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THE EFFECTS OF SMALL FARM MECHANIZATION ON EMPLOYMENT AND OUTPUT IN SELECTED RICE-GROWING AREAS IN NUEVA ECIJA, PHILIPPINES

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The issue of mechanization in small farms has been the center of controversy since the 1960's. Aside from whether the adoption of mechanical power has increased farm output significantly, and subsequently farm incomes, questions have to be answered with regard to its effects on rural employment. There is an immediate need to search for answers to these questions, especially in the context of a developing country like the Philippines.

Although government policies directly affect the direction and rate of farm mechanization of a particular developing country, the adoption of farm mechanical power as a substitute for manual and/or animal power poses a paradox. Several researchers (Smith and Gascon 1979; Duff, Barker and Cordova 1978) have indicated that mechanization of certain farm operations has resulted in the replacement and displacement of labor, particularly in countries where manual power is abundant and farming operations are labor intensive. However, other studies (Binswanger 1978) have shown that farm mechanization allows for more efficient farm operations which, in turn, positively affects yields as well as allows for greater intensity of land use. As a result of higher production and greater intensity of land cultivation, proponents of farm mechanization argue that the increase in the labor requirements of certain farming activities, i.e., harvesting, has an offsetting effect on the amount of labor displaced from other farm operations, such as land preparation. This implies

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that farm mechanization may alleviate the food problem that is common in most developing countries, like the Philippines, without necessarily displacing labor in the rural areas.

These schools of thought provide the background for this study which investigates the effects of mechanization of certain farm operations in selected rice-growing areas in the Philippines, using cross-section data.

Objectives and Scope of the Study

The following are the objectives of this research:

1. To develop a working definition of a mechanized rice farm operating under the conditions prevailing in the Central Luzon region, particularly Nueva Ecija, based on the types of farms within this area.
2. To determine whether significant differences between mechanized and nonmechanized rice farms, as well as among mechanized farm-types, exist.
3. To determine how various factors, including farm machinery, affect labor employment and output of small rice farms in Nueva Ecija.
4. To indicate the policy implications of these mechanization effects.

Brief Historical Review of Farm Machinery Adoption in the Philippines

The history of farm machinery adoption may be divided into two major periods: The pre-World War II and the post-World War II periods (Gonzales, Herdt and Webster 1981). The former may be described as the "introductory phase" which began during the 1890's and the latter as the "government intensification phase" which was initiated during the late 1940's and which has extended through the present. The latter period is the main concern of this study.

Although an intensified mechanization scheme was initiated by the Philippine government during the early years of the post-World War II period, the emphasis, like in the introductory phase, was still on the sugar industry. This continued until the 1950's and the early 1960's as a result of the higher price obtained from Philippine sugar exports after the United States embargoed Cuban sugar imports. The main farm machinery used in the major sugar plantations of the country were four-wheel tractors (Barker, Meyers, Crisostomo and Duff 1972). The 1960 census reported that 35 percent of the more than 5,000 tractors in the country were located in the Western Visayas and Pampanga provinces, the major sugar producing areas of the Philippines (Duff 1975).

However, during the early 1960's there was a shift in tractor utilization toward rice in response to government programs for the development of agriculture and the implementation of financing schemes to encourage farm machinery adoption. As a pre-requisite to such programs, the Central Bank (CB) of the Philippines negotiated a series of loans with the International Bank for Rural Reconstruction and Development (IBRD) for financing farmer purchase of four-wheel tractors and two-wheel tractors. This is known as the CB-IBRD credit project and has been the main source of institutional credit for farm machinery in the Philippines since 1966 through the local rural banking system. (Gonzales, Herdt and Webster 1981).

Studies conducted by Duff (1975) Sanvictores (1977) and SGV (1980) indicate that the major factor affecting the sales of four-wheel and two-wheel tractors is the CB-IBRD program. This is reflected in Figure 1 which indicates that, during a span of fourteen years, four-wheel and two-wheel tractor sales exhibited a positive relationship with the total number of loans availed of through the CB-IBRD program.

In order to better understand the trend of tractor sales during the years following 1965, Gonzales et al. (1981) divided the fourteen-year period, 1966-80, under the credit program into four subperiods: the initial phase (1966-68), the peso devaluation phase (1969-71), the recovery phase (1972-75), and the high fuel cost phase (1975-80).

The authors indicated that, due to the higher degree of intensive cultivation requirements resulting from the introduction of high-yielding varieties during the initial phase, an increase in the sales of two-wheel tractors was observed. Total tractor sales exhibited an increasing trend in this period, with two-wheel tractors showing higher sales than four-wheel tractors.

Unfortunately, a slack in the total sales of the tractor industry occurred from 1969 to 1971 in response to the peso devaluation which, in effect, made imported tractors relatively more expensive compared to previous years. This phenomenon, together with stricter

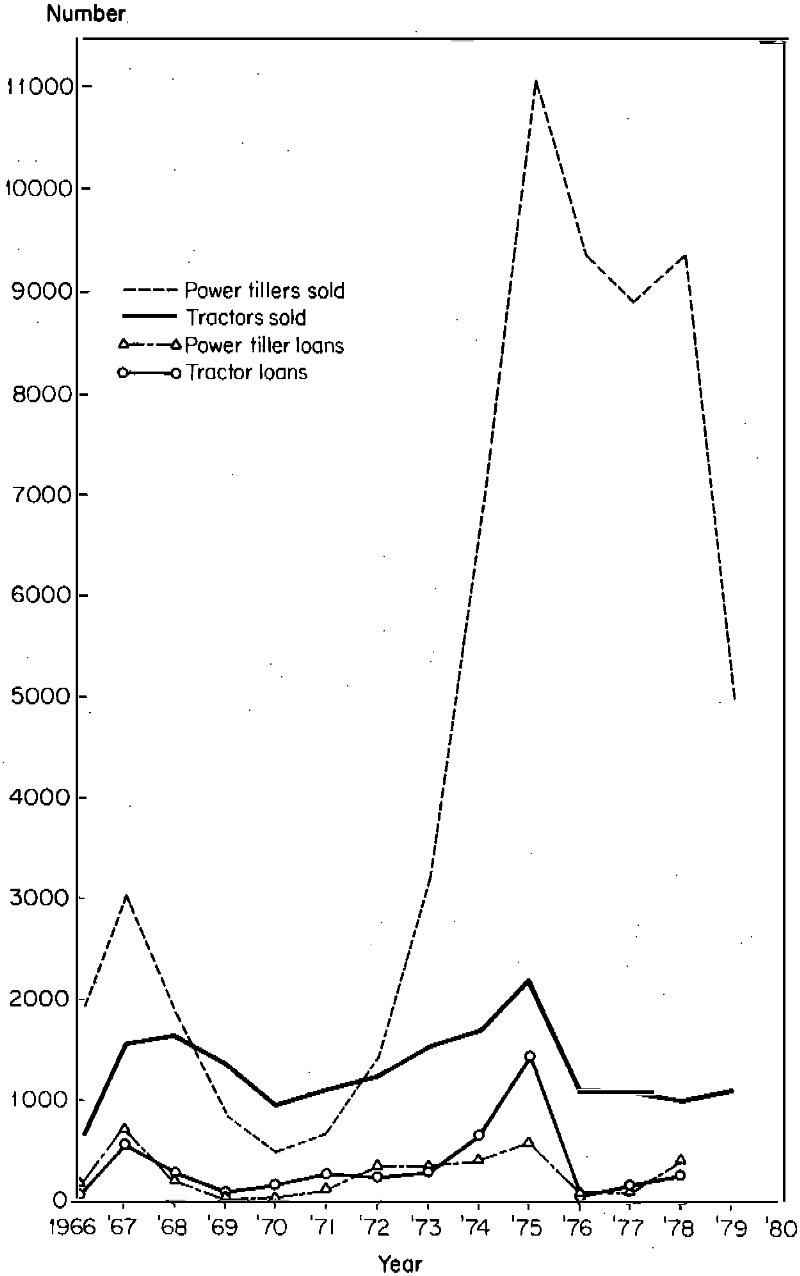

FIGURE 1

ANNUAL SALES OF TRACTORS AND TILLERS AND NUMBER OF LOANS GRANTED UNDER THE CB IBRD RURAL CREDIT PROJECTS, 1966-79 collateral requirements imposed by the rural banks on loans, resulted in fewer loans availed of during this period, thus contributing to the decrease in total tractor sales.

The period from 1972 to 1975, described as the recovery phase, exhibited increasing sales of both four-wheel and two-wheel tractors. Two-wheel tractors, in particular, showed doubling of sales for each year of this subperiod. The factors which played important roles in influencing the trend and pattern of tractor sales during these years were:

1. The fragmentation of large rice landed estates through the implementation of the land reform program which resulted in large income gains to farmer share tenants, thus increasing the demand for two-wheel tractors;

2. The incidence of the foot and mouth disease which afflicted thousands of work in animals in 1975. As a consequence, a special financing program for two-wheel tractors under the Land Bank of the Philippines and the Development Bank of the Philippines was created;

3. The manufacture of IRRI designed two-wheel tractors and the availability of financing support for locally-built farm equipment; and

4. The promulgation of General Order 47 in 1974 which expanded the market for farm machinery such as tractors and threshers;

The fourth subperiod or the high fuel cost phase, which covers the years 1975-80, exhibited annual declines in the sales of four-wheel tractors and two-wheel tractors mainly due to the high cost of fuel.

Aside from the CB-IBRD Credit Program, the government's tax/tariff policy had significant effects on the total supply pattern of farm machinery in the Philippines during the 1970's. This policy, designed to increase government revenues and to protect the local farm machinery manufacturers, initiated the imposition of an effective tax rate of 16 percent on two-wheel tractors in 1972. As a result, a decline in the importation of this type of farm machinery was observed in the following years.

As indicated by Monge (1980), the largest percentage of two-wheel tractors was in the rice producing areas of Central Luzon region with Nueva Ecija having the largest share of the total regional distribution. As of 1976, 26 percent of 6,747 two-wheel tractors were in Central Luzon. On the other hand, four-wheel tractors were concentrated in the Western Visayas region, the principal sugar producing area of the Philippines.

It is noteworthy that for the same year, "regions with high machine concentration did not necessarily have the lowest carabao numbers, implying that animal power remains an important resource in agricultural production despite widespread use of machines" (Monge 1980).

Based on such a historical background, it may be concluded that the adoption of farm machinery in Philippine rice farms was greatly affected by government policies during the past two decades, the impact of which necessitated the undertaking of this research.

Theoretical Framework

The views presented by the two schools of thought imply that mechanization of small farms has two major effects. They are: (1) labor effect — resulting from the substitution of farm mechanical power for manual and/or animal power, and (2) output effect — resulting from the upward shift of the farm specific total product curve. The latter, however, further implies a third effect — the cost effect, which arises from the downward shift of the average and marginal cost curves which, in turn, results in higher farm incomes at given input and output prices.

For the purpose of this study, the utilization of mechanical power in land preparation, i.e., seedbed preparation, plowing, harrowing, and levelling, as well as in postproduction activities, i.e., threshing, defines a mechanized rice farm. It is generally thought that farm mechanization (or mechanical technology), like biological and chemical technologies, may be considered as a form of technical change which, in turn, may enhance agricultural output growth. This implies an upward shift in the total product curves of mechanized farms, a downward shift in their cost curves, and a downward pressure on farm employment due to factor substitution. These are fully discussed in the following section.

Effects of Farm Mechanization Analysis

Based on conventional neoclassical production theory, the total amount of a particular output produced by a farm is determined by the amounts of inputs it utilizes in producing that output with a given level of technology. This relationship could be expressed in the following:

(1) $q = f(x_1, x_2, x_3, \ldots x_n \mid T)$

where: q is the level of rice output produced.

x_1 is the level of labor input employed to produce q.

x_i's are the amounts of inputs other than labor. utilized to produce q.

$i = 2, 3, \ldots, n$

T is a given level of technology.

This functional relationship suggests that as a farm varies its utilization of the necessary inputs in producing a particular output, there results a corresponding variation in the total output produced.

By varying the utilization of one input, say labor, in terms of total man-hours per hectare, while holding the level of other inputs constant at a given level of technology, the familiar production function (presented in Figure 2b by TP_L) may be obtained. In functional form, this relationship may be expressed as:

$$q = f(x_1 \mid x_2, x_3 \ldots, x_n, T)$$

Consider first the total product curve, TP_L and assume that this represents the input-output relationship of a nonmechanized rice farm. Assuming that the price of labor is given, the average and marginal cost curves corresponding to this total product curve are indicated by AC_1 and MC_1, respectively, as seen in Figure 2a. In a situation where the farm employs L_2 level of labor, the total output that will be produced by this level of employed labor is indicated by q_2. The average cost corresponding to this amount of output produced is AC_2. Suppose the amount of labor utilized by the farm is L_1, the total output produced will be q_1 while the average cost incurred in producing this level of output will be AC_1.

