + \alpha_3^*\, ln\, w_3' \\ & + \alpha_4^*\, ln\, w_4' + \beta_1^*\, ln\, Z_1 + \beta_2^*\, ln\, Z_2 + \left(1 - \sum_{i=1}^{4} \alpha_i^*\right) ln\, p_o. \end{aligned} \tag{7.8}$$

where the w_i's and p_o are nominal prices of the variable inputs and output.

Similarly by appropriate substitution the demand functions for X_2^*, X_3^* and X_4^* can be obtained. Using parameters in column (5) of Table 7.2, the own- and cross-price elasticities for output supply and factor demand are obtained. These elasticities are presented in Table 7.4.

It can be seen from Table 7.4 that the output supply is rather inelastic (0.417) with respect to the price of output. Thus, a 10 percent increase in the price of output can be expected to increase output supply only by a little over 4 percent. The cross-price elasticities of output supply are much lower even though statistically significant. Among the variable inputs, labor wage appears to be relatively the most important. A 10 percent decrease in labor wage rate would result in a 2.5 percent increase in output supply. The output supply response with respect to the price of fertilizer is quite low—only -0.08. Thus, a 10 percent decrease in the price of fertilizer can be expected to increase supply by less than 1 percent. This evidence suggests that the fertilizer subsidy program may not be very effective in raising output supply, whatever effects it may have on the income distribution. The output supply elasticities with respect to the price of animal input and mechanical input are lower still. This is a direct consequence of the low production elasticities of these inputs. The dominance of the land elasticitiy of output supply indicates clearly its importance as a productivity resource.

Turning now to examine the variable factor demand elasticities, it may be observed that as in the case of the output supply elasticities, the a priori expectations of the signs of the demand elasticities are satisfied, being negative with respect to own price and positive with respect to output price and quantities of fixed inputs. Another notable feature of the factor-demand elasticity estimates is the negativity of the cross-price elasticities which may at first glance suggest that all the variable factors are complements. However, this result is built into the Cobb-Douglas production-function model through its restrictive elasticity of substitution between the factors. Another built-in feature of the variable factor demand functions is the magnitude of the own-price elasticities, all of which are greater than -1.0 with labor relatively the most elastic at -1.254 and animal input relatively the least elastic at -1.024. The Cobb-Douglas specification of the normalized restricted profit function also leads to the expected magnitude of the output price elasticities of variable input demand, each of which is in excess of unity at around 1.4. This indicates that demand for variable inputs is strongly influenced by output price. More specifically, a 10 percent increase in the price of output can be expected to result in a 14 percent increase in the demand for the variable inputs, while the same increase in own-input price can be expected to be accompanied by a 12.5, 10.2, 10.6, and 10.8 percent decrease in the demands for labor, animal input, mechanical input, and fertilizers, respectively. The input demand responses with respect to land acreage are relatively elastic at 0.9, while those with respect to fixed assets are very inelastic at around 0.07.

RELATIVE ECONOMIC EFFICIENCY BETWEEN OWNERS AND TENANTS

In order to assess the effect of discriminating subsidy programs on the overall efficiency of the rice-producing sector, the profit-function approach is used to estimate the relative economic efficiency between owner-farm households and tenant-farm households. This is done separately for large farms (more than 3 acres) and small farms (less than or equal to 3 acres).

The methodology used is analogous to that employed in Chapter 3 for testing

TABLE 7.2.—COBB-DOUGLAS PROFIT AND FACTOR-DEMAND FUNCTIONS

		Estimated coefficients[a]		
			Restricted	
Variable (1)	Parameter (2)	No restrictions (3)	Profit maximization (4)	Profit maximization and constant returns (5)
Profit function				
Constant	$\ln A^*$	8.189*	8.606*	8.462*
		(22.206)	(63.500)	(94.430)
Labor	α_1^*	-0.175	-0.255*	-0.254*
		(-2.984)	(-34.793)	(-34.742)
Animal input	α_2^*	-0.119*	-0.025	-0.024*
		(-1.925)	(-22.173)	(22.062)
Mechanical input	α_3^*	0.039	-0.626*	-0.062*
		(-1.925)	(-36.914)	(-36.710)
Fertilizer	α_4^*	-0.066*	-0.076*	-0.076*
		(-1.716)	(-48.743)	(-48.632)
Land	β_1^*	0.923*	0.917*	0.927*
		(35.980)	(40.334)	(43.556)
Fixed assets	β_2^*	0.064*	0.052*	0.073*
		(22.403)	(20.372)	(34.206)
Dummy variables[b]	d_{xi}^*			
Sum of β_i^*		0.988	0.969	1.000

Factor equations				
Labor	α_1^{**}	-0.258*	-0.255*	-0.254*
		(-34.783)	(-34.796)	(-34.742)
Animal input	α_2^{**}	-0.025	-0.025	-0.024
		(-26.907)	(-22.176)	(-22.062)
Mechanical input	α_3^{**}	-0.063*	-0.063*	-0.062*
		(-37.964)	(-36.918)	(-36.716)
Fertilizer	α_4^{**}	-0.076*	-0.076*	-0.076*
		(-50.172)	(-48.743)	(-48.632)

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[a] Figures in parentheses are computed t-ratios (N = 350). Asterisks indicate significance at the 0.05 level.

[b] To save space the values of the coefficients of the dummy variables have not been reported.

