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ECONOMIC INEFFICIENCY AS A CONSTRAINT TO HIGH RICE YIELDS IN NUEVA ECIJA, PHILIPPINES[1]

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In 1974, the International Rice Research Institute intitiated a research project to explain the rice yield gap. The yield gap is defined as the difference between the maximum potential yield possible with improved technology under farmer's conditions and actual farmer's yields. The research involved the joint efforts of agronomists, economists and statisticians and used field experiments and farm surveys to provide data that would help researchers understand the rice yield gap.[3] The project indicated that, in general, farmers have not fully exploited the potentials of the improved rice technology. A group of scientists from other countries have joined in similar research within the International Rice Agro-Economic Network (IRAEN).

In the course of the constraints research project, there have been a number of indications that rice farmers do not apply their inputs as efficiently as possible. An illustration of inefficiency is shown in Figure 1. It shows the average return over costs of fertilizer, insect control, and weed control at the three fertilizer test levels with farmers' and maximum levels of insect and weed control in 1977. In both the wet and dry seasons, the average farmers' expenditure on fertilizer was higher than the middle fertilizer level, but returns were substantially lower than were achieved with the researchers' treatments.

These observations have led to further investigation and the suggestion that farmers' feritlizer timing could be the cause of the inefficiency. In 1976, we found that farmers apply a significant proportion of their phosphorous and potassium later than 10 days after

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[3]For a detailed discussion of the objectives, methodology and procedures of this project, see S.K. De Datta, R. Barker, R.W. Herdt and K.A. Gomez, "Handbook on Yield Constraints Methodology," paper presented at the Farm Level Rice Yield Constraints Conference, IRRI, 24-26 April 1978.

transplanting, while agronomists believe it should be applied prior to transplanting (Table 1). Further testing of this hypothesis under farmers' conditions has so far failed to confirm time of application as a major cause of inefficiency. However, despite the fact that we do not know its cause, the hypothesis that inefficiency is substantial would appear to be worth investigating.

Knowledge of the extent of economic inefficiency and its causes may be crucial in the formulation of policies. For example, the information provided by the explanation of economic efficiency differentials will be useful to several groups of people notably the policy makers and extension agents especially in the developing countries like the Philippines. In these countries, there is usually a great variety of proposed programs, all designed to hasten agricultural development, such as extension services, farming training centers, mass media programs and the like. If policy makers know the sources of technical efficiency differentials among farmers, they might have a firmer ground in choosing among such an array of programs. Also, it might help extension workers select the specific contents of their overall efforts in assisting farmers improve their management practices.

This paper's basic organization can be outlined briefly as follows. In the next section the theoretical framework is developed and illustrated. A brief discussion of the data used in the analysis follows. The empirical production function model is then presented. The estimated production function and the derived measures of efficiency will be discussed. An explanation of the efficiency differentials among farmers and its policy implications complete the paper.

Theoretical Framework

The issue of producer efficiency has received considerable attention in economic literature in recent years. Concepts have been rigorously defined to provide a useful basis for considering the possible corrective actions one may take to increase production.

Producers' failure to obtain the potential production arises from two basic sources: (1) from their failure to operate on the technically efficient production function; (2) from their failure to use the level of inputs that maximize output. The "efficient" production function is defined as the function that describes the greatest possible output from a given combination of inputs. Failure to operate on the production function is referred to as technical inefficiency. Farmers' failure to utilize the profit maximizing level of inputs is termed allocative (price) inefficiency. The literature has characterized the total of the above as economic inefficiency.

Traditional economic analysis assumes that firms operate on the most technically efficient production function. In developing agricultures, however, farmers may employ a relationship which differs from the above. Such relationship is determined, in part, by both manageable and non-manageable factors or those that are beyond the control of individual rice farmers. Hence, the definition of technical efficiency will be unique for each farmer since the maximum output it is possible for him to achieve will depend on the environmental conditions under which the inputs are used.

Farrel (1957) first identified technical efficiency and price (allocative) efficiency as two components of economic efficiency.[4] He defined "technical efficiency" as measuring a firm's success "in producing maximum output from a given set of inputs." Leibenstein assumed away the problem by referring to actual productive performance as "X efficiency" and departing from the neoclassical assumptions of maximizing decisions and the firm as an integrated decision unit (1966, 1967).

Following Farrell, analysis requires an estimate of the technically efficient production function. Much of the recent literature has focused on the issue of estimating such a technically efficient function by using linear programming to generate a frontier function (Aigner and Chu, 1968; Seitz, 1970; Timmer, 1970). The nature of the data generated in the constraints project, however, allows us to use an alternative methodology for estimating the efficient production function directly. The more recent work of Shapiro and Muller (1977) attempts to explain sources of technical efficiency.

Figure 2 shows the basic model used to conceptualize the constraints imposed on rice production by technical and allocative inefficiencies in the simple one input case. Given the efficient production function (TPP) market prices of inputs and output, no restriction on input use, profit maximizing behavior, and competitive markets, economic theory shows that producers will choose to utilize X_0 level of input where its marginal value product equals its marginal cost and produce Y_0 level of input. At this point (A) in Figure 2, the farm is both technically and allocatively efficient.