Let us now investigate the possible effects of mechanization in the model by introducing the assumption that the operator of the same farm has mechanized some of his farm operations such as land preparation and harvesting. By doing so, the farm's total product curve shifts upward (from TP_L, to TP_L^*) which, in turn, results in a downward shift in the cost curves. In Figure 2a, this shift is indicated

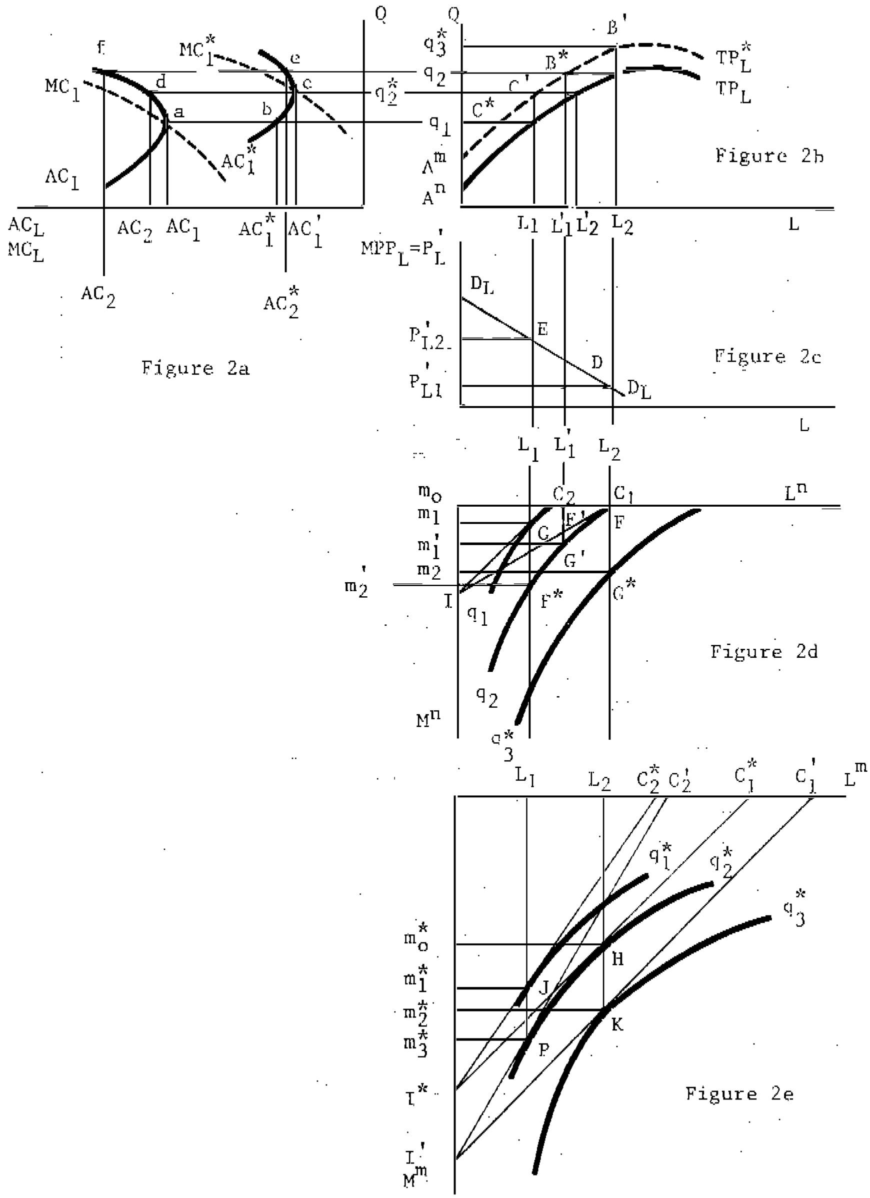

FIGURE 2
A GRAPHICAL ILLUSTRATION FOR EXPLAINING THE THEORETICAL FRAMEWORK FOR ANALYZING THE IMPACT OF MECHANIZATION ON FARM LABOR EMPLOYMENT, OUTPUT AND INCOME

by the movement of AC_1 to AC_1^*, implying greater efficiency in farm operations derived from mechanization, and MC_1 to MC_1^* which implies an increase in farm output supply. It should be noted that the adoption of farm equipment as a substitute for manual/animal power has three possible effects: output, cost and labor effects.

To illustrate the output effect, refer to Figure 2b. Assume that prior to mechanization the amount of labor utilized by the farm is L_2. This amount of labor produces q_2 level of output. With the introduction of farm machinery, more output can be produced with this same amount of labor input as indicated by q_3^*. The effect of mechanization on output, therefore, is an increase in the amount of rice produced by the farm which is equivalent to $q_2q_3^*$. Using the same line of reasoning, at L_1 level of labor input the increase in output due to mechanization is $q_1q_2^*$.

The cost effect (refer to Figure 2a) may be derived by considering a particular level of output, say q_2. Note that without mechanization, the average cost of producing this level of output is represented by AC_2. For the sake of illustration, assume that the farm under consideration adopts farm machinery for the purpose of improving the efficiency of certain farm operations. As a result, the average cost of producing the same level of output (q_2) under a mechanized scheme decreases to AC_2^*. This decrease, equivalent to $AC_2\ AC_2^*$ or FE is the cost effect of mechanization. Under conditions of constant output and factor prices, this would imply an increase in net farm income. It should be noted, however, that the upward or downward shift of the cost curves largely depends on the relative investment a particular farm has made on farm machinery.

The effect of mechanical power adoption on farm labor employment is illustrated in Figure 2d. With the aid of isoquants, which show the different level combinations of labor and mechanical power in producing a given level of output, a theoretical relationship may be established between these two factors of production. With a given level of output, such as q_2, the amount of labor input required to produce this amount is L_2 under nonmechanized operations. The introduction of farm machinery into farm operations will have a considerable impact on the level of farm employment which may be observed from the labor effect of mechanization, as shown in Figure 2d and as discussed in the following paragraphs.

It has been established that, prior to mechanization, the labor-mechanical power combination needed to produce output q_2 is

L_2m_0. This relationship is shown in Figure 2d by point F on isoquant q_2. However, under a mechanized scheme, to produce the same level of output, the total labor requirement is L_1' while the mechanical power requirement is m_1' as indicated by point G' on isoquant q_2. This implies a decrease in labor employed in the farm by as much as $L_1'L_2$ and an increase in mechanical power requirement amounting to m_0m_1'.

Based on this argument, it may be hypothesized that mechanization of small rice farms will result in:

1. an increase in farm output,
2. an increase in net farm income under conditions of constant output and factor prices, and
3. a decrease in farm labor requirements.

However, before conducting any analysis, it is worthwhile to relate the above theoretical framework to the two schools of thought regarding the impact of farm mechanization. Consider first the argument regarding farm machinery as a net contributor to total output produced as well as to total labor usage.

It was illustrated that, at initial labor input, L_2, the level of output produced under a mechanization scheme is q_3^*. As a result, output increased from q_2 to q_3^* – an increase of $q_2q_3^*$. This may be observed in Figure 2b. It may be noticed that in Figure 2d to produce q_3^* output, the labor-mechanical power combination is L_2 and m_2 which is indicated by point G^*. This implies that, in spite of farm machinery adoption, the same amount of labor is required at a higher output level. This is in line with the net contributory school of thought – that higher production results in an increase in harvesting labor requirements which, in turn, offsets the amount of displaced labor by mechanized land preparation operations.

By assuming that the adoption of mechanical technology, like biological and chemical technologies, results in shifts in a farm's production and cost curves, the subtitution view regarding farm machinery adoption may be illustrated. Holding the level of output constant at q_2, the labor-mechanical power combination under a nonmechanized scheme is L_2m_0. However, by introducing mechanical power (an amount equal to m_1') into certain farm operations, such as land preparation, less labor input is required, i.e., L_1', to produce q_2 output. This is indicated by point G_1' on isoquant q_2 in Figure 2d. In effect, an increase in mechanical power utilization of

m_0m_1' resulted in a decrease in labor input usage by an amount equal to $L_1'L_2$. This is the substitution effect of farm machinery adoption.

Effect of Price Changes on Labor Employment

In order to show the effect of factor price changes on the substitution of mechanical power for animal/manual power, it is necessary to consider the following production functions pertaining to two different farm-types, i.e., mechanized and nonmechanized farms, similar to that expressed in (2):

$$(3)\ q^m = A^m f\ (X_1^m, X_i^m \mid T^m)$$

$$(4)\ q^n = A^n f\ (X_1^n, X_i^n \mid T^n)$$

where: m refers to mechanized farms.

n refers to nonmechanized farms.

T refers to a given level of technology in each farm-type.

q is the output produced by each farm-type.

X_1 is the labor input level utilized by each farm-type.

X_i are the other inputs used by each farm-type.

For preliminary discussion purposes, first assume that both mechanized and nonmechanized farms have the same technical efficiency which implies that $A^m = A^n = A^o$ and that the slopes at any point on the total product curve are the same for both farms.[1] This implies that both farm-types operate along the same production function curve (TP_L for discussion purposes). Furthermore, assume both farm types are price efficient since they are able to equate their respective value marginal product of labor to the wage rate as indicated by points D and E (as seen in Figure 2c) which are points on the labor demand curve for both farms. It should be noted that the farms may not face the same input and output prices but are assumed to be able to equate the value of the marginal product of labor (or any other factor) to its farm-specific opportunity cost.

Under conditions of homogeneous output (or technology) and profit maximization under perfect competition, subject to a set of exogenous variables such as input and output prices, the labor

1. The assumptions used in the succeeding discussion follow those of Lau and Yotopolous (1972, pp. 11-18).

demand curve, $D_L D_L$, may be derived from the profit maximization condition:

(5) $VMP_L = P_L$

(6) $(P_q)(MPP_L) = P_L$

where: VMP_L is the value marginal product of labor.

P_L is the price of labor.

Pq is the price of output.

MPP_L is the marginal physical product of labor.

Equation (6) implies that a firm is price-efficient if it equates the value of marginal product of labor (or of each variable input) to its price. It should be noted that (6) may be further expressed as:

$$(7) \qquad MPP_L = \frac{P_L}{P_q} = P_L'$$

Equation (7) defines the labor demand curve as shown in Figure 2c which implies that an increase (decrease) in the price of labor relative to the output price results in a decrease (increase) in the labor utilization by both farms. To illustrate, assume that at output price, P_q, and labor price, P_{L1}, both farms maximize profit at point D where $VMP_L = P_{L1}$ or $MPP_L = P'_{L1}$. The amount of labor utilized by each farm at this labor price is L_2 while the amount of output produced is q_2. An increase in the price of labor from P'_{L1} to P'_{L2} will result in a reduction in labor utilization in both farm-types, which will decrease from L_2 to L_1. This reduction in labor input utilization, in turn, results in a decrease in output produced, from q_2 to q_1, for both farms.

In order to illustrate the effect of factor price changes on the substitution of mechanical power for animal/manual power, consider Figures 2d and 2e which depict the profit maximizing condition of a nonmechanized and mechanized farm, respectively, with the use of isocost and isoquant curves.

Consider first the profit maximizing output and labor input levels, q_2 and L_2 in Figure 2b. At these levels, both farm types are able to maximize profit since their respective $VMP_L = P_L$ (Figure 2c).

This profit-maximizing condition for both farms is depicted in Figures 2d and 2e. In Figure 2d, the nonmechanized farm is said to be maximizing profit at point F where its isocost line, IC_1, is tangent to isoquant, q_2. At this level of output, the total labor utilized is L_2 while the total mechanical power usage is zero. This is indicated by m_0 level of mechanical power utilization in Figure 2d. On the other hand, the profit-maximizing condition for the mechanized farm is indicated by point H, in Figure 2e, where the isocost curve $I^*C_1^*$ is tangent to isoquant curve q_2^*.

It should be noted that tangency of the isocost line to a particular isoquant implies equality in the slopes of the isocost and the isoquant. This may be expressed as:

$$(8) \qquad -\frac{\partial L}{\partial M} = \frac{P'_M}{P'_L}$$

where:

$\dfrac{\partial L}{\partial M}$ is the slope of the isoquant curve.

P'_M is the price of mechanical power normalized by output price

P'_L is the price of labor normalized by the output price.

$\dfrac{P'_M}{P'_L}$ is the slope of the isocost line.

Recall that the slope of the isoquant indicates the marginal rate of technical substitution of a particular input for another. In other words:

$$(9) \qquad \frac{\partial L}{\partial M} = \frac{MPP_M}{MPP_L} = MRTS_{ML}$$

where: MPP_M is the marginal physical product of farm machinery.