TABLE 7.3.—STATISTICAL HYPOTHESIS TESTED

Maintained hypothesis	Tested hypothesis	Computed F	Critical $F_{0.01}$
Profit maximization	Profit maximization[a]	F(4,1732) = 2.60	F(4,∞) = 3.32
	Constant returns[b]	F(1,1732) = 0.24	F(1,∞) = 6.63
	Constant returns[c]	F(1,1736) = 0.91	F(1,∞) = 6.63

[a] There are four restrictions implied by the hypothesis of profit maximization, $\alpha_1^* = \alpha_1^*$, $\alpha_2^* = \alpha_2^*$, $\alpha_3^* = \alpha_3^*$, and $\alpha_4^* = \alpha_4^*$

[b] The restriction implied by the hypothesis of constant returns to scale is $\beta_1^* + \beta_2^* = 1$

[c] This hypothesis implies both sets of restrictions applicable for profit maximization and constant returns.

the absence of structural change. In addition, the possibility that the technical and/or price-efficiency parameters may differ between owner farms and tenant farms is explicitly allowed. The system of equations may be written as

$$\begin{aligned} \ln \Pi^* = {} & \ln A^* + \delta_o^* \ln D_1 + \sum_{i=1}^{4} \alpha_i^* \ln w_i + \sum_{i=1}^{2} \beta_i^* \ln Z_i \\ & + \sum_{i=3}^{7} d_i^* D_i, \end{aligned} \tag{7.9}$$

and

$$-\frac{w_i X_i}{\Pi^*} = \alpha_{i1}^* D_1 + \alpha_{i2}^* D_2, i = 1, \dots, 4. \tag{7.10}$$

The hypothesis of equal price efficiency implies and is implied by the restrictions $\alpha_{i1}^* = \alpha_{i2}^*$, $i = 1, \dots, 4$. The hypothesis of equal relative economic efficiency implies and is implied by the restriction $\delta_o^* = 0$. The hypothesis of equal technical *and* price efficiency implies and is implied by the restrictions $\delta_o^* = 0$ *and* $\alpha_{i1}^* = \alpha_{i2}^*$, $i = 1, \dots, 4$. Finally, the hypothesis of absolute price efficiency of the j^{th} group of farms implies $\alpha_{ij}^* = \alpha_i^*$, $i = 1, \dots, 4$. These hypotheses are tested separately for the large and small farms and are reported in Tables 7.5 and 7.6.

The results indicate that no statistically significant difference exists between either technical or price efficiencies of owner and tenant farms.[3] This conclusion is true for both large and small farms. The implication of this finding indicates that based on efficiency considerations alone there is no reason to prefer either form of farm organization. Any such preference will need to be argued on the basis of equity considerations.

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[3] Although at the 5 percent level of significance it is possible to reject the hypothesis of equal relative economic efficiency for the small farms.

Table 7.4.—Computed Elasticities of Output Supply and factor Demand

	Exogenous						
Endogenous	$ln\ p_0$	$ln\ w_1$	$ln\ w_2$	$ln\ w_3$	$ln\ w_4$	$ln\ Z_1$	$ln\ Z_2$
Output supply, $ln\ Y_s^*$	0.417	-0.255	-0.025	-0.062	-0.076	0.927	0.073
Labor demand, $ln\ X_1^*$	1.417	-1.255	-0.025	-0.062	-0.076	0.927	0.073
Animal input demand, $ln\ X_2^*$	1.417	-0.255	-1.025	-0.062	-0.076	0.927	0.073
Mechanical input demand, $ln\ X_3^*$	1.417	-0.025	-0.025	-1.062	-0.076	0.927	0.073
Fertilizer demand, $ln\ X_4^*$	1.417	-0.255	-0.025	-0.062	-1.076	0.927	0.073

TABLE 7.5.—STATISTICAL HYPOTHESES: RELATIVE EFFICIENCY OF LARGE OWNERS VERSUS LARGE TENANTS

Null hypotheses	Computed F	Critical $F_{0.01}$
Equal relative economic efficiency[a]	$F(1,1727) = 1.547$	$F(1,\infty) = 6.63$
Equal price efficiency[b]	$F(5,1727) = 1.415$	$F(4,\infty) = 3.32$
Equal technical and price efficiency[c]	$F(5,1727) = 1.306$	$F(5,\infty) = 3.02$
Absolute price efficiency[d]	$F(4,1731) = 2.619$	$F(4,\infty) = 3.32$

[a] The hypothesis of equal relative economic efficiency implies the restriction $\delta_o^* = 0$.

[b] The hypothesis of equal price efficiency implies the restriction $\alpha_{i1}^* = \alpha_{i2}^*$ for $i = 1, \ldots, 4$.

[c] The hypothesis of equal technical and price efficiency implies the restrictions $\delta_o^* = 0$ and $\alpha_{i1}^* = \alpha_{i2}^*$ for $i = 1, \ldots, 4$.

[d] Absolute price efficiency is tested under the maintained hypothesis of equal price efficiency. For the j^{th} group of farms it implies the restriction $\alpha_{ij}^* = \alpha_i^*$, for $i = 1, \ldots, 4$.