The farm at point Q is technically inefficient in the use of X_0 because its output, Y_0', is lower than Y_0. This farmer is operating on a technically inefficient production function. In general, a farmer's actual output, given his actual input levels, would equal potential output

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[4]This dichotomy was adhered to by recent investigators notably Lau and Yotopoulos (1971).

only if he operated on the efficient production function. The technical efficiency score is the ratio of his actual to efficient output, Y_0'/Y_0, or $Y_0'/Y_0 \times 100$ on a percentage basis. All farms have a technical efficiency ranking of 100 or less on this basis, with the lower limit being zero if the farm uses inputs but produces no output.

On the other hand, a farm is allocatively or price efficient if it uses its inputs so as to maximize its profits. In Figure 2, allocative inefficiency occurs with the use of X_1 level of input, which if used in the technically efficient way will produce Y_1 (point B). The degree of price inefficiency measured along the technical inefficient production function, but we follow the other, more conventional approach. These concepts can be generalized into multi-factor space as illustrated by Timmer (1970). They have the advantage, as illustrated, of separating the technical from the allocative decision, something that ordinary cost comparisons cannot do.

For purposes of explaining the total yield gap, measures of technical and allocative efficiencies that could be added together are useful. The following measures, which involve slight modifications of the above definitions will be used:

(1) Technical efficiency: $$E_t = 1 - \frac{Y_1 - Y_1'}{Y_1'}$$

(2) Allocative efficiency: $$E_a = 1 - \frac{Y_0 - Y_1'}{Y_1'}$$

In effect, these measure the gains that could be achieved if a producer first becomes technically efficient and then becomes allocatively efficient. The two measures may be added to give an overall measure of economic efficiency.

The model also allow estimation of the yield gap as defined in the constraints project. This is simply $Y_{max} - Y_1'$ in Figure 2. With the devised measures above, the yield gap can now be attributed to three factors: (1) profit-seeking behavior, i.e. the desire of farmers to maximize profits rather than yields $(Y_{max} - Y_0)$, (2) allocative inefficiency $(Y_0 - Y_1)$, and (3) technical inefficiency $(Y_1 - Y_1')$. Depending on which of these components is most important, corrective actions can be suggested. If artificially distorted prices can be shown to significantly increase the portion of the yield gap due to profit-seeking behavior, it may be possible to recommend that the government remove such distortions. Also, improving our knowledge of what factors are responsible for technical inefficiencies will improve the possibility of their removal.

Sources of data

Experimental, record keeping and survey data gathered under the IRRI Constraints project in Nueva Ecija from the wet season of 1974 to the dry season of 1977 are used in our analysis. The experiments were conducted by the IRRI Agronomy Department in 56 farmers' fields over five municipalities in Nueva Ecija (Figure 3). The record keeping and farm surveys were implemented by the Agricultural Economics Department.

Experiments. The experiments have been designed to measure the maximum yield under farmers' conditions that could be obtained by manipulating the main inputs under farmers' control, the actual farmers' yield and the contribution of each main factor responsible for the differences. Table 2 shows the set of treatments that have been included in most of the experiments.

Treatment 1 is intended to simulate the level and method of input use by the farmers on whose fields the experiments were located. Treatment 5 is intended to provide the level of inputs needed for maximum yield. Treatments 2, 3 and 4 have intermediate levels of each input between the farmers' level and the maximum yield level. Treatment 6 through 11 are factorial combinations of the inputs at the farmers' input level and the maximum yield input level. Treatment 12 through 19 are factorial combinations of various intermediate input levels. These treatments were added in 1977.

Among this set of experimental treatments, numbers 2-5 and 14-19 are designed by and under the control of the researchers, and therefore, it can be argued, lie on the efficient production function. It is the objective of the researchers to get the highest possible yield with the inputs used. They are not constrained by input costs, they have a higher level of knowledge than farmers. On the other hand, they have designed the experiments to include only materials that are generally available in the areas where the experiments are being conducted. Hence, M_2 through M_5 are points on the efficient production function.

If data from treatments 2 through 5 were used to empirically estimate a production function with the arguments F, W and I, the resulting estimate would be the efficient production function. However, it is highly unlikely that data from those treatments alone could generate an acceptable estimate of the production function because of multicollinearity among the inputs F, W and I. This is illustrated in Figure 4 for the two-input case where the problem is essentially that of estimating the isoquant for F and I, given a level of W. The choice of M_2-M_5 is such that they are points on the expansion path. The isoquant cannot be estimated unless points like 6, 8, 13, 14 and 15 are also included (Figure 4).

During the first 2 years of the research, only treatments 1-11 were included in the experiments. In general, two replications were included at each site, providing enough observations of the correct design to permit an estimate of the production function. If such observations can be pooled across sites through the use of environmental variables, the data base is quite adequate. However, if no recognition is made of the potential difference in farmer's and researcher's efficiency, the estimated function will not be a good representation of the production function because of the inclusion of treatments 6-13, which include the farmers' level and method of use for at least one input. The difficulty is illustrated in the one input case in Figure 5. The production function is the solid line. The dashed line shows the function that would be estimated if Y_1F_1 is included as an observation because it reflect technical inefficiency in the use of the input by the farmer.