MPP_L is the marginal physical product of labor.

$MRTS_{ML}$ is the marginal rate of technical substitution of mechanical power for manual labor.

Substituting (8) into (9), the following expression may be obtained:

$$(10) \quad \frac{P'_M}{P'_L} = \frac{MPP_M}{MPP_L} = MRTS_{ML}$$

Equation (10) implies that the price ratio of two inputs (in this case, mechanical power and labor) is equal to the marginal rate of technical substitution of these two inputs.

In order to find out the effect of a price change on the $MRTS_{ML}$, assume an increase in the price of labor from P'_{L1} to P'_{L2} while holding the price of mechanical power constant at P'_M. At P'_{L1}, the $MRTS_{ML}$ is equal to (P'_M/P'_{L1}) and at P'_{L2}, the $MRTS_{ML}$ is equal to (P'_M/P'_{L2}). Since $P'_{L2} > P'_{L1}$, labor utilization in both farms will decrease from L_2 to L_1, with a tendency toward increased used of mechanical power. This is indicated by the increase in mechanical power utilization in Figure 2d, from m_0 to m_1, and in Figure 2e from m_0^* to m_1^*. This implies an increase in the MPP_L and a decrease in the MPP_M which, in turn, results in a decrease in the $MRTS_{ML}$ for each farm-type. In Figures 2d and 2e, this is indicated by the rotation of the isocost curve to the left, i.e., from IC_1 to IC_2 for the nonmechanized farm, and from $I^*C_1^*$ to $I^*C_2^*$ for the mechanized farm. As a result, a new profit-maximizing condition is obtained for both farms. This is indicated by points *G* and *J* for the nonmechanized and mechanized farms, respectively.

It may be observed that, due to the labor price increase, both farms are maximizing profit at a lower output level, q_1 for the nonmechanized farm, and q_1^* for the mechanized farm. Furthermore, although both farms are producing lower levels of output, they are still at equilibrium.

It is worthwhile to mention that even if the technical efficiency parameters of the two-farm types are different, i.e. $A^m > A^n$, both farm types may still experience this equilibrium condition given their respective technology. To illustrate, assume that at each level of labor input, more output is produced by a mechanized farm. This is depicted in Figure 2b where TP_L^* refers to the total product curve of a mechanized farm while TP_L refers to that of a nonmechanized farm. It should be noted that a maintained hypothesis in this analysis is that the production function is identical for both mechanized and nonmechanized farms up to a neutral efficiency parameter. This means that although the efficiency parameter of the two farm-types, differs the marginal physical product of a particular input, say labor (L), will be the same for both farms. This is indicated in Figure 2c, in which the demand curve (or the MPP_L) remains unchanged for both mechanized and nonmechanized farms, although the efficiency parameter of the former is greater than that of the latter, i.e., $A^m > A^n$.

At initial prices of P'_{L1} and P'_{M1} the profit-maximizing condition for the two farm-types is at point D in Figure 2c. With the aid of isocost and isoquant curves, the profit-maximizing condition for both nonmechanized and mechanized farms at these initial prices is depicted in Figures 2d and 2e, respectively. As illustrated, it may be observed that the nonmechanized farm employs L_2 level of labor input and m_0 (or zero) level of mechanical power to produce output q_2. On the other hand, the mechanized farm utilizes the same level of labor input (L_2) and m_2^* mechanical power to produce q_3^* output. The nonmechanized farm is said to be at equilibrium at point F (Figure 2d), the point of tangency of the isocost line IC_1 and isoquant curve q_2 while the mechanized farm is at equilibrium at point K (Figure 2e).

In order to investigate the effects of a price change, assume an increase in the price of labor from P'_{L1} to P'_{L2}. This change in the labor price will result in a decrease in the amount of labor utilized by the nonmechanized farm (and by the mechanized farm), from L_2 to L_1. The profit-maximizing condition at labor price P'_{L2} and labor usage L_1 is indicated by point E on the demand curve $D_L D_L$, in Figure 2c. It should be noted that this decrease in the quantity of labor demanded also results in a decrease in the amount of output produced by each farm-type, i.e., from q_2 to q_1 for the nonmechanized farm and from q_3^* to q_2^* for the mechanized farm (Figure 2b).

Referring to Figure 2d, prior to the labor-price increase, the nonmechanized farm is at equilibrium at point F. At this equilibrium condition, the farm utilizes L_2 amount of labor and m_0 level of mechanical power. The profit maximizing output at this input level is q_2. It may be observed that an increase in the price of labor decreased labor utilization from L_2 to L_1 and increased mechanical power usage from m_0 to m_1. As a result of these changes in the input levels, a reduction in the $MRTS_{ML}$ is observed. This is attributed to the decrease in MPP_M (due to increased mechanical power utilization), thus causing the isocost line IC_1 to rotate to the left. These adjustments bring about a new equilibrium condition for the nonmechanized farm which is indicated by point G, where the new isocost line IC_2 is tangent to isoquant curve q_1. Note that point G indicates the new profit-maximizing condition at lower levels of output and labor utilization and at a higher level of mechanical power usage.

Similar changes and effects occur in the mechanized farm. At the initial labor price P'_{L1}, this farm maximizes profit at L_2 and m_2^* levels of labor and mechanical power, respectively. The amount of output produced by these levels of input is q_3^*. The equilibrium condition at these input-output levels is depicted by point K in Figure 2e. Due to the increase in the labor price to P'_{L2} a decrease in labor utilization from L_2 to L_1 may occur. Since mechanical power becomes relatively less expensive (its price does not change), the usage of this input increases from m_2^* to m_3^*. This substitution of mechanical power for labor results in adjustments which give rise to a new profit-maximizing condition for the mechanized farm at point P. This is indicated by the point of tangency of isocost line $I'C'_2$ and isoquant curve q_2^*.

From the above discussion, it may be observed that if both farms are price efficient, a farm which is technically more efficient will realize more profit than another farm which is less technically efficient. In the present example, the mechanized farm will then realize more profit than one which is nonmechanized since $A^m > A^n$.

This theoretical framework serves as a guide for the analysis of the effects of mechanization in small rice farms in the Philippines. It provides the researcher a theoretical explanation on the possible effects of mechanical power adoption as well as a basis for comparing mechanized versus nonmechanized farms.

The Model

A model which depicts the factors that affect the aspects of farm output, profit, the level of farm mechanization and labor employment is presented in Figure 3.

Consider first the factors that affect farm output. Based on the diagram, it may be observed that the level of farm production (Q) is influenced by the amount of input (X) utilized by the farm. However, the level of input usage may be affected by factors such as

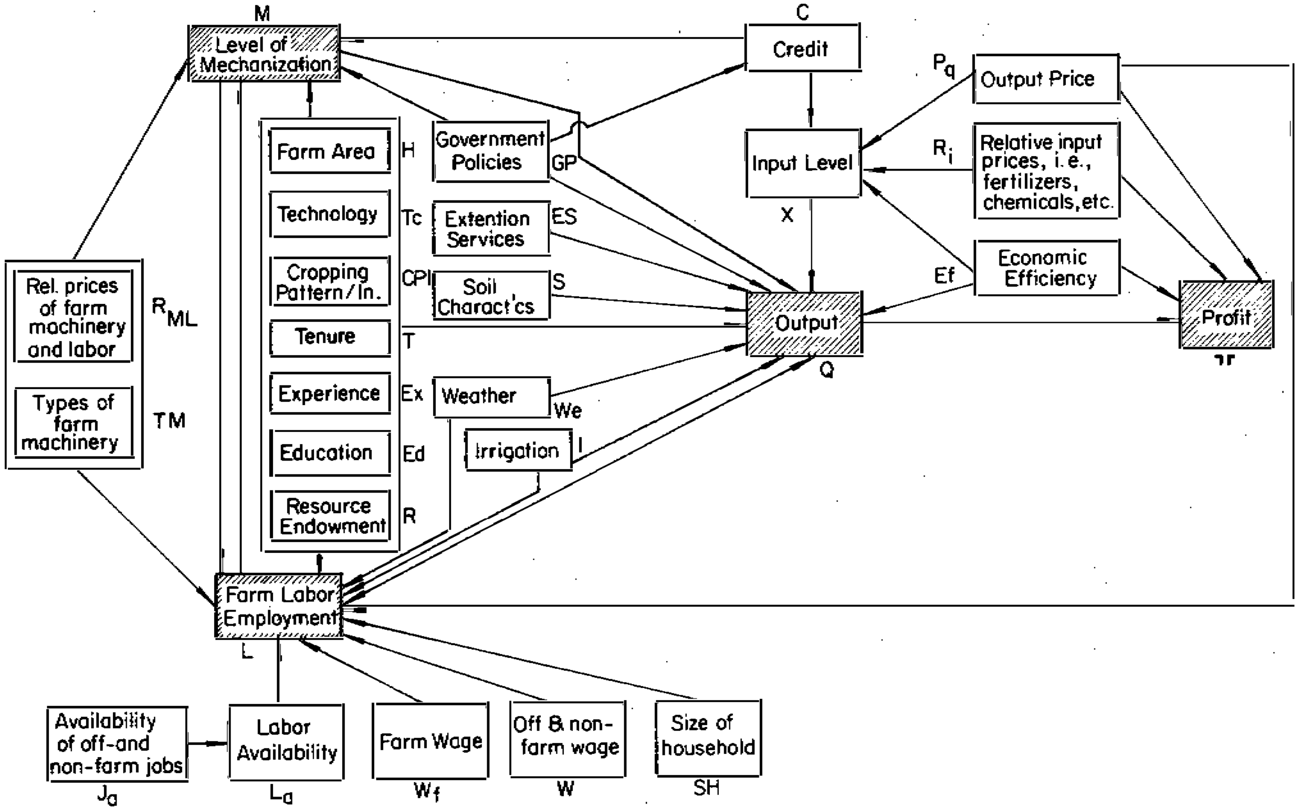

FIGURE 3
A MODEL FOR EXPLAINING THE IMPACT OF MECHANIZATION ON LABOR EMPLOYMENT, OUTPUT AND INCOME

credit availability (*C*), the price of output (P_q), the relative input prices (R_i) as well as the economic efficiency (*Ef*) of the individual farm. Farm output is further affected by the size of farm area (*H*), the type of technology (*Tc*) which has been adopted by the farm, the farm's cropping pattern and intensity (*CPI*), land tenure (*T*), the experience (*Ex*) and educational level attained (*Ed*) by the farmer operator as well as the farm's resource endowments (*R*) which are relevant to the production of its output. Other factors such as government policies (*GP*), the quality of extension services (*ES*), soil characteristics of the farm (*S*), weather (*We*), irrigation (*I*), the level of mechanization (*M*), and total farm labor employment (*L*) also play important roles in influencing farm output fluctuations.

It should be noted that the level of farm machinery adoption (*M*) and labor employment (*L*) are, likewise, jointly affected by the total farm area (*H*), the technology (*Tc*) adopted by the farm (as reflected by the elasticity of substitution between mechanical power and labor), the farm's cropping pattern and itensity (*CPI*), land tenure (*T*), the farmer's experience (*Ex*) and educational level attainment (*Ed*) as well as the resource endowments (*R*) of the farm. The relative prices of farm machinery and labor (R_{ML}) also influence a farmer's decision whether or not to adopt mechanical power for certain farm operations. In this connection, it may be argued that the different types of machinery (*TM*) utilized in a farm (i.e., tractors for land preparation and mechanical threshers for threshing) will, therefore, have a considerable impact on the farm's degree of mechanical power adoption (*M*) as well as on its level of labor input utilization (*L*).

It cannot be denied that certain government policies (*GP*) may also encourage machinery adoption in farms. This may be done through a credit program (*C*) which enables farmers to acquire financial assistance, at reasonable interest rates, for the purpose of purchasing farm machinery.

Aside from the abovementioned variable factors that affect farm labor employment (*L*), other variables such as farm household size (*SH*), the price of output (P_q) off- and nonfarm wages (*W*), as compared with farms wages (W_f), together with the availability of farm labor (*La*) largely depends on the availability of off- and nonfarm jobs (*Ja*).

Farm profit (π), on the other hand, is affected by total output (*Q*) of the farm as well as the output price (P_q), relative input prices or R_i (i.e., fertilizer, chemicals, seeds, etc.), and the economic efficiency (*Ef*) of the farm.

We have, so far, established the interrelationships of the factors that create changes in the levels of the different farm dimensions, i.e., output, profit, levels of mechanization and labor employment. Based on the above discussion, it may, therefore, be inferred that farm differences may arise due to variations in the level of mechanical power usage.