TABLE 7.6.—STATISTICAL HYPOTHESES: RELATIVE EFFICIENCY OF SMALL OWNERS VEESUS SMALL TENANTS

Null hypotheses	Computed F	Critical $F_{0.01}$
Equal relative economic efficiency[a]	$F(1,1727) = 4.122$	$F(1,\infty) = 6.63$
Equal price efficiency[b]	$F(4,1727) = 1.665$	$F(4,\infty) = 3.32$
Equal technical and price efficiency[c]	$F(5,1727) = 1{,}410$	$F(5,\infty) = 3.02$
Absolute price efficiency[d]	$F(4,1731) = 2.782$	$F(4,\infty) = 3.32$

[a] The hypothesis of equal relative economic efficiency implies the restriction $\delta_o^* = 0$.

[b] The hypothesis of equal price efficiency implies the restriction $\alpha_{i1}^* = \alpha_{i2}^*$ for $i = 1, \ldots, 4$.

[c] The hypothesis of equal technical and price efficiency implies the restrictions $\delta_o^* = 0$ and $\alpha_{i1}^* = \alpha_{i2}^*$ for $i = 1, \ldots, 4$.

[d] Absolute price efficiency is tested under the maintained hypothesis of equal price efficiency. For the j^{th} group of farms it implies the restriction $\alpha_{ij}^* = \alpha_i^*$, for $i - 1, \ldots, 4$.

TABLE 7.7.—DIRECT AND INDIRECT ESTIMATES OF THE ELASTICITIES OF THE PRODUCTION PUNCTION*

Variables	Elasticities (indirect)	Elasticities (direct)[a]	Barnum and Squire elasticies (direct)[b]
Labor, X_1	0.180	0.182[c] (4.785)	0.290[c] (0.070)
Animal services, X_2	0.017	0.027 (1.412)	
Mechanical services, X_3	0.044	0.064[c] (3.351)	
Fertilizer, X_4	0.054	0.337[c] (17.220)	
Land, Z_1	0.654	0.412[c] (8.831)	0.620 (0.070)[c]
Fixed assets, Z_2	0.051	0.049[c] (2.725)	0.010 (0.030)
Other variable inputs			0.080[c] (0.030)
Sum of elasticities	1.000	1.071	1.000

*Data for the last column are from Howard H. Barnum and Lyn Squire (1976), "Aggregation, Labor Heterogeneity and Agricultural Production Functions," Development Economics Department, World Bank, Washington, D.C., unpublished papers.

[a] Figures in parentheses are t-statistics.

[b] Figures in parentheses are estimated standard errors.

[c] Significant at the 0.05 level.

DIRECT AND INDIRECT ESTIMATES OF PRODUCTION ELASTICITIES

For comparison purposes the direct and indirect estimates of production elasticities are presented in Table 7.7, as well as the estimates obtained by a contemporary study of the same irrigation region (Barnum and Squire, 1976). The most obvious feature of the table is the dominance of the output elasticity with respect to land at 0.654 compared to the next highest, which is labor at 0.180. The other estimates are all very low, ranging from 0.017 for animal services to 0.051 for fixed capital. This implies that land is the most important source of productivity, followed by labor. It should be noted, however, that for fertilizer and land the direct and indirect estimates differ substantially. The indirect estimates are preferable because of the possible existence of simultaneous equations bias in the direct estimates, although one should bear in mind that the direct and indirect estimates are obtained under two different stochastic specifications.

SUMMARY AND CONCLUSIONS

The results of this study provide some insight into the response of output supply and factor demand to various incentives. The results validate the assumption that farmers behave rationally according to profit-maximization principles, given the price regimes of output and variable inputs and given the quantities of fixed factors. This is in itself an important conclusion. Moreover, constant returns to scale in all inputs are found to exist. This finding has direct relevance on land policy since it precludes the concept of the optimum farm size.

The own-price elasticity of output supply is quite low and the fertilizer price elasticity of output supply is very small indeed. This estimate suggests that both the output price support and fertilizer price subsidy programs deserve to be reexamined. In particular, the latter program may not be an effective instrument for raising output.

Finally, no statistically significant difference in relative technical and price efficiencies can be found between owner farms and tenant farms. Thus, based on efficiency considerations alone, there is no reason to prefer one form of farm organization over the other.

CHAPTER VIII.

ECONOMIC EFFICIENCY OF AGRICULTURAL PRODUCTION IN NORTHEAST CHINA, CIRCA 1940*

LAWRENCE J. LAU, RAMON H. MYERS,
AND ERWIN C. CHOU

The agricultural sector has always loomed large in the Chinese economy. Even today, fully 800 million out of a total population of 958 million live in the rural areas and are dependent on agriculture for their livelihood. The agricultural sector accounts for between 25 and 35 percent of the gross domestic product and a much higher percentage of personal consumption. Thus, whether or not agricultural production is carried out efficiently has a substantial effect on both the level of the gross domestic product and the standard of living of the population.

The leading issues in Chinese agriculture are not substantially different from those of any other developing country. Are inputs efficiently utilized? Are there economies of scale in agricultural production? Is the agricultural sector responsive to changes in incentives? Are there identifiable inefficiencies in the institutional arrangements? Many aspects of these issues can be analyzed within a profit-function framework.

Unfortunately, data currently available on post-1949 Chinese agriculture are not sufficient for an analysis of agricultural efficiency using either the more traditional production-function approach or the profit-function approach which underlies this collection of essays. There are, however, available survey data on individual farms in various parts of China which were collected in the 1930s and 1940s. These survey data contain sufficient information for the application of the profit-function approach. In this chapter, data from a sample of 67 farms located in Northeast China collected in 1940-41 are used in the empirical analysis.