This problem may be overcome by using analysis of covariance within multiple regression to specify slope shifters to the coefficients of F, W and I in the estimating equation such that the magnitude of the former reflects the difference in efficiency between the farmer and the researcher. In this way, wehave a direct measure of the farmer's level of efficiency relative to that of the researcher's.

Record keeping and survey data. Record keeping involving weekly visits to farm households was carried out during the 1975 wet and 1976 dry seasons. A detailed information of farmers' input use and other cultural practices are available for an intensive data parcel on each farm. A follow-up survey consisting of a technical knowledge test as well as additional information on input use, prices of inputs and output, yield constraints perceived by farmers, and farmers' attitude to credit and risk was conducted toward the end of the crop season on all farmers participating in the project.

In search of factors that might explain the differentials in the obtained measures of efficiency, a terminal field survey was conducted on the same farmers on whose fields the experiments were conducted. The survey sought to obtain information on factors normally associated with efficiency such as economic mindedness, husbandry, technical knowledge, acquired skills, education, information and modernization and other similar discreet explanatory variables.

The empirical models:

Production function model. The effect of variability in the physical environment from farm to farm is reflected directly in the estimated production function by including the physical factors as variables in the function. With an appropriate response model, it is possible to separate the effects of manageable factors from those which are beyond the control of the farmers. Another source of variability is that of the economic environment which cannot be taken into account directly in the production function, but which is adjusted for in analyzing differentials in the obtained measures of economic efficiency.

The model assumes that all rice farmers in the study area have access to the same technology. It, therefore, incorporates farm inputs, environmental variables, and efficiency parameters:

$$Y = f(X_1, X_2, \ldots, X_k, \; Z_1, Z_2, \ldots, Z_n, \; E_1, E_2, \ldots, E_n, \; U)$$

where

Y is rice yield
X_i are inputs
Z_i are environmental variables
E_i are zero-one variables used to reflect efficiency
U is an error term

The regression model includes traditional inputs, uncontrolled environmental variables, interaction terms, and efficiency variables. The environmental factors considered are the four physical effects of solar radiation, typhoon, water stress, and soil plus two others which are strongly influenced by them namely, insect damage and disease incidence. The latter two could be considered environmental variables subject to some degree of management, while the former four are largely beyond the control of individual farmers. Three soils characteristics, organic matter, texture and extractable P, measured at each site were included in the estimating equation. Another variable was age of seedlings for each experiment. This makes a total of seven variables measured for each experiment, or site, referred to subsequently as site variables. The input factors were controlled at specific levels of each plot, and they along with with insect and disease incidence are referred to as plot variables.

The variables included in the regression analysis were specified as follows. Applied fertilizer (F) is the total amount of nutrients (N + P + K) in kg/ha. Insect and weed controls were expressed as expenditures in pesos per hectare. Age of seedlings was the number of days from sowing to the time of transplanting. Damage due to insects and disease incidence was expressed numerically using a scale from zero to nine. Stress days were counted as the number of days after the first 3 that the soil surface had dried up. Soil organic matter and texture were expressed as percentage while extractable P was expressed in ppm. Solar radiation was expressed as the total energy received during the 45 days immediately prior to harvest. Typhoon occurrence was specified as a dummy variable

Regression model to explain economic efficiency. The intent was to explain the variation in the economic efficiency ratings among farmers using variables both internal and external to the farms. In explaining variation in technical efficiency rating, variables generally associated with management were explored. Bhati (1973) listed

technical knowledge, education, tenurial status, access to external economies, and others as affecting farmers' management ability. More recently, Shapiro and Muller (1971) used information and modernization in explaining technical efficiency differentials among farmers. Technical knowledge was shown by Bhati to be directly related to farmers' level of efficiency. Education may have productive value in agriculture both because it may enable a farmer to better obtain and use information for managerial decisions on the purchase of input factors (Fane, 1975).

Based on theory and some available evidence, we hypothesized that the less technically and less allocatively efficient farmers would be relatively: (a) older, (b) incapable of obtaining farm information, (c) possess less technical knowledge in growing rice, (d) poorly educated, (e) spend more days out of the farm, (f) lack irrigation facilities, (g) have insufficient labor, (h) have less income, (i) have a larger total rice area, and (j) share tenants.

Some factors that may not be related to technical efficiency but may be associated with the variation in the allocative efficiency index such as degree of exposure to natural risk factors and availability of credit were used in explaining allocative efficiency in addition to the factors listed above. Credit is generally believed to ease capital constraints while risk aversion reduces allocative efficiency.

Ten variables were used to explain variation in technical efficiency (Table 8) and twelve to explain variation in allocative efficiency. The variables were specified as follows. Total area devoted to rice which include all parcels cultivated by the farmer was expressed in hectares. Information index was developed from Guttman scales of factors reflecting information such as knowledge of input and output prices and ability to seek agricultural information. Age of farmer and educational level were expressed as years in existence and years spent in school, respectively. Gross family income was total income in pesos derived from operations including income derived from crops and livestock, and other farm and off-farm employment.