For the purpose of this paper, the main focus will be on the dimensions of farm labor employment and output. In this connection, a simplified version of Figure 3 is presented in Figure 4 which will serve as the basis for analyzing the impact of farm machinery adoption on these dimensions of rice production.

METHODOLOGY

A mechanized farm is one that utilizes mechanical power in land preparation as well as in postproduction activities defines a mechanized rice farm. In this respect, farms using carabao power for land tillage and manual labor for threshing are classified as nonmechanized farms (or *C*). On the other hand, farms which avail themselves of the services of two-wheel tractors (or a combination of two-wheel tractor and carabao power) as well as the services of mechanical threshers are defined as mechanized farms. Within the classification of mechanized farms, five types are defined. They are:

a. Carabao/thresher farms (*CT*) — those that utilize carabao power for land preparation and mechanical thresher for postproduction operations,

b. Two-wheel tractor farms (*TW*) — those that utilize two-wheel tractors for land preparation and manual labor for postproduction operations,

c. Two-wheel tractor /thresher farms (*TWT*) — these are rice farms which use two-wheel tractors for land preparation and mechanical threshers for postproduction operations,

d. Two-wheel tractor/carabao farms (*TWC*) — these are rice farms which use a combination of two-wheel tractor and carabao power for land preparation and manual labor for postproduction operations, and

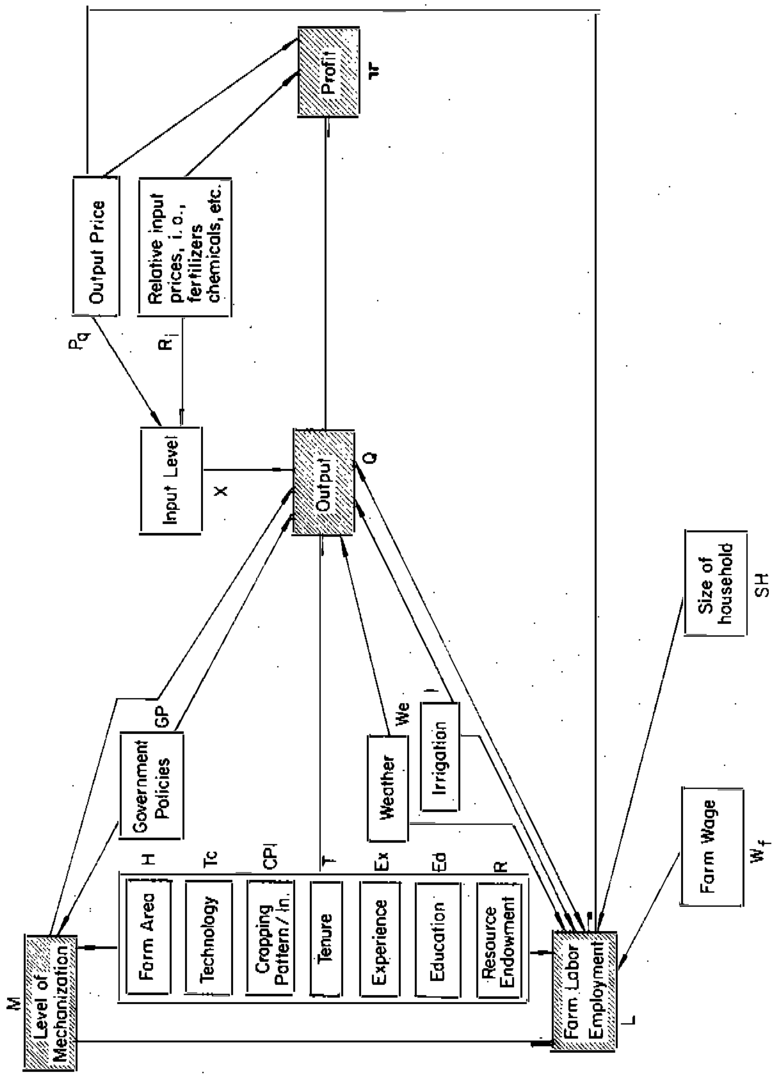

FIGURE 4
A SIMPLIFIED MODEL FOR EXPLAINING THE EFFECTS OF MECHANIZATION ON LABOR EMPLOYMENT, FARM OUTPUT AND INCOME USING SELECTED VARIABLES

e. Two-wheel tractor/carabao/thresher farms (*TWCT*) — these are farms which use two-wheel tractor and carabao power for land preparation and mechanical thresher for postproduction operations.

The above classifications are then utilized in constructing tables for analyzing labor differences among the farm groups for different rice production operations such as land preparation, planting, care/cultivation and postproduction. For analytical purposes, labor is expressed in man-hours per hectare. Furthermore, the tables are constructed for both wet and dry seasons in order to obtain information whether the same farm classifications differ in the amount of labor requirements between seasons.

Covariance analysis. This approach is a quantitative assessment of mean labor utilization by mechanization groups. The basic advantage of this method of analysis is that it incorporates corrections for differences in other factors which may have significant effects on labor employment at the farm level. The basic models that will be used for this analysis is are shown below.

a. *Total labor for all operations*

$$(11) \quad L_i = A_0 + A_1M_1 + A_2A_2 + A_3A_3 + A_4A_4 + A_5A_5 + A_6S + A_7I + A_8T + A_9HM + A_{10}Q + A_{11}Ex + A_{12}Ed + A_{13}WRP + A_{14}CPI + A_{15}NW + e$$

b. *Labor for land preparation operations*

$$(12) \quad L_i' = A_0' + A_1'M_1 + A_2'M_2 + A_3'M_3 + A_4'M_4 + A_5'M_5 + A_6'S + A_7'T + A_8'\,HM + A_9'Ex + A_{10}'Ed + A_{11}'\,WRP + A_{12}'CPI + A_{13}'NW + e'$$

c. *Labor for postproduction operations*

$$(13) \quad L_i^* = A_0^* + A_1^*M_1 + A_2^*M_2 + A_3^*M_3 + A_4^*M_4 + A_5^*M_5 + A_6^*S + A_7^*T + A_8^*HM + A_9^*Q + A_{10}^*\,Ex + A_{11}^*\,Ed + A_{12}^*WRP + A_{13}^*CPI + A_{14}^*NW + e^*$$

where: L_i, L_i' and L_i^* refer to the total man-hours in terms of either (a) total hired labor, (b) total family labor or (c) total labor for their respective farm operations.

M_i refers to a mechanization dummy which takes a value of unity if the farm belongs to mechanization group i, such as: $M_1 = TW$, $M_2 = TWC$, $M_3 = CT$, $M_4 = TWT$ and $M_5 = TWCT$. The reference group is the carabao farm category C.

S is a season dummy which takes a value of unity for dry season and zero for wet season.

I is an irrigation dummy which takes the value of unity for irrigated farms and zero for nonirrigated farms.

T is a tenure status dummy which takes the value of unity for farmer-owned farms and zero, otherwise.

HM is the total number of household members per farm above ten years old.

Q is kilogram rough rice per hectare.

Ex is the total number of years of farming experience of the farm operator.

Ed is the number of years education the farm operator had.

WRP is the ratio of the average wage rate per hour for all farm operations and the average price per kilogram of rough rice.

CPI is cropping intensity, computed as follows:

$$CPI = \frac{\text{wet season rice farm area} + \text{dry season rice farm area}}{\text{total available area per farm}}$$

NW is the farm net worth, expressed in pesos.

e is the residual term.

Dummy variables, M_1, M_2, M_4, and M_5 are expected to exhibit negative regression coefficients for land preparation labor covariance analysis due to the fact that these farm groups utilize two-wheel tractors solely or in combination with carabao power. The carabao/

thresher farms group or *CT*, as represented by dummy variable M_3, is not expected to show any significant difference from the reference farm group, *C*, in terms of land preparation labor utilization. The reason for this is that both farm-types mainly rely on carabao power for primary tillage. However, for postproduction labor covariance analysis, only farms using mechanical threshers such as *CT*, *TWT* and *TWCT* (represented by M_3, M_4 and M_5, respectively) are expected to exhibit negative regression coefficients due to the displacement of some postproduction labor by mechanical threshers.

The season dummy should exhibit a positive regression coefficient, i.e., $A_6 > 0$, which implies that more labor is used during the dry season than in the wet season. This is particularly true for the land preparation labor covariance analysis since the dry condition of the soil requires more effort and time for land preparation operations, Postproduction operations, likewise, should require more labor employment during the dry season since the ideal growing conditions, i.e., absence of strong winds and prolonged cloudy and rainy days, result in higher yields. This, in turn, results in higher postproduction labor utilization.

The irrigation variable, *I*, should also exhibit a positive regression coefficient since water management requires additional labor, particularly for farm operators.

It is maintained that farmers who own the land they are cultivating are financially better-off compared with those farmers who rent, lease or borrow the land they are farming. It is therefore, hypothesized that farm owners utilize more hired and less family labor, compared with those who do not own the land they are tilling. This implies that the regression coefficient of the tenure dummy variable, *T*, will be positive.

Output, on *Q*, should have positive effects on the amount of labor used on a farm or in a hectare of land.

The inclusion of the variable referring to the total number of household members per farm, *HM*, is only applicable for the hired labor covariance analysis model. Its inclusion will indicate whether an inverse relationship exists between the potential source of family labor and the amount hired labor utilized by the farm.

It is difficult to predict the signs of the regression coefficients of the variables representing the number of years farming experience (*Ex*) and number of years education of the farmer (*Ed*) since these variables imply certain inherent managerial qualities of the farm operator. In terms of the covariance model, these two variables pertain to the farm operator's ability to manage labor utilization based on his farming and educational experiences. Since the employment of more (or less) labor does not imply good (or bad) management, the regression coefficients of *Ex* and *Ed* will only be tested for their significance with regard to their effects on labor utilization. However, the cropping intensity variable (*CPI*) is expected to exhibit a positive regression coefficient.

It should be noted that the labor wage rate per hour varies depending on the type of farm operation labor being hired for. This being the case, the wage rate for land preparation differs from that for planting, care/cultivation and postproduction operations. Furthermore, not all farms face the same wage rates for similar farm operations due to variations in labor demand during the rice production period. Due to the heterogeneity of the labor wage rate among farm operations and individual farms within each farm classification, an average labor wage rate was specified to reflect the wage rate of all farm operations in each farm classification. Having calculated the farm-specific average labor wage rate (P_{Lij}), the wage:rice price ratio (*WRP*) is then specified by dividing P_{Lij} by the average price per kilogram of rough rice received by the farm in the *i*th farm classification, P_{qij}.

The wage: rice price ratio (*WRP*) is expected to be negative for the labor covariance models which analyze the hired labor component of each farm operation. This implies that a high (or a low) labor wage rate relative to the price per kilogram of rough rice results in a decrease (or increase) in the amount of hired labor employed for a particular farm operation. In analyzing the total labor demand, this ratio is also expected to exhibit a negative sign. However, for the family labor covariance analysis, the variable *WRP* is expected to be positive — meaning that a high labor wage rate relative to the price per kilogram of rough rice results in an increase (or decrease) in the amount of family labor utilized in a particular farm operation. This phenomenon is expected to occur since hired labor becomes more (or less) expensive, thus forcing the farm household to rely more on its family labor resource.

Since net worth (*NW*), reflects the financial status of a particular farm, farms with high net worth values, i.e., well-to-do farm households, are expected to utilize more labor than those with low net worth. Therefore, the regression coefficient of *NW* is expected to exhibit a positive sign.

Production function analysis. A farm, as a technical unit, transforms inputs into outputs within the constraints of its production technology and the random effects of uncontrollable factors. The decision making unit of the technical unit is the farm operator who decides "what to produce," "how much to produce" and "how to allocate his limited resources in the production of the commodity to produce." The quality of the decision making ability of the farm operator is, in turn, reflected by the profit he realizes or by the loss he incurs as a result of his decisions involving the overall farm operations. With this farmer behavioral background, it seems realistic to assume that a farming entity attempts to maximize its profits.

However, in its process of maximizing profits, the firm is faced with two constraints – (1) market constraints, and (2) technological constraints (Varian 1978). For the purpose of this paper, each farm unit, i.e., rice farm unit, is assumed to be a price taker with respect to input and output prices. This implies that the farm is one of the many rice producers in a competitive rice industry – which is the case in the Philippine rice industry. Technological constraints are simply those constraints that concern the feasibility of the production plan such as the level of technology on hand, the amount of resources a farm is able to readily utilize in the production process and the various uncontrollable factors which may affect both the amount of resources used and the amount of output produced. For the purpose of developing a production function model, consider the short-run production function of the *j*th farm group with the following relationships:

$$(14) \quad Q_j = f(X_{1j}, X_{2j}, \bar{X}_{3j})$$

where:

Q_j is the output produced by farm *j*.