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The normalized restricted profit function employed in this chapter is assumed to be of the Cobb-Douglas form:

$$ln\,\Pi^* = ln\,A^* + \alpha_L^*\,ln\,q_L + \beta_K^*\,ln\,Y_K + \beta_T^*\,ln\,Y_T + \sum_{i=2}^{5}\delta_i R_i + \sum_{i=1}^{4}\tau_i T_i, \tag{8.1}$$

where Π^* is restricted profit (current revenue less current variable costs) normalized by the price of output; q_L is labor wage per day normalized by price of output; Y_K is quantity of capital (total number of physical units of farm structures and work animals); Y_T is total cultivated land area in Japanese *se* (= .0245 acre); R_i are regional dummy variables; and T_i are tenure-type dummy variables to be defined below. Only one variable input—labor—and two fixed inputs—capital and land—are distinguished.[1] The labor-demand function is given by

$$X_L = \frac{-\partial\Pi^*}{\partial q_L} \quad \text{or} \quad -\frac{q_L X_L}{\Pi^*} = \frac{\partial\, ln\,\Pi^*}{\partial\, ln\,q_L} = \alpha_L^*. \tag{8.2}$$

Assuming that the farms are price-takers, a test for farm profit-maximizing behavior is whether the estimated coefficient α_L^* in Equation (8.1) equals the estimated coefficient α_L^* in Equation (8.2) (for a derivation of this result, see Chapter 2). Tests for absence of tenure effect and/or regional effect is made by testing the hypothesis H_0: $\delta_i = 0$ for all i and/or H_0: $\tau_i = 0$ for all i.

Under the usual stochastic assumptions, Zellner's (1952) estimator for seemingly unrelated regressions is consistent and asymptotically efficient. This is the method of estimation used in this study.

THE DATA

The data base for this study was derived from part of a comprehensive survey undertaken by the Manchukuo Bureau for Agricultural Promotion from February 1, 1940 to January 30, 1941 (China, 1942). The study used a sample of 67 farms located in south, central, and northern Manchuria. All non-monetary items used by these farms were converted into money values by current market prices. The monetary unit is the Manchukuo *yuan* of 1940.

Total revenue is defined as the income from agricultural activities including forestry. Income from assets, interest receipts, wage income from outside employment, and other sources of income not related to agricultural activities are excluded. Labor data include total days of hired labor, total days of own (family) labor, and total cost of hired labor. By dividing the total cost of hired labor by the total days of hired labor, the wage rate in terms of yuan per day is obtained. Using this wage rate the cost of own (family) labor may be estimated and added to the cost of hired labor to obtain total labor cost for each farm. Thus, the wage rate of

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[1] To the extent that there are other variable inputs, it is assumed that they are employed in fixed proportions with output.

family labor is imputed to be the same as that of hired labor. To the extent that hired labor is concentrated in the peak agricultural season, during which the wage rate is relatively high, this procedure may overestimate the average annual wage rate of family labor. The capital figure represents the quantity of farm structures and labor animals such as mules. Land is the cultivated area farmed by each household measured in units of Japanese se. Regional distinctions consist of the given five regional groupings. Finally, there are five types of land tenure as defined below: Type 0 = households owning and farming their land; Type 1 = landlord households that owned, leased, and rented land, but farmed only a part of the land they owned and/or rented; Type 2 = households farming land they owned and rented in which the land they owned exceeded the land they rented; Type 3 = farms that owned and rented land in which the land they owned is less than the land they rented; and Type 4 = farms that rented land but did not own land. Note that the tenure types correspond to the i-subscript of the tenure dummy variable in Equation (8.1).

Output prices are not available for each farm. It is assumed that output prices do not differ across farms within the same region but may differ across regions. Consequently, any differences that did occur would be captured by the regional dummy variables. Therefore, one may use money-profit and money-labor wage rate in place of the normalized profit and normalized labor wage rate in the regression equation.

Any farm with one or more of the following deficiencies was eliminated from the sample: negative profits, zero total labor costs, zero labor wage rate, zero quantity of capital, and zero cultivated land area. With the exception of the case of negative profits, all the other cases clearly indicate the existence of error or omission in the data for that farm. One is therefore justified in dropping these observations. The existence of negative profits, on the other hand, is inconsistent with profit maximization and with the Cobb-Douglas specification in particular: one cannot take the logarithm of a negative number. Negative profits may arise for many reasons—a very poor harvest, a measurement error in the wage cost, or a measurement error in the quantities of family and hired labor input. It is not possible, however, to determine the precise cause of each case of negative profits. Fortunately, the total number of farms eliminated from the sample for all cases taken together is only 6 out of 67. Any bias that may result from the omission of the 6 observations is unlikely to be severe.

EMPIRICAL RESULTS

The results of the statistical tests are reported in Table 8.1. First, the hypothesis of profit maximization is tested. The results indicate that the hypothesis of profit maximization cannot be rejected at the 5 percent level of significance. Conditional on the hypothesis of profit maximization, the hypotheses of identical technical efficiency for different land tenure arrangements and different regions are tested successively. Neither hypothesis can be rejected at the 5 percent level of significance. Finally, conditional on the hypothesis of profit maximization, the joint test for the hypothesis of identical technical efficiency for different land tenure arrangements and different regions cannot be rejected .