Number of days worked off farm was the total number of days that the farm operator left unattendedduring the cropping season from transplanting to harvest. Technical knowledge score was developed from a valid Guttman scale of a subset of items that were included in a technical knowledge test administered to all farmer cooperators. Tenure status was expressed as a dummy variable equal to 0 for owners and leaseholders and equal to 1 for share tenants. Labor availability was expressed as a dummy variable equal to 0 if the farm family possessed an amount of labor that was enough for the farm and equal to 1 if it was not enough. Credit availability was expressed as a dummy variable equal to 0 if the farm operator obtained credit from any source and equal

to 1 if he did not borrow. Risk was expressed as a dummy variable equal to 0 if the farmer did not experience losses from natural risk factors such as typhoons, drought, insects and disease during the last 5 years, and equal to 1 if he reported severe losses.

Results

The production function. Some previous experience with measuring the effects of production inputs to rice growth among a diverse set of locations has previously been reported (Mandac, 1974; Rosegrant, 1977). These equations have typically been based on a quadratic response to fertilizer, modified by a relatively large number of other variables and interaction terms. Such complex functions cannot normally be estimated with economic data because of the multicollinearity problem, but because the experiments have been designed with appropriate combinations of inputs and because of the variation in environmental factors across sites, the complex functions are econometrically satisfactory.

The initial group of independent variables selected for the regression analysis include the linear and quadratic effects of applied F, W, and I, the linear effects of pest damage and disease incidence plus the seven site variables mentioned above and three efficiency variables. Insect and weed control were believed to influence the expected response from F. Therefore, three interaction variables were included namely IF, I^2F, and WF. In the same manner, it was expected that the effect of F would be larger at lower levels of insect damage and disease incidence, so interactions with the two variables were added. Also, soil organic matter, extractable P, seedling age, solar radiation, and water stress were believed to affect the response from F, so another six interaction variables were specified. The effect of water stress is expected to be greater at higher levels of solar radiation. Finally, it was suspected that the effect of organic matter and of texture would be parabolic, so the quadratic effect of these variables were included. This brought the total number of independent variables to 32 in Model I. In another model, individual efficiency measures with respect to fertilizer were included. Because there were 37 sites for which such individual efficiency measures were calculated, this procedure brought the total number of independent variables to 69.

The first step in the analysis was simultaneously to regress yield on the 32 independent variables. The 32 regression coefficients in Model I were tested for significance as usual using the t-statistic. Eleven coefficients were not significant at the 5% significance level. Water stress, which field observations suggested was very effective in reducing yields, had a small negative t value. On the other hand, soil texture, which was not expected to greatly influence yields, had very large regression coefficient. The results of Model I are shown in Table 3.

In Model II, the 69 independent variables were regressed on yield to determine if the inclusion of efficiency parameters of individual farmers would improve on Model I. Thirty-seven regression coefficients were at least significant at the 5% significance level. The effect of water stress is captured in its interaction term with fertilizer. Similar to the earlier model, however, the coefficients of insect and weed controls had the unexpected signs. The regression coefficients are shown in Table 4.

Using both adjusted R^2 and residual sum of squares of deviations from regression, $\Sigma(Y - Y)^2$, as criteria for selecting the better model, Model II appears to be superior to Model I. Another test to the validity of the models is to determine whether or not the individual regression coefficients make sense. One way to determine whether the effects of the independent variables are fairly consistent is to calculate the marginal productivities of each variable at some specified level of input factors and the environmental variables. For purposes of this analysis, the marginal productivities of the independent variables are estimated at the M3 level of F, W, and I and at the mean of the environmental and other varialbes. The results are shown in Table 5.

The marginal productivities are comparable for the two models except for insect control where Model II gave a more realistic effect, i.e., a one peso expenditure on insecticides produced about 1.1 kilogram of palay compared to only 0.3 with Model I. The estimated coefficients measuring efficiency in fertilizer use are -1.97 and -4.28, respectively for MOdels I and II, both of which are significant at the 1% significance level. The coefficient measuring weed control efficiency is relatively stable with significant values of -1.56 for Model I and -1.92 for Model II. The measured efficiency of insect control are -0.47 and -0.28 for Models I and II, respectively. However, it was significant at the 5% level in the former model only. Both functions reflect a consistent degree of technical inefficiency by farmers in the use of the three input factors.

Farmers' efficiency

From our formulation, three different efficiency measures can be generated. For purposes of further analysis, the production function estimated via Model II will be used. The value of the environmental site variables specific to each farm were substituted into the function, providing a production function specific to the environment faced by each farmer, with variables in F, W and I. This function conceptually corresponds to the TPP curve in Figure 2. Using it and prevailing prices, the measures of efficiency can be determined. The three efficiency measures calcualted for individual farms are: (1) economic efficiency, (2) allocative efficiency, and (3) technical efficiency as defined above. They are presented in Table 6 along with rankings for each category.