X_{1j} and X_{2j} are the variable inputs employed by the *j*th farm in the production of Q_j.

X_{3j} is a fixed input where the maximum level X_{3j} is given by $\bar{X}_{3j}$.

Expressing the above expression in a Cobb-Douglas production function form the following is obtained:

(15) $Q_j = A_j X_{ij}^a X_{2j}^b X_{3j}^c \, e^{uj}$

where: $X_{ij}, X_{2j} > 0$

$\bar{X}_{3j}, X_{3j} > 0$

$1 > a, b, c > 0$

A_j is the technical efficiency parameter of the jth farm.

a, b, and c are the elasticities of output with respect to the individual inputs employed which also indicate the relative share of each input in the total product (Chiang 1974).

u_j is a random error term.

The estimation of a single equation production function, (15), often gives rise to such problems of simultaneous equation bias and specification bias. The latter arises out of omitting farm-specific factors from the production function model. On the other hand, simultaneous equation bias results from the estimation of only one equation which is embedded in larger system of equations (Lingard et al. 1981) – "the system is such that some of the independent variables, as well as the dependent variable, are functions of the disturbance term in the given equation. This contradicts the assumptions underlying single equation regression since the presumed independent variables are in fact correlated with the disturbance" (Hoch 1958). The succeeding discussion provides information on how to avoid the problem of simultaneous equation bias.

It is conventional to assume that the production function of the jth farm group is stochastic. Furthermore, the random error u_j is assumed to have the usual classifical properties and can be rationalized as being due to random error, i.e., unpredictable variations in other factors which affect output but not included in the specified production function. Since the effects of the random error on output is not known until after the factors of production have been committed, farmers undertake decisions regarding input utilization under conditions of uncertainty. Under such conditions, it is realistic to assume that the main objective of farmers is to maximize expected output and, subsequently, their expected profit. In mathematical terms, this is expressed by the following:

$$(16)\quad \text{Max} \quad E[\pi_j] = \text{Max}\, P_q \cdot E[Q_j] - P_1 X_{1j} - P_2 X_{2j} - F_j$$

subject to:

$$X_{1j} > 0$$
$$X_{2j} > 0$$
$$X_{3j} = \bar{X}_{3j}$$

where: $E[\pi_j]$ is the expected profit of the jth farm.
P_q is the price of output.
$E[Q_j]$ is the expected output of the jth farm.
P_1 is the price of input X_{1j}
P_2 is the price of input X_{2j}
F_j is the cost of fixed input X_{3j}.

The first order, necessary conditions for a maximum for a price-taking farm are:

$$(17a)\quad P_q . a \frac{E[Q_j]}{X_{1j}} = P_1$$

$$(17b)\quad P_q . b \frac{E[Q_j]}{X_{2j}} = P_2$$

Equations (17a) and (17b) imply that if a profit maximizing farm uses both X_1 and X_2 inputs, then each should be utilized until the input price of X_1 (or X_2) is equal to the expected marginal value product of X_1 (or X_2).

The second-order, sufficient conditions for a maximum will always be satisfied if the production function is strictly concave for all positive values of X_1 and X_2. This implies that $(a + b) < 1$ or decreasing returns which, in turn, implies the operation of variable proportions (Lingard et al. 1981).

Taking the logarithm of equations (15), (17a) and (17b) and expressing the system of equations in matrix form, the following is obtained:

$$(18) \quad \begin{bmatrix} 1 & 0 & -a & -b \\ 0 & 1 & -1 & 0 \\ 0 & 1 & 0 & -1 \end{bmatrix} \begin{bmatrix} lnQ_j \\ ln\,E[Q_j] \\ ln\,X_{1j} \\ ln\,X_{2j} \end{bmatrix} = \begin{bmatrix} ln\,A + c\,ln X_{3j} \\ ln\,(P_1/P_q) - ln a \\ ln\,(P_2/P_q) - ln b \end{bmatrix} + \begin{bmatrix} u_j \\ 0 \\ 0 \end{bmatrix}$$

From the above relationship, it may be observed that inputs X_1 and X_2 are independent of the random error term, u_j, in the production function. This implies that "shifts in the production relation affect actual output, Q_j, but not expected output, $E[Q_j]$, and hence, when these shifts occur, the level of input is not affected" (Hoch 1958). Therefore, ordinary least squares estimates of the parameters of the production function are unbiased and consistent.

In the process of developing a model, in this case a production function model, the researcher tends to omit variables due to (1) data limitations; (2) lack of knowledge regarding the factors that determine the phenomenon being studied; (3) problems of multicollinearity, since economic variables tend to be correlated with each other; and (4) the desire to simplify the model in order to facilitate statistical analysis and/or to permit feasible data collection. To minimize the occurrence of specification bias due to the omission of relevant variables, other factors that exert their influence on output variations are included in the model. Based on a priori knowledge, unquantifiable variables such as irrigation and weather are included, aside from those that are quantifiable such as labor hours, amount of fertilizer and chemical expenditure. Furthermore, an attempt is made to incorporate other demographic variables (such as years of education and experience of farmer) and institutional variables (such as the quality of extension services and membership in farmers' organization) in the estimated production function in order to investigate whether such variables play important roles in output variations. This is expressed in the following functional relationship:

$$(19) \quad Q_{ij} = f(L_{ij}, F_{ij}, Ch_{ij}, I_{ij}, Ed_{ij}, Ex_{ij}, ES_{ij}, FO_{ij}, S)$$

where: i refers to the individual farm belonging to farm group j.

j refers to farms with different modes of mechanization such as C, CT, TW, TWT, TWC and $TWCT$ farms which have been previously defined.

Q is farm output per hectare of the ith farm belonging to the jth farm group which is measured in terms of total kilograms.

L is for the total man-labor hours utilized for rice production per hectare.

F is the total amount of fertilizer used per hectare, in kilograms.

Ch is the total expenditure per hectare on weedicides/herbicides, insecticides and other chemicals used for rice production, in pesos.

I is an irrigation dummy which takes the value of one if the farm is irrigated and zero if it is rainfed.

Ed is the total number of schooling years the farm operator has had.

Ex is the number of years experience the farmer has in farming.

ES is the quality of extension services provided to the farmer which is a subjective assessment by the farmer himself, i.e., it takes the value of one if the farmer thinks that the extension services provided are adequate and zero, if not.

FO is the dummy variable representing government policies. This tries to measure the effect of institutional factors such as membership in a village organization i.e., Samahang Nayon. This takes the value of one for members and zero, otherwise.

S is a season dummy variable which takes the value of zero for wet season and one for dry season.

Expressing (19) in terms of a Cobb-Douglas production function, the following is obtained:

$$(20) \quad Q_{ij} = A_j L_{ij}^{a_1} F_{ij}^{a_f} Ch_{ij}^{a_c} C^{b^*}$$

where: A_j is the technical efficiency parameter of the jth farm.

$$b^* = (b_i I_{ij} + b_{ed} Ed_{ij} + b_{ex} EX_{ij} + b_{es} ES_{ij} + b_{fo} FO_{ij} + b_s S + u')$$

The estimating equation is:

$$(21) \quad lnQ_{ij} = lnA_j + a_l lnL_{ij} + a_f lnF_{ij} + a_c lnCh_{ij} + b_i I_{ij} + b_s S + b_{ed} ED_{ij} + b_{ex} Ex_{ij} + b_{es} ES + b_f FO_{ij} + u'$$

where: a_i's and b_i's are the regression coefficients.

u' is the residual term.

It should be noted that equation (21) will be estimated on a per hectare basis.

Project Site Description

The data for this study was obtained from the farm survey conducted by the International Rice Research Institute (IRRI) in the province of Nueva Ecija. The province is located in the Central Luzon region which is considered as the rice granary of the Philippines.

The project site consists of two municipalities, Cabanatuan City and the town of Guimba, from which eight sample villages — four from each municipality — were selected for farmer interviews. The interviews were initially undertaken within the period of March-April 1979 for the purpose of establishing a census of all farm households in the selected villages. This census later served as the basis for drawing a stratified random sample from the household list.

The villages. Most of the household heads in both the municipalities were farmers. However, Cabanatuan City exhibited more households which derive income from nonagricultural sources, compared with Guimba, due to proximity to the city proper. Of the total number of households found in both municipalities, at least 14 percent were landless.

Across villages, it may be said (Table 1) that the households are relatively homogeneous in terms of the average age, education and experience of farm operator as well as the average total number of members per household. Average farm size ranges from 1.8 to 2.7 hectares with rice being the major crop grown in all villages. The average area planted to rice ranges from 1.7 to 2.3 hectares. Of the total rice area, 97 to 100 percent is planted to improved rice varieties.

TABLE 1

SELECTED AVERAGE CHARACTERISTICS OF SURVEYED VILLAGES IN CABANATUAN CITY AND GUIMBA, NUEVA ECIJA, 1979

Item	*Cabanatuan City*				*Guimba*			
	San Isidro	*Lagare*	*Kalikid Sur*	*Caalibang-bangan*	*Galvan*	*Narvacan I*	*San Andres*	*Bunol*
No. of households	111	107	138	198	108	72	109	199
Age of household head (yrs.)	48	46	45	45	46	40	42	45
Education of household head (yrs.)	5	4	4	5	4	5	5	5
Farming experience of household head (yrs.)	22	18	19	21	22	14	17	19
No. of household members	6	5	6	6	6	6	6	6
Farm area (hectares)	2.35	1.82	2.71	1.81	1.74	1.81	1.98	2.12
Area planted to rice (hectares)	2.29	1.82	2.43	1.76	1.70	1.80	1.94	1.98
Rice yield per hectare (kg.)	3,435	4,620	1,609	4,025	2,409	2,464	1,937	3,105
Total irrigated area (%)	98.2	99.0	8.4	99.4	8.8	68.5	8.7	45.7
Degree of mechanization (%)[a]	98.4	93.6	26.2	93.9	29.2	33.0	71.4	61.8
Overall rice cropping intensity (%)[b]	194	201	100	199	105	118	111	131

a. Proportion of total rice area which availed of the services of mechanical power for the farm operation.
b. Total farm area planted to rice in both wet and dry seasons divided by effective rice area per farm multiplied by 100.

Source: Household Census (1979) and Farm surveys (Wet Season 1979 and Dry Season 1980), Consequences of Small Rice Farm Mechanization Project, the International Rice Research Institute, Los Baños, Laguna, Philippines.

The average rice cropping intensity for an average farm in each village ranges from 100 to 201 percent, with the villages of San Isidro, Lagare and Caalibangbangan exhibiting the highest cropping intensity. These same villages rely heavily on gravity irrigation as well as farm machinery which facilitates the growing of a second crop during the production year. The combined impact of these factors, together with high rates of fertilizer application, may be reflected by the high average yields attained by farms in these three villages.

The farm classifications. Based on the population described above, farm households with different modes of mechanization were selected and classified into the different categories of mechanized farms as defined previously.

Tables 2 and 3 show the relative demographic homogeneity of farms within the different classes. These farms differ in size, however, with the smallest farms using carabao power in land preparation and the largest utilizing mechanical power solely or in combination with carabao power in both wet and dry seasons. In addition, farms with mechanized land preparation operations were observed to devote a larger portion of the total farmholding to rice cultivation relative to those which mainly use carabao power, as indicated by the intensity of land use index. Although the variation of this index is not too pronounced among the different farm classifications during the wet season, it is quite obvious in the dry season. Intensity of land use during the dry season was generally above 90 percent for mechanized farms, with the exception of farms under the two-wheel tractor/carabao classification. In contrast, the same index for farms using carabao power for land preparation, i.e., carabao *(C)* and carabao/thresher *(CT)* farm classifications, remained within the 50 to 60 percent level. It is interesting to note that the intensity of land use index exhibits a relationship with the irrigation index across the different farm types. This is indicated by the fact that farm-types with a high irrigation index, i.e., above 80 percent, are able to utilize farm land more intensively compared to those which have limited water facilities as reflected by their low irrigation indices. This implies that, aside from mechanical power, the intensify of land use is largely dependent on water availability, particularly for the dry season.