TABLE 8.1.—TESTS OF HYPOTHESES

Degrees of freedom	Profit maximization[a]	No tenure effects conditional on profit maximization[b]	No region effects conditional on profit maximization[c]	No tenure and region effects conditional on profit maximization[d]	Critical values	
					1 percent	5 percent
1,109	1.846				6.90	3.94
4,110		1.287			3.49	2.45
4,110			1.337		3.49	2.45
8,110				1.491	2.67	2.02

[a] The hypothesis implies one restriction, $\alpha_L^{*} = \alpha_L^{*}$.

[b] Conditional on profit maximization, the hypothesis implies an additional restriction that $\tau_i = 0$ for all i.

[c] Conditional on profit maximization, the hypothesis implies an additional restriction that $\delta_i = 0$ for all i.

[d] The hypothesis implies all three restrictions mentioned above.

Restricted regressions are then computed on the assumption that each of the hypotheses tested is valid and reported in Table 8.2. One may note that the sum of the elasticities of profit with respect to capital and land, under the hypothesis of profit maximization and no tenure and region effects, is 0.7463. This result, as shown in Lau (1978), indicates the existence of decreasing returns to scale in production. (There are constant returns to scale if $\beta_K^* + \beta_T^* = 1$.)

Finally, estimates for the implicit production-function elasticities are obtained from the profit-function elasticities with the formulae given in Lau and Yotopoulos (1971). Since the estimator of the profit-function elasticities is consistent and asymptotically efficient, so too is the implied estimator of the production-function elasticities, which are direct transformations of the profit-function elasticities. These derived estimates of the production-function elasticities are reported in the first column of Table 8.3. One can also estimate the production-function elasticities directly by regressing the natural logarithm of output on the natural logarithm of the inputs and the tenure and region dummy variables.[2] Such an ordinary least squares estimator is generally inconsistent because of simultaneous equation bias. These direct estimates are reported in the second column of Table 8.3. The two sets of estimates differ substantially in magnitude. Based on considerations of bias and asymptotic efficiency, the first set of estimates are to be preferred. However, it must be pointed out that 61 observations hardly constitute a large sample.

CONCLUSION

On the basis of the empirical findings, one can conclude that the data are consistent with the hypothesis that prewar Chinese farmers in Northeast China employed their variable inputs fairly close to the profit-maximizing levels. They are also consistent with the hypothesis that different tenure arrangements did not affect the technical efficiency of the farms.

The empirical findings, based on data almost 40 years old, are probably of limited relevance to Chinese agricultural policy today. Moreover, there is some question as to whether these results are totally representative of Chinese agriculture of the 1940s, since the sample was drawn from Northeast China alone. The growing season is shorter thus limiting multiple cropping in the Northeast, and the population-to-cultivated land ratio is more favorable than the rest of the country. These factors may seriously affect the ability to generalize of these results to the rest of China even for the 1940s.[3] Nevertheless, based on these results, one might have predicted in the 1940s that changes in the land tenure arrangements would not lead to significant changes in either the total supply of output or the demand for labor. Production and efficiency would have remained about the same. In addition, the empirical findings indicate the existence of decreasing returns to scale. This would have suggested that consolidation of farms per se, without the introduction of additional new inputs, technologies, or varieties, would not have led to any significant increase in production.

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[2] Note that the stochastic specification of such a model is in general different from that of the profit-function model.

[3] This was first pointed out to us by Professor Robert Dernberger.

TABLE 8.2.—CHINA PROFIT REGRESSIONS

	Estimated coefficients[a]					
			Restricted			
Variable	Single equation OLS	No restrictions	Profit maximization[b]	Profit maximization and no tenure effects[c]	Profit maximization and no region effects[d]	Profit maximization and no tenure and region effects[e]
Profit Function						
Constant	2.259	2.986	3.098	3.020	3.748	3.756
($\ln A^*$)	(2.680)	(6.265)	(6.578)	(6.595)	(10.246)	(10.521)
Labor	-0.434	-0.410	-0.420	-0.369	-0.404	-0.345
(α_L^*)	(-1.571)	(-2.656)	(-2.723)	(-2.455)	(-2.749)	(-2.472)
Capital	0.284	0.024	0.024	0.074	0.073	0.128
(β_K^*)	(0.942)	(0.142)	(0.143)	(0.487)	(0.445)	(0.873)
Land	0.896	0.828	0.827	0.826	0.638	0.618
(β_T^*)	(3.890)	(6.423)	(6.143)	(6.874)	(6.150)	(6.432)
Region 2	-0.306	-0.318	-0.321	-0.361		
(δ_2)	(-0.808)	(-1.502)	(-1.514)	(-1.771)		

Region 3	0.678	0.329	0.329	0.314		
(δ_3)	(1.400)	(1.214)	(1.216)	(1.276)		
Region 4	-0.663	-0.530	-0.528	-0.629		
(δ_4)	(-1.204)	(-1.721)	(-1.713)	(-2.173)		
Region 5	-0.130	-0.246	-0.245	-0.326		
(δ_5)	(-0.311)	(-1.057)	(-1.054)	(-1.479)		
Tenure 1	-0.008	0.221	0.223		0.337	
(τ_1)	(-0.018)	(0.911)	(0.918)		(1.497)	
Tenure 2	-0.198	0.025	0.027		0.094	
(τ_2)	(-0.601)	(0.138)	(0.146)		(0.541)	
Tenure 3	-0.101	-0.138	-0.139		-0.097	
(τ_3)	(-0.243)	(-0.596)	(-0.603)		(-0.433)	
Tenure 4	-0.743	-0.580	-0.580		-0.557	
(τ_4)	(-1.327)	(-1.850)	(-1.850)		(-1.898)	
Factor equation						
Labor	-6.027	-6.027	-0.420	-0.369	-0.404	-0.345
(α_L^*)	(-1.467)	(-1.491)	(-2.723)	(-2.455)	(-2.749)	(-2.472)

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[a] Numbers in parentheses are asymptotic t-ratios.