The degree of technical efficiency at the farm level relative to the three factors of production can be judged from Table 6. Less than half (25%) of the farmers studied had measured efficiencies within 20% of the production function. The least technically efficient farmer (site 44) is more than 600% away from the production function. Similarly, there is a low degree of allocative efficiency with less than half (41%) of the farmers within 20% of the economic optimum. The least allocatively efficient farmer (site 41) is more than 100% away from the optimum. Considering our overall measure of efficiency, only nine of the farms or 16% are within 20% of the production function and the economic function.

Economic efficiency and the yield gap

To summarize the measures of efficiency, the magnitude of the yield gap is presented in Table 7. The yield gap is attributed to three factors -- profit-seeking behavior, allocative efficiency, and technical efficiency. The average yield gap is shown as calculated directly from experiments and from the production function for the average of all wet and dry season experiments. For purposes of estimating the farmers' yield using the function, the farmers' input level with farmers' efficiency is used. The maximum yield was estimated disregarding input costs and with researchers' efficiency.

The yield gap estimated using the function coincided with that indicated by the experiments in the wet season, although there was a slight overestimate of both the farmers' and high input yields by the function. The yield gap of 0.9 t/ha is principally due to technical inefficiency which explains 78%. The remaining 0.2 t/ha can be attributed equally to profit-seeking behavior and allocative efficiency. In the dry season, the function gave a slightly lower yield gap estimate than the experiments. Of the 1.6 t/ha yield difference, 63% and 31%, is explained by technical and allocative efficiencies, respectively. The contribution of profit-seeking behavior is rather small at 0.1 t/ha.

Sources of technical efficiency

The estimated equation is shown in Table 8. The R^2 indicates that about 77.1% of the variation in technical efficiency is explained by the 10 independent variables included in the equation. Six variables are at least significant at the 20% significance level.

The most significant variable is total area planted to rice. For example, farmers cultivating 3 hectares or less were 10 percentage points more technically efficient than farmers cultivating more than 3 hectares (Table 10). It is plausible that increased farm size would diminish the timeliness of certain farm operations such as weed and insect controls. To the extent that farm activities are staggered in larger farms, it would be more difficult for farmers to keep track of their operations schedule than their smaller counterparts.

The result of the ND variable, the number of days spent off-farm, was exactly the opposite of the original expectation which was based on the argument that farmers lack the time to look after the important details of farm management as he spends more time off the farm. However, a counter-argument is used here, i.e., that in spending more time off the farm, the farmer can have more time in gathering farm information which would help him in making adjustments in his farm operations. This explanation is probable especially when one looks at the information (I) variable which tends to show a positive impact on technical efficiency.

The gross family income (GFI) variable is significant at the 5% significant level. Farms with income over ₱20,000 had 72% technical efficiency rating while those with lesser income had only 63%. The possible explanation is that farmers with higher incomes have a better chance of acquiring the various inputs for the farm at the time they are needed. Caution on the interpretation of this variable should be exercised, however, since there is a possibility that increased family income results from high technical efficiency.

The interpretation of the irrigation variable (DI) is rather straightforward. Irrigation increases the efficiency of fertilizer use in several ways. Under flooded conditions, the availability of phosphorous increases because iron, aluminum, magnesium, and calcium become more soluble -- releasing phosphorous chemically bound under non-irrigated conditions (Villegas and Feuer, 1970). Also, irrigation reduces denitrification and contributes to effective weed control thereby allowing more of the applied nutrients to be taken up by the rice plant. Moreover, rainfed farms are expected to have lower technical efficiency resulting from their inability to implement their farm operations in time. For example, previous research has shown that improved water control permits earlier transplanting and harvesting (Valera, et al., 1975), thereby, reducing the probability that a farmer's rice crop will be damaged by late season typhoons (Bernsten, 1978). Finally, based on our measures, irrigated and rainfed farms had 66 and 33% tedhnical efficiency ratings, respectively.

There is some indication that technical efficiency is negatively related to age of farmers. This is significant at only the 90% confidence level, however. Nevertheless, it suggests that younger farmers possess relatively higher productivity than older farmers whose productivity may already be on the decline.

Sources of allocative efficiency

Twelve independent variables were used to explain variation in allocative efficiency. the list of variables used are shown in Table 9 along with the results.

About 77.2% of the variation in allocative efficiency was accounted by the 12 explanatory variables included in the regression analysis. Five variables were significant at least at the 5% significance level. Variable A, the total area, was again the most significant variable. Four variables, DR, DC, DL and TK had their standard errors larger than the absolute value of their respective coefficients.

It is rather easy to make sense out of the effects of the significant variables. Total area has a negative effect on allocative efficiency. The plausible explanation is that the farmer cultivating a larger area has to spread out his capital more thinly and in so doing he is less likely to reach the economic optimum under his environment. For example, farmers with less than 3 hectares applied 52 kg/ha more nitrogen and spent ₱38/ha more for weed control than farmers with bigger farms. The former were 76% allocatively efficient compared to the latter's 61%.

The GFI variable is significant at 1% significance level. The interpretation is that, farmers with higher incomes encounter less capital restrictions, and therefore, they are more likely to apply more of the three inputs considered. Here, farmers with larger incomes were 21% more allocatively efficient than farmers with smaller incomes. The former applied 50 kg/ha more fertilizer and spent ₱38/ha more for insect control than the latter.