In terms of land tenure status, most of the farm operators owned the land they were cultivating, particularly for farms under the carabao (*C*), carabao/thresher (*CT*), two-wheel tractor carabalo (*TWC)*, and

TABLE 2
SELECTED CHARACTERISTCS OF THE DIFFERENT TYPES OF FARM CLASSIFICATIONS IN EIGHT VILLAGES IN CABANATUAN CITY AND GUIMBA, NUEVA ECIJA, 1979 WET SEASON

Item	Type of farm household					
	Carabao (C)	*Carabao/ thresher (CT)*	*Two-wheel (TW)*	*Two-wheel/ thresher (TWT)*	*Two-wheel carabao (TWC)*	*Two-wheel/ carabao thresher (TWCT)*
Number of households	72	58	21	41	31	27
Demographic characteristics						
Average age of household head (years)	41.77	42.58	44.41	47.63	43.14	43.69
Average education of household head (years)	4.32	4.58	4.03	4.14	5.14	4.79
Average experience in farming (years)	18.28	19.36	24.05	21.00	19.68	16.04
Average number of household members	5.50	5.45	5.52	5.88	5.74	5.00
Land characteristics						
Average size of farm holding (ha.)	1.85	2.14	2.57	2.66	2.07	1.94
Average rice crop area (ha.)	1.52	2.05	2.50	2.63	1.98	1.94
Intensity of land use (%)[a]	82.16	95.79	97.28	98.87	95.65	100.00
Irrigation index (%)	81.62	93.46	97.28	84.59	88.89	94.85
Tenure status						
Owner (%)	48.60	63.80	28.60	17.10	61.30	50.00
Part owner (%)	4.20	3.50	4.70	7.30	6.50	10.70
Lessee (%)	29.10	17.20	66.70	70.70	29.00	21.40
Share-cropper (%)	4.20	–	–	–	–	3.60
Others (%)	13.90	15.50	–	4.90	3.20	14.30
Average yield (kg./ha.)						
Rice-traditional	1,131	872	–	–	–	–
Rice-improved	2,185	2,043	4,099	3,854	2,721	2,848
% area planted to improve rice varieties	98	98	100	100	100	100
Average years mechanized	–	–	7.8	7.5	7.5	6.1

a. Rice cropped area divided by size of farm holding multiplied by 100.
b. Irrigated farm area divided by size of farm holding multiplied by 100.
c. Average number of years each farm-type has been using two-wheel tractors for land preparation.

TABLE 3
SELECTED CHARACTERISTICS OF THE DIFFERENT TYPES OF FARM CLASSIFICATIONS IN EIGHT VILLAGES IN CABANATUAN CITY AND GUIMBA, NUEVA ECIJA, 1980, DRY SEASON

Item	Type of farm household					
	Carabao (C)	*Carabao/ thresher (CT)*	*Two-wheel (TW)*	*Two-wheel/ thresher (TWT)*	*Two-wheel/ carabao (TWC)*	*Two-wheel carabao/ thresher (TWCT)*
Number of households	26	47	11	54	6	25
Demographic characteristics						
Average of age of household head (years)	40.81	40.09	36.53	47.24	42.00	44.32
Average education of household head (years)	4.12	4.91	4.00	3.81	6.67	4.96
Average experience of household head (years)	18.92	15.89	14.36	21.76	16.83	19.36
Average number of household members	5.69	5.83	5.27	5.76	6.83	5.44
Land characteristics						
Average size of farm holding (ha.)	1.40	1.71	1.58	2.38 .38	2.68	1.88
Average rice crop area (ha.)	0.82	0.91	1.46	2.32	1.49	1.96
Intensity of land use (%)[a]	58.57	51.22	92.41	97.48	55.60	99.00
Irrigation Index (%)	45.88	54.97	84.18	96.22	62.69	99.00
Tenure status						
Owner	61.60	42.60	27.30	29.60	66.70	40.00
Part owners	–	–	–	3.70	–	4.00
Leasees (%)	11.50	46.80	54.50	59.30	33.30	40.00
Share-croppers (%)	7.70	4.20	–	–	–	–
Others	19.20	6.40	18.20	7.40	–	16.00
Average yield (kg./ha.)						
Rice-traditional	–	–	–	–	–	–
Rice-improved	2,505	4,199	4,336	4,173	3,541	4,546
% area planted to improve rice varieties	100	100	100	100	100	100
Average years mechanized	–	–	7.7	7.6	7.4	6.2

a. Rice cropped area divided by size of farm holding multiplied by 100.
b. Irrigated farm area divided by farm holding multiplied by 100.
c. Average number of years each farm-type has been using two-wheel tractors for land preparation.

two-wheel tractor/carabao/thresher (*TWCT*) classifications. However, for the two-wheel tractor and two-wheel tractor/thresher classifications, most of the farmers were lessees. This observation holds true for both seasons.

The crop mainly grown in all farm classifications is rice, with improved rice varieties taking up at least 98 percent of the total rice area. However, the data in Tables 2 and 3 do not indicate any meaningful yield pattern which may be useful for comparing rice yield across the different farm categories. For the wet season, rice yield ranged from 2.2 to 4.2 metric tons across the different farm-types, while for the dry season the range was 2.5 to 4.5 metric tons.

Most of the mechanized farms have been using two-wheel tractors for land preparation for approximately 6 to 7 years.

Results and Discussion

In this section, an attempt to compare labor data among the different farm classifications is undertaken. For this purpose, the tabular method of comparison and covariance analysis are employed in order to provide information regarding labor differences between each farm classification. This preliminary analysis, in turn, will serve as the basis for further comparisons between the different farm-types using production function analysis.

Comparison of Labor Utilization

The total labor hours per hectare utilized by each farm-type is presented in Table 4 for both wet and dry seasons of crop year 1979-1980. For land preparation, farms such as *TW*, TWT, *TWC* and *TWCT* utilized considerably lower levels of manual labor than farms with nonmechanized land preparation operations, i.e., *C* and *CT*. This essentially reflects the pattern of hired and family labor utilization for these particular farm operations as presented in Table 5. With regard to postproduction, in general, farms which used mechanical threshers required less amount of labor hours to complete such operation compared to farms which relied mainly on manual labor (Table 4). This may be generally attributed to the decrease in hired labor utilization by mechanical thresher users (Table 5).

Of the four major farm operations, land preparation and care/cultivation largely depended on family labor as indicated by Table5.

TABLE 4
AVERAGE LABOR HOURS USED PER HECTARE FOR VARIOUS FARM OPERATIONS FOR EACH SELECTED FARM CLASSIFICATION, NUEVA ECIJA, PHILIPPINES, CROP YEAR 1979-1980

Item	*Average labor hours used for various farm operations*									
	Land preparation		*Planting*		*Care/ cultivation*		*Post production*		*Total hours*	
	Hours	%	Hours	%	Hours	%	Hours	%	Hours	%
Wet Season										
Carabao	105	18	198	33	34	6	251	43	588	100
Carabao/thresher	112	19	211	35	32	5	242	41	597	100
Two-wheel	30	6	211	43	22	4	233	47	496	100
Two-wheel/thresher	37	8	199	45	26	6	182	41	444	100
Two-wheel/carabao	61	12	178	36	32	6	224	46	495	100
Two-wheel/carabao/thresher	54	11	208	42	24	5	206	42	492	100
Dry Season										
Carabao	143	23	222	35	26	4	235	38	626	100
Carabao/thresher	158	20	291	37	32	4	314	39	795	100
Two-wheel	34	7	166	36	22	5	242	52	464	100
Two-wheel/thresher	33	8	190	44	99	6	182	42	434	100
Two-wheel/carabao	58	11	228	43	29	5	216	41	531	100
Two-wheel/carabao/thresher	55	13	166	38	33	7	181	42	434	100

TABLE 5

DISTRIBUTION OF LABOR HOURS PER HECTARE, HIRED AND FAMILY LABOR, FOR VARIOUS FARM OPERATIONS OF SELECTED FARM CLASSIFICATIONS, NUEVA ECIJA, PHILIPPINES, CROP YEAR 1979-1980

Farm classification	*Average hired and family labor used for various farm operations*									
	Land preparation		*Planting*		*Care/ Cultivation*		*Post-production*		*Total labor hours*	
	H[a]	*F*[b]	*H*	*F*	*H*	*F*	*H*	*F*	*H*	*F*
Wet Season										
Carabao	24	81	152	45	4	30	174	77	354	233
Carabao/tresher	30	82	176	35	—	32	160	82	366	231
Two-wheel	4	26	207	4	3	18	232	2	446	50
Two-wheel/thresher	6	31	180	18	2	23	161	16	355	8
Two-wheel/carabao	19	42	154	24	1	30	193	31	367	127
Two-wheel/carabao/thresher	19	35	195	13	1	22	160	47	375	117
Dry Season										
Carabao	18	125	183	39	1	25	130	105	332	294
Carabao/thresher	21	137	253	39	—c	32	270	43	544	251
Two-wheel	6	28	161	5	2	20	239	3	408	56
Two-wheel/thresher	7	27	177	13	5	24	179	3	368	67
Two-wheel/carabao	11	47	209	20	—	29	216	—	436	96
Two-wheel/carabao/thresher	13	42	153	2	5	27	180	1	351	82

a. Hired labor.
b. Family labor.
c. Considerably less than one hour.

This may also be observed in Table 6 which presents the percent hired and percent family labor per farm operation, for wet and dry seasons. Such a trend is not suprising since almost all farmers own a carabao for use as draft animals in land preparation to supplement the services of hired draft animal and mechanical power. As for those farms which totally rely on two-wheel tractor services, the informal tractor hiring/lending system enables farmers to rent or borrow a two-wheel tractor from friends and/or relatives. The farmers themselves operate these machines with the agreement that they pay for the cost of fuel, maintenance and some amount to cover depreciation. At times, the machines may be hired with an operator but in such cases, some farmers still assists, in the land preparation operations.

Due to the prevalent use of chemicals, care/cultivation operations have become less labor intensive. Weeding work, which used to be accomplished mainly by hired labor, has been considerably reduced through the proper application of herbicides/weedicides. As a consequence, hired and family labor input requirements have substantially decreased for this farming activity.

On the other hand, planting and postproduction operations required more hired labor than family labor since these operations are labor intensive in nature.

It should be noted that differences in the labor hour utilization of the six different farm-types are not observable for those farm operations which were not mechanized at all, such as planting and care/cultivation. Furthermore, no distinct pattern of hired labor employment and family labor use may be noticed for these same operations in all farm classifications.

However, it may be concluded that:

(1) Mechanized farms required less total labor hours to accomplish all farm operations than nonmechanized farms.

(2) Family labor hour requirements of mechanized rice farms were lower than those of farms which are non-mechanized.

(3) Farms which utilized two-wheel tractors for land preparation and mechanical threshers for postproduction operations exhibited reductions in hired labor use for these operations.

TABLE 6

PER CENT LABOR HOURS UTILIZED PER HECTARE, HIRED AND FAMILY LABOR, FOR VARIOUS FARM OPERATIONS OF SELECTED FARM CLASSIFICATIONS, NUEVA ECIJA, PHILIPPINES, CROP YEAR 1979-1980

Farm classification	Land preparation		Planting		Care/ Cultivation		Post-production		Total labor hours	
	Ha	Fb	H	F	H	F	H	F	H	F
Wet Season										
Carabao	23	77	77	23	13	87	69	31	60	40
Carabao/thresher	27	73	83	17	—	100	66	34	61	39
Two-wheel	13	87	98	2	15	85	99	1	90	10
Two-wheel/thresher	15	85	91	9	9	91	92	8	80	20
Two-wheel/carabao	32	68	86	14	5	95	86	14	74	26
Two-wheel/carabao/thresher	35	65	94	6	6	94	77	23	76	24
Dry Season										
Carabao	12	88	82	18	5	95	55	45	53	47
Carabao/thresher	13	87	87	13	—c	100	86	14	68	32
Two-wheel	18	82	97	3	10	90	99	1	88	12
Two-wheel/thresher	19	81	93	7	17	83	98	2	85	15
Two-wheel/carabao	19	81	91	9	—	100	100	—	82	18
Two-wheel/carabao/thresher	24	76	92	8	16	84	100	—c	81	19

a. Hired labor.
b. Family labor.
c. Considerably less than one hour.

Covariance Analysis

The tabular analysis does not provide information regarding the causal relationship between mechanization and labor utilization. Furthermore, it does not indicate how other factors, aside from mechanization, affect the degree of labor utilization and employment among farm groups. In order to investigate whether a causal relationship between variables exists as well as that for significant differences between the various classifications, a corariance analysis is undertaken.

A summary of the results is presented in Tables 7, 8 and 9 regarding estimated differences in hired, family and total labor among the different farm classifications for specific farm operations. Based on these results, reductions in total family and total labor utilization were observed to occur in all farms using two-wheel tractors for land preparation as well as mechanical threshers for postproduction activities (Table 7). This is implied by the mechanization dummy variables M_1, M_2, M_4 and M_5 which exhibited negative and significant regression coefficients. The decrease in the labor utilization among *TW, TWC, TWT* and *TWCT* farms may largely be attributed to the significant reduction in total family labor requirements for land preparation operations. This is supported by Table 8 which indicates that total land preparation labor decreased significantly due to reductions in the amount of family labor requirements among *TW, TWC, TWT* and *TWCT* farms. Furthermore, the decrease in labor use among *TWT* and TWCT farms may also be attributed to significant reductions in hired labor requirements for postproduction operations due to the use of mechanial threshers. Table 9, which shows significant negative impact on the total postproduction labor requirement for these particular operations due to significant reductions in hired labor employment, supports the findings in Table 7.