[b] The hypothesis implies one restriction, $\alpha_L^* = \alpha_L^*$.

[c] Conditional on profit maximization, the hypothesis implies an additional restriction that $\tau_i = 0$ for all i.

[d] Conditional on profit maximization, the hypothesis implies an additional restriction that $\delta_i = 0$ for all i.

[e] The hypothesis implies all three restrictions mentioned above.

TABLE 8.3.—PRODUCTION-FUNCTION ELASTICITIES

	Indirect	Direct
Labor	0.256	0.556
Capital	0.095	0.046
Land	0.460	0.317

The events of the 1950s bore out both of these predictions. In the early 1950s, Chinese agriculture went through a rapid succession of institutional transformations from individual farms, to mutual aid teams, to elementary producers' cooperatives, to advanced producers' cooperatives, and to communes. The view of many scholars of Chinese agriculture is that agricultural productivity was not enhanced by these reorganizations per se. Instead, increases in output were mostly brought about by increases in inputs—initially in cultivated land area and labor input and then in chemical fertilizer and tractor input.

The empirical evidence is also consistent with the hypothesis that the individual Chinese farmers included in the sample maximized profits. This implies first, that the Chinese farmers utilized their inputs efficiently and, second, that they did respond to price incentives. Today the incentive problem has remained an important one for Chinese agriculture. In many different areas in China, farmers appear preoccupied with cultivation of their own individual private plots and not the communal land. This widespread phenomenon may be regarded as yet another manifestation of the response of Chinese farmers to incentives.

The above discussion must be qualified in two ways. First, while land-tenure arrangements did not seem to have significant effects on agricultural productivity, they did have significant adverse effects on the income distribution. Hence, the post-1949 changes in the agricultural institutions probably led to substantial improvements in the equality of income distribution, at least at the local level. One might therefore justify these reorganizations on purely equity grounds. Second, the investment behavior of the farmers was not analyzed because of inadequate data. The level of investment, which would affect the level of fixed capital, might well be sensitive to the form of the land-tenure arrangements. In this regard the post-1949 changes in the agricultural institutions might have affected investment in at least two ways. First, there was greater central control over the distribution of the output between consumption and investment. Second, they provided the framework with which labor could be mobilized for large-scale agricultural investment projects.

However, the effects of all the institutional changes on technical efficiency, that is, the quantity of output for *given* quantities of inputs, is at best ambiguous. Further analysis is needed. If individual establishment data of the type used here ever became available for the post-1949 period, it might then be possible to reach a more definitive conclusion.

CHAPTER IX.

SUMMARY AND CONCLUSIONS

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Judging from the results of the preceding chapters, it is clear that the profit-function approach provides a useful tool for the analysis of the determinants of agricultural production. The data bases used in the preceding chapters are drawn from both developed and developing economies. Geographically they range from one end of Asia to the other. Temporally they range from the 1940s to the 1970s. And in terms of population densities they range from low to very high. Thus the studies span many different agricultural environments. Yet despite this diversity in the data bases, the profit-function approach appears to have worked well for all of the studies. It is especially encouraging that the estimated coefficients in all of these studies are consistent with a priori expectations with regard to both signs and magnitudes.

THE HYPOTHESIS OF PROFIT MAXIMIZATION

One hypothesis which is central to the economic theory of production is profit maximization on the part of the individual firm. The profit-function approach is ideally suited for the testing of this hypothesis. In each of the studies included in this volume, the hypothesis of profit maximization is explicitly tested. The results are summarized in Table 9.1.

The entries in the outcome column of Table 9.1 represent the decisions made by the respective authors with regard to their particular test. The results of course are not directly comparable since the choice of an overall level of significance as well as its allocation among different hypotheses differ from study to study. For the benefit of readers who may wish to use different levels of significance for the test of the hypothesis of profit maximization, the critical values of $F(m, \infty)$ corresponding to levels of significance equal to .1, .05, and .01 are presented in Table 9.2.

Entries in Tables 9.1 and 9.2 indicate that at the .01 level of significance the hypothesis of profit maximization cannot be rejected for any of the six studies. At the .05 level of significance, the hypothesis of profit maximization can be rejected for Japan, Malaysia, and Turkey. The choice of the level of significance is of course somewhat subjective, being a compromise between tolerating Type I and Type II errors. Since the hypothesis of profit maximization is so fundamental to economic theory, it is better to err on the conservative side, that is, to allocate

Table 9.1.—Tests of the Hypothesis of Profit Maximization

Country	Time period	F-Statistic	Outcome
China	1940-41	F(1,109) = 1.85	Do not reject
Japan	1965	F(4,336) = 2.68	Do not reject
Malaysia	1973	F(4,132) = 2.60	Do not reject
Taiwan	1967	F(4,177) = 2.08	Do not reject
	1968	F(4,182) = 1.79	Do not reject
Thailand	1973	F(4,139) = 2.21	Do not reject
Turkey	1976	F(3,338) = 2.84	Do not reject