The explanation of the irrigation variable (DI) is, again, rather straightforward. Farmers in the non-irrigated areas apply less of the inputs considered. Rainfed farmers, for example, applied 25 kg/ha less nitrogen and spent less on insect and weed controls than their irrigated counterparts. This corroborates findings in an earlier survey of irrigated and rainfed farmers in Central Luzon (Herdt, et. al., 1978). Irrigated farms had 73% allocative efficiency rating compared to 67% for rainfed farms. This is equivalent to a difference in yield of 0.7 t/ha at the mean of all other variables (Table 10).

One significant finding in this study is the significant effect of credit on allocative efficiency. The result shows that farmers who did not borrow at all were significantly less allocatively efficient than farmers who availed themselves of credit. In this study, 16 farmers or 29% did not borrow at all, 20 farmers obtained loans from Masagana 99 and the rest borrowed from other sources. Farmers who obtained loans applied 47 kg/ha more fertilizer and spent more on insect control than farmers without loans. Both groups spent almost similar amounts for

weed control which was in most cases a non-cash cost as many farmers employed family labor doing handweeding. the former had an allocative efficiency rating of 77% compared to only 60% for the latter. This brought about a difference in yield of about 0.2 t/ha.

Although the information variable is significant at only the 10% significance level, it suggests that the amount of information that farmers get from agricultural fairs, seminars and visits with extension agents as well as information on prices of inputs and output improved their allocative efficiency.

Policy implications

There exists a rice yield gap which could be economically recovered especially in the dry season. Bridging the gap requires the improvement of farmers' technical and allocative efficiencies. The proportion of the rice yield gap that could be covered by improving allocative efficiency is rather small in the wet season. In the dry season, the untapped yield potential could be gained by government programs that would shift farmers into higher technical and allocative efficiencies.

Total area planted was taken as a proxy for lack of timeliness in farm operations. The multifarious operations inherent under the existing rice technology requires some record keeping ability of individual farm operators. However, our experience in the Department of Agricultural Economics at IRRI with record keeping indicates that, in general, farmers do not have the ability to keep records. This is true even in relatively more progressive areas like Laguna province. Improvement of the farmers' record keeping ability is a logical recommendation here. This could possibly be achieved in two ways: (1) direct assistance by extension agents in keeping farm records, and (2) including record keeping as a course in the secondary schools where the farmers' sons and daughters could be taught to keep records. The latter is probably the more practical recommendation inasmuch as the farmers' sons are the future farmers.

Government investments in irrigation can be expected to have a yield increasing impact by improving farmers' technical and allocative efficiencies. It is common knowledge that unreliable water source limit the farmers' decisions on the timing of farm operations as well as the amount of input use. Aside from its yield increasing effect, it would also allow the expansion of area planted during the dry season where the greatest potential for increasing yield exists. An alternative would be to invest more in research to develop more fertilizer responsive varieties of crops grown under rainfed conditions. It is likely that research in this area would bring high pay offs.

Results suggested that increased family income and credit relaxed capital constraints to enable the farmer to operate nearer the economic optimum. Why some farmers did not borrow at all was beyond the scope of this study. There is some indication, however, the farmers cultivating several parcels tended to enroll their farms in Masagana 99 partially as shown by the negative correlation between size of farm and credit. This led to a thinning out of input application on the bigger farms which is responsible for the lower allocative efficiency rating. Farmers' participation in Masagana 99, therefore, should be encouraged as one avenue toward improving the allocative efficiency of farmers.

Again, farmers who spent some days working off-farm possibly acquired better information on prices of inputs and output that enabled them to adjust their timing and amount of input application. The insignificance of the general education variable suggests that specific information obtained from rice production seminars, agricultural fairs and visits with extension agents are more important in improving farmers' efficiency. This is particularly true in places like Nueva Ecija where a minimum literacy rate has been attained. Extension would do better if it engaged more on the above activities.

Limitations of the study

Several limitations of the study should be recognized. First, the above observations are intended to provide information on the extent of technical and allocative efficiencies in rice production and the possible sources of inefficiencies. Removing such inefficiencies are the key factors toward increased yields under the existing technology. This is a task that involves both economic and non-economic costs. For example, the proper timing of some farm operations may be at the expense of the proper timing for other crops. These issues have not been considered here.

Secondly, the follow-up surveys were conducted after harvest and like all other surveys it required farmers to recall last seasons' cultural practices. This type of data is subject to measurement errors. However, efforts were made to minimize measurement errors by conducting record keeping during two crop seasons.

Finally, Nueva Ecija farmers follow a relatively modern rice agriculture. Modern inputs such as fertilizer, insecticides and herbicides have been used extensively for a long time. The literacy rate is high compared to other rice producing areas in the country. As such, the constraints imposed by economic efficiency might be different from those found in the less modern communities.

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Table 1. Timing of fertilizer application by farmers in constraints experiments on farmers' fields, Nueva Ecija, 1976 wet season.