The statistically insignificant coefficients of some of the mechanization dummy variables in the covariance analysis for the hired labor component do not allow one to conclude that reductions in hired labor occurred in all farm operations (Table 7) nor in land preparation (Table 8) due to mechanization. However, it may be generalized that the results provide information with regard to the direction of change in hired labor employment for land preparation with the use of farm machinery.

For all farm operations, as well as for postproduction operations, no significant difference was observed in labor employment and uti-

TABLE 7
ESTIMATED DIFFERENCE IN TOTAL LABOR USE IN RICE PRODUCTION AMONG FARMS WITH DIFFERENT MODES OF MECHANIZATION, CROP YEAR 1979-1980

Independent variables		*For all farm operations*		
		Total hired labor	*Total family labor*	*Total labor*
Constant		163.63**	482.69***	647.31***
		(2.63)	(10.10)	(10.38)
Two-wheel	(M_1)	–29.96	–94.54**	–123.38**
		(–0.65)	(–2.38)	(–2.39)
Two-wheel/carabao	(M_2)	–17.86	–107.65***	–118.94***
		(–0.44)	(–3.20)	(–2.62)
Carabao/thresher	(M_3)	49.62*	–39.06	9.47
		(1.67)	(1.52)	(0.20)
Two-wheel/thresher	(M_4)	–87.99***	–143.31***	–234.34***
		(–2.58)	(–4.86)	(–6.08)
Two-wheel/carabao/thresher	(M_5)	–76.75**	–124.75***	–194.10***
		(–2.04)	(–3.83)	(–4.57)
Seasonal effect	(S)	–22.77	21.81	1.44
		(–1.00)	(1.11)	(0.06)
Irrigation	(I)	–16.87)	–10.54	–34.54
		(–0.69)	(–0.50)	(–1.25)
Tenure	(T)	17.52	–23.97	–8.18
		(0.78)	(–1.24)	(–0.32)
Household members	(HM)	–3.97	–	–
		(–0.90)	–	–
Output	(Q)	0.07***	0.01***	0.09***
		(9.62)	(2.90)	(10.49)
Experience	(Ex)	1.53*	–2.25***	–0.99
		(1.69)	(–2.88)	(–0.97)
Education	(Ed)	6.51*	–6.67**	–1.44
		(1.70)	(–2.01)	(–0.33)
Wage-rice price ratio	(WRP)	14.91	–53.42***	–65.56***
		(0.76)	(–3.15)	(–2.96)
Cropping intensity	(CPI)	–0.25	–0.80***	–0.85***
		(–1.04)	(–3.83)	(–3.13)
Net worth	(NW)	–0.0001	0.00004	–0.00004
		(–.31)	(0.14)	(–0.10)

Table 7 (Continued)

Independent variables	For all farm operations		
	Total hired labor	*Total family labor*	*Total labor*
R^2	0.24	0.23	0.34
F-value[b]	8.42	8.80***	14.88***
Number of observations	419	419	419

a. Values in parentheses are calculated *t*-values.
b. *F*-statistic for testing the significance of the regression model.
*** Significant at P=1%.
** Significant at P=5%.
* Significant at P=10%.

lization during the wet and dry seasons. However, more labor per hectare was required for land preparation during the dry season than in the wet season. This is verified by the positive regression coefficient of the season dummy (S) for both the family and total labor covariance models in Table 8.

The effects of irrigation (*I*) and tenure (*T*) on labor utilization and employment were found to be insignificant. The variable representing the number of household members per farm unit (*HM*), although insignificant in both Tables 7 and 9, exhibited a negative regression coefficient. This implies an inverse relationship between hired labor employment and family labor.

A highly significant variable which positively influenced labor utilization and employment is the amount of output (*Q*) produced per hectare. For all regressions, this variable was significant up to the 1 percent level.

Experience (*Ex*) and education (*Ed*) were observed to exhibit some effect on the utilization (or management) of total hired and family labor but it is difficult to derive any definite conclusion regarding their effect on total labor utilization.

As hypothesized, the wage:rice price ratio (*WRP*) exhibited a negative regression coefficient in the total labor covariance model in Tables 7 and 9. This implies a decrease (or increase) in the demand for total labor during periods when the ratio between average labor wage rate and the price of rough rice per kilogram is relatively high (or low). However, the significant negative sign of this same variable

TABLE 8
ESTIMATED DIFFERENCE IN TOTAL LAND PREPARATION LABOR USE IN RICE PRODUCTION AMONG FARMS WITH DIFFERENT MODES OF MECHANIZATION, CROP YEAR 1979-1980

Independent		*Land preparation* Total hired labor	Total family labor	Total labor
Constant		41.87***	116.16***	146.37***
		(4.05)[a]	(7.14)	(9.12)
Two-wheel	(M_1)	−6.60	−64.76***	−71.71***
		(−0.86)	(−4.77)	(−5.35)
Two-wheel/carabao	(M_2)	−1.89	−45.77***	−49.03***
		(−0.28)	(−3.80)	(−4.13)
Carabao/thresher	(M_3)	2.55	10.36	13.04
		(0.51)	(1.17)	(1.50)
Two-wheel/thresher	(M_4)	−6.96	−72.63***	−80.16***
		(−1.23)	(−7.24)	(−8.09)
Two-wheel/carabao/ thresher	(M_5)	−1.30	−58.92***	−60.49***
		(−0.21)	(−5.29)	(−5.50)
Seasonal effect	(S)	−1.80	23.83***	21.28***
		(−0.49)	(3.65)	(3.30)
Tenure	(T)	12.43***	−26.49***	−13.63***
		(3.37)	(−4.06)	(−2.12)
Household members	(HM)	−1.52**	–	–
		(−2.04)	–	–
Experience	(Ex)	−0.25	−0.20	−0.46*
		(−1.60)	(−0.73)	(−1.70)
Education	(Ed)	0.55	−1.70	−0.94
		(0.84)	(−1.47)	(−0.83)
Wage-rice price ratio	(WRP)	−7.08**	5.74	0.89
		(−2.14)	(0.98)	(0.15)
Cropping intensity	(CPI)	−0.04	−0.10	−0.15***
		(−1.03)	(−1.46)	(−2.15)
Net worth	(NW)	−0.00001	0.00003	0.00001
		(−0.17)	(0.26)	(0.0009)
R^2		0.12	0.28	0.34
F-value[b]		4.32	13.27	17.66
Number of observations		419	419	419

a. Values in parentheses are calculated t-values.
b. F-statistic for testing the significance of the regression model.
*** Significant at P=1%
** Significant at P=5%.
* Significant at P=10%.

for the family labor covariance model implies that, as labor wage increases relative to the price of rice, farmers tend to work in other farms, thereby possibly reducing reliance on family labor in their own farms. This further implies that farmers have a higher valuation of the opportunity cost of their labor services relative to their valuation of the effort they exert in their own farm. However, under such a situation, it is unlikely that off-farm job opportunities will be sufficient to absorb the additional labor supplied in the market since farms will tend to maintain or reduce current levels of hired labor employment at existing high wage rates. This is supported by the insignificant regression coefficient of *WRP* in the hired labor covariance models in Tables 7 and 9.

In Table 8, the negative and significant regression coefficient of *WRP* in the hired labor covariance model implies that, as far as land preparation is concerned, less hired labor is employed as the average wage rate increases. Although the coefficient of the variable *WRP* was not found to be significant in the family labor covariance model, its positive sign nevertheless implies that more family labor is utilized as substitute for hired labor under such a situation.

The cropping intensity variable (*CPI*) in all covariance models in Tables 7, 8 and 9 exhibited a negative coefficient, contrary to what has been previously hypothesized. After reviewing the data and the regression results, such a phenomenon is not surprising since farms with high *CPI* generally have lower levels of labor input requirements due to the fact that these farms rely heavily on mechanical power. This may be supported by the significant and negative regression coefficients of M_1, M_2, M_4 and M_5 which imply that mechanized farms utilize less labor than nonmechanized farms.

Of the major operations of rice production, mechanization significantly reduced labor utilization and employment in land preparation and postproduction, as verified by the statistical tests. The evidence shows that the use of two-wheel tractors, singly or in combination with carabao power, in land preparation has reduced family labor requirements as well as hired labor employment. In the case of farms using mechanical threshers, it may be concluded that these farms utilized less family and hired labor in postproduction operations compared to those farms which did not use such machinery. Furthermore, labor utilization and employment effects differed among farms with different modes of mechanization. Aside from two-wheel tractor and mechanical thresher usage, other factors that

TABLE 9
ESTIMATED DIFFERENCE IN TOTAL POST-PRODUCTION LABOR USE IN RICE PRODUCTION AMONG FARMS WITH DIFFERENT MODES OF MECHANIZATION, CROP YEAR 1979-1980

Independent Variables		*Postproduction*		
		Total hired labor	*Total family labor*	*Total labor*
Constant		23.98	220.90**	256.26***
		(0.55)	(8.32)	(6.78)
Two-wheel	(M_1)	−16.41	4.43	−10.96
		(−0.51)	(0.20)	(−0.35)
Two-wheel/carabao	(M_2)	1.96	−42.66**	−34.32
		(0.07)	(−2.16)	(−1.25)
Carabao/thresher	(M_3)	16.03	−24.44*	−9.25
		(0.77)	(−1.71)	(−0.46)
Two-wheel/thresher	(M_4)	−67.98***	−30.47*	−99.77***
		(−2.84)	(−1.86)	(−4.77)
Two-wheel/carabao/ thresher	(M_5)	−55.33**	−25.84	−75.82**
		(−2.10)	(−1.43)	(−2.95)
Seasonal effect	(S)	−17.55	7.53	−8.00
		(−1.10)	(0.69)	(−0.52)
Tenure	(T)	10.81	3.24	13.29
		(0.70)	(0.31)	(0.88)
Household members	(HM)	−1.02	–	–
		(−0.33)	–	–
Output	(O)	0.05***	−0.007**	0.04***
		(9.32)	(−2.14)	(8.27)
Experience	(Ex)	1.19*	−1.06**	−0.04
		(1.87)	(−2.45)	(−0.06)
Education	(Ed)	1.99	−1.86	−0.85
		(0.74)	(−1.01)	(−0.32)
Wage-rice price ratio	(WRP)	5.64	−26.93***	−40.38***
		(0.41)	(−2.87)	(−3.02)
Cropping intensity	(CPI)	−0.006	−0.44**	−0.32***
		(−0.04)	(−3.85)	(−2.00)
Net worth	(NW)	−0.0002	−0.00001	−0.0002
		(−0.72)	(−0.01)	(−0.63)
R^2		0.21	0.17	0.21
F-value[b]		7.89***	6.45***	8.32***
Number of observations		419	419	419

a. Values in parentheses are calculated t-values.
b. F-statistic for testing the significance of the regression model.
*** Significant at P=1%
** Significant at P=5%.
* Significant at P=10%.

were observed to affect labor utilization are amount of output produced (Q), season (S), and factors which may enhance the managerial capability of the farm operator such as experience (Ex) and education (Ed) and cropping intensity (CPI).

Production Function Analysis

The production function approach to the analysis of mechanization impact on rice output provides one with information regarding the distribution of output among inputs as well as the sensivity of such distribution to changes in the levels of input applied with a given technology (Ranade and Herdt 1978). For analytical purposes, production functions of the Cobb-Douglas type are estimated to obtain such information.

With the use of dummy variables (i.e, M_1, M_2, M_3, M_4, and M_5) which represent rice farms with different modes of mechanization, a test for differences in the technical efficiency parameters of each farm classification was conducted. Since preliminary tests indicate that the different farm groups operate on different production functions, further estimates were conducted for each farm classification with identical functional specification. This is expressed as:

$$(22) \quad Q_{ij} = A_j L_{ij}^{a_1} F_{ij}^{af} Ch_{ij}^{ac}\ e\ (b_i I_{ij} + b_s S + u^*)^2$$

In logarithmic form,

$$(23) \quad l_n Q_{ij} = lnA_j + a_l lnL_{ij} + a_f lnF_{ij} + a_c lnCh_{ij} + b_i I_{ij} + b_s S + u^*$$

The results in Table 10 show that farms using mechanical power, whether solely or in combination with animal power, exhibited higher technical efficiency parameters than those which are purely non-mechanized, i.e., C farms. In addition, the labor variable was found to be significant in most of the estimated production functions, except for the TW farm classification. The labor coefficient is highest for farms with purely nonmechanized land preparation operations, i.e., C and CT farms, while those farms using only two-wheel tractors

2. Since the results obtained from preliminary estimates showed that variables Ed, Ex and FO exhibited statistically insignificant regression coefficients, these variables were dropped from the previously specified production function as expressed in equation (21). Furthermore, the exclusion of these variables did not alter the R_2 in the newly estimated production function.