Table 9.2.—Critical Values of F(m,∞)

	Levels of significance		
Numerator degrees of freedom m	0.1	0.05	0.01
1	2.71	3.84	6.63
2	2.30	3.00	4.61
3	2.08	2.60	3.78
4	1.94	2.37	3.32

Table 9.3.—Tests of the Hypothesis of Constant Returns to Scale

Country	Time period	F-statistic	Outcome
Japan	1965	F(1,336) = 8.17	Reject
Malaysia	1973	F(1,173) = 0.24	Do not reject
Taiwan[a]	1967	F(1,181) = 0.30	Do not reject
	1968	F(1,186) = 0.71	Do not reject
Thailand[a]	1973	F(1,143) = 1.50	Do not reject
Turkey	1976	F(1,338) = 11.51	Reject

[a] The test results reported here are conditional on the validity of the hypothesis of profit maximization which cannot be rejected for the respective studies.

lower levels of significance for its test. Based on the results reported in this volume, one may conclude that the hypothesis of profit maximization is supported by the data.

THE HYPOTHESIS OF CONSTANT RETURNS TO SCALE

A second leading hypothesis in the economic theory of production is whether there are constant returns to scale. It is a property of the normalized restricted profit function that if the production function is characterized by constant returns to scale in all inputs, variable and fixed, then the normalized restricted profit function is characterized by constant returns to scale in the fixed inputs, and vice versa. This implies that if all the fixed inputs are doubled holding all normalized prices constant, normalized restricted profits will be doubled. In the Cobb-Douglas profit-function case, the test of the hypothesis of constant returns to scale consists in checking whether the sum of the elasticities of normalized profit with respect to the fixed inputs is unity. Although an F-statistic is used to test for constant returns to scale, it would be equally possible to use a t-statistic for two-tailed test.

Whether there are substantial increasing returns to scale in agricultural production is an extremely important determinant of the optimum form of organization for agricultural production. For example, if there are increasing returns to scale, then the economic argument for consolidation of plots and farms will be quite strong. On the other hand, if there are constant or decreasing returns to scale in agricultural production, then consolidation will have to be argued on other than productivity grounds. Of course other, possibly noneconomic, considerations may be relevant in the choice of an optimum form of organization for agricultural production.

In five of the studies included in this volume, the hypothesis of constant returns of scale is explicitly tested. The results are summarized in Table 9.3. The entries in the outcome column of Table 9.3 again represent the decisions made by the authors with regard to their particular test, and hence are subject to the same criticism of noncomparability as discussed earlier in connection with Table 9.1. As before, the reader may wish to use different levels of significance and may consult Table 9.2 for the critical values of the test statistics.

The results of the tests of the hypothesis of constant returns to scale indicate that the hypothesis cannot be rejected for Malaysia, Taiwan, and Thailand at almost any reasonable choice of levels of significance. However, the hypothesis can be rejected for Japan and Turkey, again at almost any reasonable choice of levels of significance. It is noteworthy that in the case of Japan, the empirical evidence suggests increasing returns to scale, whereas in the case of Turkey, the empirical evidence suggests decreasing returns to scale. It is not immediately apparent why there are such differences in the scale effects. One possible explanation for the Japanese case may be her greater degree of mechanization, which may have substantial scale economies. And one possible explanation for the Turkish case may be the relative scarcity of unmeasured inputs such as irrigation. However, whether these ad hoc explanations are valid can be determined only by

TABLE 9.4.—INDIRECT ESTIMATES OF THE PRODUCTION ELASTICITIES

Inputs	China	Japan	Malaysia	Taiwan	Thailand	Turkey
Labor	0.26	0.28	0.18	0.44	0.30	0.02
Animal input	—	—	0.02	0.02	0.05	0.18
Mechanical input	—	—	0.04	0.00	0.07	
Chemical input	—	0.22	0.05	0.10	0.06	
Capital	0.10	0.22	0.05	0.03	0.24	0.15
Land	0.46	0.37	0.65	0.41	0.29	0.58
Total	0.82	1.09	1.00	1.00	1.00	0.93

further in-depth examination of the agricultural technology of the countries in question. The implications on agricultural policy are of course vastly different for the different cases.

RELATIVE ECONOMIC EFFICIENCY

Another important application of the profit-function approach is in the comparison of relative economic efficiency between two groups of farms. Among the six studies included in this volume, there are four explicit comparisons of relative economic efficiency between groups of farms: for China the comparison is between farms under different land tenure arrangements; for Malaysia the comparison is between owner and tenant farms; for Taiwan the comparison is between farms of two different years; and for Turkey the comparison is between the early tillage and late tillage farms.

In each of these four cases, the authors could find no significant difference in relative economic efficiency. Thus for China differences in land-tenure arrangements did not lead to differences in either technical efficiency or price efficiency, although they probably led to substantial differences in the standard of living. Changes in the land-tenure arrangements alone could not be expected to increase either production or profits. Likewise for Malaysia neither technical nor price efficiency differ between owner and tenant farms. And for Turkey, no differences in either technical efficiency or price efficiency could be found between the early tillage and late tillage farms. In fact, no differences in either technology or behavior could be found.