Time of application (DAT)	Nitrogen applied (kg/ha)	Farmers applying (No.)	Phosphorous and potash applied (kg/ha)	Farmers applying (No.)
0	2.2	1	1.9	1
1 - 10	22.6	4	10.3	3
11 - 20	15.6	2	2.4	1
21 - 30	2.8	1	0.0	0
31 - 40	15.7	2	2.4	1
41 - 50	2.2	1	1.8	1

Table 2. Treatments in constraints experiments conducted in farmers' fields bv IRRI Agronomy Department, 1974-77.a/

Treatment		Level of inputs		
		Fertilizer	Weed control	Insect control
1	(M1)	F1	W1	I1
2	(M2)	F2	W2	I2
3	(M3)	F3	W3	I3
4	(M4)	F4	W4	I4
5	(M5)	F5	W5	I5
6		F5	W1	I1
7		F1	W5	I1
8		F1	W1	I5
9		F5	W5	I1
10		F1	W5	I5
11		F5	W1	I5
12		F3	W1	I3
13		F4	W1	I3
14		F3	W5	I5
15		F4	W5	I5
16		F3	W5	I3
17		F3	W5	I4
18		F4	W5	I3
19		F4	W5	I4

a/ Treatments 1-11 were included in 1974, 1975 and 1976. Treatments 12-19 were included in 1977.

Table 3. Production function estimated from combined all sites, Nueva Ecija, 1974 wet season to 1977 dry season (Model I).

Independent variables	Symbol	Regression coefficient	Standard error	Beta coefficient
Constant		2422		
Applied fertilizer (linear)	F	-5.18876	5.33468	-0.20684
Applied fertilizer (quadratic)	F^2	-0.02986*	0.01653	-0.35060
Insect control cost (linear)	I	-1.68886***	0.61323	-0.37203
Insect control cost (quadratic)	I^2	0.00232***	0.00062	0.60078
I x F	IF	0.00675**	0.00302	0.30868
I^2 x F	I^2F	-0.0000083***	0.00000	-0.45104
Weed control cost (linear)	W	0.85781	1.28866	0.02863
Weed control cost (quadratic)	W^2	0.01264*	0.00550	0.09637
W x F	WF	-0.00894	0.00598	-0.05403
Age of seedlings	A	-15.61711***	5.95718	-0.07208
A x F	AF	0.08966**	0.04270	0.12605
Pest damage index	P	1.47486	3.11494	0.01146
P x F	PF	-0.13196***	0.02630	-0.12992
Disease incidence index	D	-27.33710***	6.46962	-0.11420
D x F	DF	-0.26612***	0.05326	-0.13271
Soil organic matter (linear)	OM	3111.28400***	649.66513	1.19050
Soil organic matter (quadratic)	OM^2	-657.80790***	157.17207	-0.76489
OM x F	OMF	0.22347	2.12819	0.02202
OM x F^2	OMF^2	0.00147	0.00773	0.03866
Soil texture (linear)	T	-106.29080***	16.50442	-1.29917
Soil texture (quadratic)	T^2	0.71679***	0.11145	0.87578
Soil extractable P	EP	5.68052***	0.99250	0.28270
EP x F	EPF	-0.01764**	0.00732	-0.10493
Late water stress	SL	-44.19641	32.37871	-0.13517
SL x F	SLF	0.04427	0.07666	0.01674
Solar radiation	SR	89.35734***	12.92486	0.20622
SR x F	SRF	0.92762***	0.92762	0.82397
SR x SL	SRSL	1.17469	1.71753	0.06647
Dummy variable for typhoon occurrence	DT	-471.31890***	44.86941	-0.14285
Farmers' fertilizer efficiency	DFF	-1.97364***	0.34924	-0.07000
Farmers' insect control efficiency	DII	-0.47455**	0.21590	-0.02834
Farmers' weed control efficiency	DWW	-1.56297**	0.65332	-0.06775

$R^2 = 0.661$ $\bar{R}^2 = 0.658$ $F = 179.087$

* is significant at the 10% level (t = 1.645)
** is significant at the 5% level (t = 1.960)
***is significant at the 1% level (t = 2.576)

Table 4. The production function estimated using Model II from combined all sites, Nueva Ecija, 1974 wet season to 1977 dry season.