Table 10

ESTIMATED COBB-DOUGLAS PRODUCTION FUNCTIONS OF SMALL RICE FARMS[a] WITH DIFFERENT MODES OF MECHANIZATION, NUEVA ECIJA, PHILIPPINES, CROP YEAR 1979-1980

Independent Variable	Carabao (C)	Carabao/ thresher (CT)	Two-wheel tractor (TW)	Two-wheel tractor/ thresher (TWT)	Two-wheel tractor/ carabao (TWC)	Two-wheel tractor/ carabao/ thresher (TWCT)	Pooled Regression[c]
Constant	0.59 (0.42)[b]	4.00*** (6.88)	7.26*** (7.64)	5.68*** (10.24)	1.69* (1.81)	4,86*** (6.25)	3.98** (9.07)
Labor (L)	0.97*** (4.03)	0.76*** (4.70)	0.18 (0.91)	0.16* (1.79)	0.69*** (3.56)	0.23* (1.82)	0.42** (5.71)
Fertilizer (F)	0.02 (0.26)	0.11*** (3.12)	0.08 (1.42)	0.04* (1,86)	0.03 (0.51)	.031*** (2;69)	0.04* (1.61)
Chemicals (CH)	0.15** (2.01)	0.01 (0.44)	0.07 (1.08)	0.22*** (6.00)	0.35*** (2.97)	0.04 (0.80)	0.18** (6.78)
Irrigation (I)	0.05 (0.21)	0.24*** (2.44)	0.35* (1.80)	0.25** (2.89)	0.31* (1.80)	0.44*** (3.63)	0.36** (4.95)
Season (S)	0.20 (0.74)	0.25** (2.33)	0.02 (0.13)	0.13* (1.93)	0.08 (0.44)	0.31** (2.33)	0.21** (2.90)
R^2	0.27	0.57	0.28	0.42	0.81	0.64	0.36
F-value	6.67***	25.90***	1.98	13.03***	26.62***	16.69***	45.46**
Number of observations	98	105	32	95	37	52	419
Degrees of freedom	92	99	26	89	31	46	413

[a]Estimated on a per hectare basis.
[b]Values in parentheses are t-values.
[c]A production function with same independent variable was estimated by pooling all the data obtained from the six farm classification into one estimating regression equation.

***Significant at P = 1%
**Significant at P = 5%
*Significant at P = 10%

for these same operations, i.e., *TW* and *TWT* farms, exhibited the lowest labor coefficients. Such behavior of the labor coefficient implies that increases in the degree of mechanization results in labor redundancy, particularly in land preparation operations.

The influence of fertilizer on rice output was found to be significant in those farms, i.e., *CT*, *TWT* and *TWCT* farms, which incurred high expenditures on this input. It should be noted that the *TW* farms also applied high levels of fertilizer but did not exhibit significant regression coefficients for this variable. As far as the effect of chemicals on rice output is concerned, only *C*, *TWT* and *TWC* farms exhibited significant regression coefficients.

Since most of the mechanized farms, whether partially or fully mechanized, are located in areas with irrigation facilities only these farm-types showed significant influence of irrigation on rice output. The regression coefficient of the irrigation variable in the production function of *C* farms was insignificant which is not surprising since these farms are generally nonirrigated or are inefficiently irrigated. The season dummy variable for all farm classifications was found to be positive — implying that greater rice output is produced during the dry season by all farm-types. It should be noted that the low R^2 of each estimated farm-specific production function implies considerable weakness in the explanatory power of the independent variables included in the regression equations. However, since the main concern of the production function analysis is to determine whether farms with different modes of mechanization differ in output produced as well as to find out which factors of production have significant impact on output, the low R^2 of each regression model does not invalidate the analysis.

Based on the above estimated production functions, it may be said that all farmswith different degrees of mechanization, i.e., *CT*, *TW*, *TWT*, *TWC* and *TWCT* farms, attain greater technical efficiency compared to those which are nonmechanized, i.e., *C* farms. This is implied by the significantly larger regression constant for all these said farm-types. However, the question of whether or not each farm-type utilizes labor at a level in which the profit-maximizing condition is attained needs to be considered. Given their respective level of technology, as well as factor and product price, each farm-type's profit-maximizing condition is represented by:

$$(24) \quad (Pq_j)\ [(a_{lj})\,(\bar{Q}_j/\bar{L}_j)] = P_{Lj}$$

where:

Pq_j is the average price per kilogram of rough rice for the *j*th farm.

a_{lj} is the output-labor elasticity as obtained from the production function estimates of each farm-type.

Q_j is the average amount of rough rice produced by each farm classification per hectare, in kilograms.

L_j is the average amount of labor-hour input utilized by each farm classification for all farm operations per hectare.

P_{Lj} is the average labor wage rate per hour, in pesos.

$[(a_{lj})\ (\bar{Q}_j/\bar{L}_j)]$ is the marginal physical product of labor or MPP_L.

$P_{qj}[(a_{lj})\ (\bar{Q}_j/\bar{L}_j)]$ is the value marginal product of labor or VMP_L.

The above relationship implies that profit maximizing farms utilize labor at a level where their respective value marginal products are equal to the farm-specific labor price. The results of the above calculations are presented in Table 11.

It may be observed in Table 11 that farms with large output elasticity values with respect to labor (i.e., *C* and *CT* farms) exhibited high MPP_L values. This implies that for each additional unit of rice output, a large portion of this unit may be attributed to labor. However, for farms which are highly mechanized, such as *TW* and *TWT* farms, their marginal physical products of labor exhibited lower absolute values — implying that the contribution of labor, relative to other inputs, to each additional unit of output is lower in farms with highly mechanized operations. Multiplying the MPP_L values of each farm classification by the farm-specific average rice price, P_q, the VMP_L and P_L values indicate that farms with nonmechanized land preparation operations (i.e., *C* and *CT* farms) are unable to optimize labor utilization due to a very low labor wage rate. For these farm classifications, $VMP > P_L$, which implies that to maximize profit they must expand their labor utilization beyond their current levels, in spite of the fact that these farms already use considerably more labor input hours than the other farm-types which have mechanized land preparation operations. It should be noted that such results do not differ from the graphical illustration presented in Figure 2. In the case of the farms using only carabao power for land preparation, the very low labor wage rate faced by these farms does not provide any

TABLE II
INFORMATION REGARDING THE VALUE MARGINAL PRODUCT AND AVERAGE LABOR WAGE RATE PER HOUR OF FARMS WITH DIFFERENT MODES OF MECHANIZATION, NUEVA ECIJA, PHILIPPINES, CROP YEAR 1979-1980.

	Carabao (C)	Carabao/ thresher (CT)	Two-wheel tractor (TW)	Two-wheel tractor/ thresher (TWT)	Two-wheel tractor/ carabao (TWC)	Two-wheel tractor/ carabao/ thresher (TWCT)
Average rice price (Pq)	1.11[a]	1.10	1.12	1.13	1.12	1.13
Output elasticity of labor (a_1)	0.97[b]	0.76	0.18	0.16	0.69	0.23
Rice yield per hectare ($\bar{Q}$)	2.270[c]	3,008	4,181	4,035	2,854	3,664
Labor hours per hectare ($\bar{L}$)	597	686	550	438	501	464
Marginal physical product of labor (MPP_L)	3.69[d]	3.33	1.37	1.37	3.93	1.82
Value marginal product of labor (VMP_L)	4.10[e]	3.66	1.52	1.66	4.40	2.06
Average labor wage rate (P_L)	1.70[f]	1.54	2.22	2.12	1.88	2.22

[a] Peso per kilogram.
[b] Regression coefficient of the labor variable.
[c] In kilograms.
[d] $MPP_L = (a_1) [(\bar{Q}/\bar{L})]$.
[e] $VMP_L = (P_9) (MPP_L)$.
[f] Peso per man-hour.

incentive for their operators to use mechanical power. As a result, given their respective farm budgets and the relatively high price of man-machine services, these farms will tend to rely mainly on labor-animal power. In Figure 2d, this is indicated by point F which is the point of tangency of isocost curve IC_1 and isoquant q_2.

However, in the case of the mechanized farms, except for the two-wheel tractor/carabao farms (*TWC*), the difference between the VMP_L and P_L values is not too pronounced due to (1) the lower share of the labor input for each additional unit of rice, and (2) the higher average labor wage rate in these farms. The higher labor wage rate in the mechanized farms may be due to the higher level of "specialized" labor required to accomplish certain farm operations, i.e., land preparation and threshing with mechanical power, in these farm-types. As a result of the lower output share of labor and the higher average wage rate, mechanized farms are able to utilize this factor closer to the profit-maximizing labor input level than those which are not mechanized. From the above discussion, one may expect that as long as the contribution of labor remains at a low level and the labor wage rate continues to be high, mechanized farms will tend to employ less labor compared to nonmechanized farms.

This implies that, under a mechanized scheme (Figure 2e), a mechanized farm with isocost curve IC_2' and producing the same amount of output as a nonmechanized farm, i.e., q_2^* output, it will utilize labor at that level where it is able to maximize profit. In this case, at L_1 amount of labor which is less than what a nonmechanized farm requires to produce the same level of output.

Summary and Conclusions

Rice, the major staple crop in the Philippines, is grown predominantly by small farms with different levels of mechanization. In order to investigate the impact of farm machinery adoption on labor employment and output in small rice farms, two municipalities in Nueva Ecija were surveyed to gather relevant information for this purpose.

Statistical analyses showed that the major effect of mechanical power adoption is the significant reduction in the labor input requirements of farms using two-wheel tractors for land preparation and mechanical threshers for postproduction operations. This is reflected by the fact that the use of two-wheel tractors, singly or in combination with carabao power in land preparation, reduced family labor requirements and hired labor employment as well. In addition, mechanical threshers were found to have the potential of replacing and displacing postproduction labor. Aside from the adoption of farm machinery, other factors that were observed to affect labor utilization were the amount of output produced, cropping season and managerial capability of the farmer operator.

Although the statistical analyses indicated that mechanized farms realized higher levels of rice output than nonmechanized farms, these results are not conclusive as far as attributing the difference solely to mechanization due to the fact that mechanized farms apply higher levels of fertilizer and chemicals which may also account for the higher yields attained by these farms. Furthermore, these same farms have better irrigation facilities than nonmechanized farms.

Based on these findings, it may be concluded that the substitution of farm machinery for manual power in certain operations such as land preparation and postproduction has resulted in the reduction of labor requirements for such tasks, and subsequently in the reduction in total labor requirement for all operations. In addition, contrary to the "net contributory" argument — that mechanized land preparation operations result in higher yields — it may be concluded that yield-differences between mechanized and nonmechanized farms may be attributable to other factors such as the intensity of fertilizer and chemical usage and proper water management. Furthermore, although mechanized farms realized higher yield levels per hectare, no evidence was observed to support the net contributory argument that greater output results in increased harvesting labor requirements which, in turn, offsets the amount of labor displaced in land preparation due to mechanization.

Policy Implications

It would seem that any policy promoting the adoption of farm machinery in small rice farms in the Philippines will have differential impacts on the two major components of farm labor, i.e., hired and family labor. Closer analysis must be made with regard to the degree that family labor is displaced and/or replaced by farm machinery — not only in terms of the number of how many man-machine hours have been substituted for man-animal hours but also in terms of which of the family household members have been relieved from farm work. Furthermore, it is necessary to know the alternative activities to which this displaced family labor has been diverted.

Generally, hired labor services are derived from (1) landless laborers whose main source of income is farm employment, and (2) farm households with surplus family labor. It is, therefore, apparent that the displacement of hired labor from mechanized farm activities will considerably affect landless laborers. Thus, mechanization policies should substantially include programs which may facilitate the redirection of surplus farm labor toward other income-earning endeavors.

A more immediate question that one has to answer is: Given the current economic environment, is the adoption of farm machinery (such as tractors and threshers) the appropriate engine of growth for facilitating agricultural production efficiency and subsequently, agricultural development? In the light of high fuel cost and import restrictions due to dwindling foreign exchange reserves, more local research must be done to develop appropriate mechanical technology which improves rice production efficiency without necessarily substituting for labor and which is not dependent on petroleum-base energy fuel for operation – such as fertilizer applicators, chemical sprayers, mechanical weeders and the like. These research and development programs should encourage the utilization of indigenous materials and expertise.

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