These findings are consistent with the reasoning that if there were indeed significant differences in profitability among groups of farms under different land-tenure arrangements, there would be economic incentives for farms to change the land-tenure arrangements to the more profitable ones. In true equilibrium, one should observe no significant differences in profitability among groups of farms under different land-tenure arrangements which survive the test of time. The same argument applies to the comparison of relative economic efficiency between early tillage and late tillage farms. Note, however, that this argument depends on the assumption that each individual economic agent will seek out the best economic alternative.

ESTIMATES OF PRODUCTION ELASTICITIES

One advantage of the profit-function approach is that from the estimated profit elasticities one can obtain indirect estimators of the production elasticities which are statistically consistent. These indirect estimates of the elasticities are presented in Table 9.4.

It is difficult to explain the differences in the production elasticities across countries. Perhaps a detailed comparison of the natural endowments may yield some clues. It suffices to note that these indirect estimates of the production elasticities do satisfy a priori expectations with regard to sign (positive) and magnitude (less than one) and according to the respective chapters are broadly consistent with alternative estimates available from other sources. Generally, land and labor elasticities of production are larger than the other input elas-

TABLE 9.5.—ESTIMATES OF OUTPUT SUPPLY ELASTICITIES

		Independent variables		
Country	Time period	Output price	Capital	Land
China	1940-41	0.35	0.13	0.62
Japan	1965	0.98	0.28	0.73
Malaysia	1973	0.42	0.07	0.93
Taiwan	1967-68	1.25	0.07	0.93
Thailand	1973	0.90	0.46	0.54
Turkey	1976	0.52	[a]	0.88

[a] The value is not provided since capital has been defined as a variable factor of production.

TABLE 9.6.—ESTIMATES OF OWN-PRICE INPUT DEMAND ELASTICITIES

		Dependent variables	
Country	Time period	Labor	Chemical inputs
China	1940-41	-1.35	—
Japan	1965	-1.55	-1.04
Malaysia	1973	-1.25	-1.08
Taiwan	1967-68	-1.98	-1.23
Thailand	1973	-1.57	-1.11
Turkey	1976	-1.03	-1.27

ticities. The only exception is the case of Turkey, in which the estimated labor elasticity has the extremely low value of 0.02. This finding suggests a low marginal productivity of labor which may have been caused by the limitation of irrigation and of chemical input.

OUTPUT SUPPLY ELASTICITIES

From the point of view of application another advantage of the profit-function approach is the straight forward derivation of output supply elasticities. The elasticities of the supply of output with respect to the price of output and the quantities of capital and land are of substantial policy interest. They figure prominently in any discussion of price, investment, and land policy. The supply elasticities are presented in Table 9.5.

The price elasticity of output supply appears to range from low to very high. China, Malaysia, and Turkey have relatively lower price elasticities of output, as compared with the rest of the countries, while Taiwan is characterized by an elasticity greater than one. This difference in the magnitudes of the elasticity estimates is probably partly related to the degree of aggregation of the agricultural output variable. The studies of Malaysia and Turkey refer to one crop, rice and wheat, respectively. The supply of this crop given the quantity of cultivated land devoted to it, is less responsive to prices as opposed to the supply of aggregate agricultural output given the quantity of cultivated land available that is represented in the other studies. In the latter case there is the possibility of intercrop substitution even though the total cultivated land area is fixed.

The output elasticities with respect to the fixed inputs of production measure the response of price-taking, profit-maximizing firms with respect to an exogenous change in fixed factors, holding the prices of output and variable factors constant. They reflect, as a result, the mutatis mutandis situation of a firm that is allowed to adjust output and variable inputs optimally in response to a certain change in its fixed endowment. Conceptually these elasticities are different from the ceteris paribus elasticities of the production function (Table 9.4), which take the levels of the other factors of production as given. It is not surprising then that the mutatis mutandis elasticities are invariably greater than the production elasticities. In Table 9.5 the output elasticity is almost unitary with respect to land in the case of Malaysia and Taiwan and negligible with respect to capital. In Thailand, on the other hand, the output response to changes in land is not too different from that for changes in capital.

INPUT DEMAND ELASTICITIES

It is also of interest to examine the magnitudes of the own-price elasticities of demands of the variable inputs. These elasticities are presented in Table 9.6. The own-price elasticities for labor and chemical inputs are all greater than one in absolute values. This is a property of the Cobb-Douglas production-function technology under profit maximization. The absolute values of the elasticity of labor are consistently greater than those of chemical inputs, except in the case of Turkey.

CONCLUSION

The chapters in this volume, as well as other similar studies reported elsewhere, have amply demonstrated the usefulness and flexibility of the profit-function approach. It can be successfully applied to data bases drawn from diverse economic environments and can be used to address a number of important agricultural economic problems.

The range of application of the profit-function approach has by no means been exhausted. For example, it is possible to investigate whether the fixed inputs have been allocated among the farms efficiently. The partial derivative of the profit function with respect to a fixed input provides an estimate of its shadow price on the farm. If fixed inputs were efficiently allocated, its shadow price ought to be the same across all farms. Thus, it is possible to verify whether the data are consistent with this hypothesis.

It suffices to say that with the accumulated experience in its application, the profit-function approach has now become a proven method and should find increasing scope in future studies of agricultural production. One possible extension is to use more flexible functional forms for the profit function of, for example, the transcendental logarithmic function introduced by Christensen, Jorgenson, and Lau (1971, 1973), so that the assumption of unitary elasticities of substitution between all pairs of inputs can be relaxed.

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