Independent variables	Symbol	Regression coefficient	Standard error	Beta coefficient
Constant		2810		
Applied fertilizer (linear)	F	-0.21554	5.49244	-0.00859
Applied fertilizer (quadratic)	F^2	-0.05115***	0.01750	-0.60058
Insect control cost (linear)	I	-2.26400***	0.60668	-0.49873
Insect control cost (quadratic)	I^2	0.002686***	0.00061	0.73953
I x F	IF	0.00865***	0.00295	0.39570
I^2 x F	I^2F	-0.00001***	0.00000	-0.54125
Weed control cost (linear)	W	-0.90869	1.35299	-0.03033
Weed control cost (quadratic)	W^2	0.01289**	0.00593	0.09830
W x F	WF	-0.00926	0.00598	0.00560
Age of seedlings	A	-10.80225*	5.99521	-0.04985
A x F	AF	0.02048	0.04269	0.02879
Pest damage index	P	-1.73331	2.89503	-0.01347
P x F	PF	-0.12031***	0.02474	-0.11845
Disease incidence index	D	-29.67564***	6.39614	-0.12397
D x F	DF	-0.31496***	0.05179	-0.15707
Soil organic matter (linear)	OM	-1531.61200***	305.35052	-0.58605
Soil organic matter (quadratic)	OM^2	508.60140***	79.82862	0.59140
OM x F	OMF	-0.10516	2.25603	-0.01036
OM x F^2	OMF^2	0.00069	0.00810	0.01810
Soil texture (linear)	T	12.43286	7.59191	0.15196
Soil texture (quadratic)	T^2	-0.03824	0.04506	-0.04673
Soil extractable P	EP	-1.79466***	0.68108	-0.08932
EP x F	EPF	0.03040***	0.00393	0.18084
Late water stress	SL	-3.13451	33.58551	-0.00959
SL x F	SLF	-0.21518***	0.07431	-0.08138
Solar radiation	SR	61.49733***	14.48738	0.14193
SR x F	SRF	1.02933***	0.08293	0.91432
SR x SL	SRSL	-0.14880	1.79744	-0.00842
Dummy variable for typhoon occurrence	DT	-433.38490***	47.71463	-0.13135
Farmers' average fertilizer efficiency	DFF	-4.28776***	1.64759	-0.15207
Farmers' insect control efficiency	DII	-0.28412	0.21310	-0.01697
Farmers' weed control efficiency	DWW	-1.92670***	0.65327	-0.8352
Farmer's individual fertilizer efficiency:				
Site 03	DFF3	-2.41180	3.31608	-0.00896

Table 4 continued.

Independent variables	Symbol	Regression coefficient	Standard error	Beta coefficient
Site 04	DFF4	-7.70692**	3.82801	-0.02408
Site 06	DFF6	-8.31644	4.94524	-0.01940
Site 07	DFF7	7.45434**	3.29266	0.02712
Site 08	DFF8	6.12868**	2.66591	0.03030
Site 09	DFF9	-1.91804	3.24077	-0.00728
Site 10	DFF10	-25.11785***	7.66858	-0.03671
Site 11	DFF11	-3.83880**	1.87698	-0.04513
Site 13	DFF13	-5.39740**	2.44209	-0.03097
Site 14	DFF14	10.00331**	4.30530	0.02663
Site 15	DFF15	8.41202**	3.47502	0.02819
Site 18	DFF18	-1.84928	17.90487	-0.00111
Site 20	DFF20	9.62402*	5.43842	0.01958
Site 24	DFF24	7.74508***	2.32185	0.05302
Site 25	DFF25	-0.79412	2.07655	-0.00633
Site 26	DFF26	-5.36403***	2.07779	-0.04206
Site 27	DFF27	1.27021	2.94262	0.00547
Site 29	DFF29	-3.50502	2.33896	-0.02152
Site 31	DFF31	6.45511*	3.55119	0.02345
Site 33	DFF33	-3.88982	4.16383	-0.01063
Site 34	DFF34	-7.52351**	2.92401	-0.02748
Site 35	DFF35	18.78438***	3.28649	0.06566
Site 36	DFF36	-5.26555**	2.51885	-0.02973
Site 37	DFF37	2.98890	3.61365	0.01045
Site 41	DFF41	24.50659***	2.12091	0.04612
Site 42	DFF42	12.32023***	2.46989	0.09156
Site 44	DFF44	40.02514***	4.68612	0.09988
Site 45	DFF45	2.44435	3.96523	0.00710
Site 46	DFF46	1.68637	1.85230	0.02131
Site 48	DFF48	6.48234	7.23337	0.00974
Site 49	DFF49	8.60361**	3.97489	0.02408
Site 51	DFF51	3.06914	2.58356	0.01733
Site 55	DFF55	-4.98170	5.12635	-0.01046
Site 58	DFF58	1.65895	2.08377	0.01331
Site 70	DFF70	-2.58512	3.18800	-0.00958
Site 72	DFF72	18.59452***	3.310116	0.07236

$R^2 = 0.706$ $\bar{R}^2 = 0.698$ $F = 80.741$

* is significant at the 10% level (t = 1.645)

** is significant at the 5% level (t = 1.960)

***is significant at the 1% level (t = 2.576)

Table 5. Marginal productivities derived from the two models used to estimate the production function.

Independent variables	Production function model	
	I	II
Fertilizer	8.786	9.038
Insect control	0.312	1.115
Weed control	1.483	1.512
Seedling age	-6.	-8.816
Insect damage	-11.325	-13.402
Disease incidence	-53.150	-60.227
Organic matter	515.556	498.986
Soil texture	13.699	6.030
Extractable P	3.969	1.154
Late water stress	-16.266	-24.007
Solar radiation	182.504	160.900
Typhoon damage	-471.319	-433.384

Table 6. Ratings of economic, technical and allocative efficiencies.

Site	Economic efficiency		Technical efficiency		Allocative efficiency	
	Rating	Rank	Rating	Rank	Rating	Rank
10	1.2888	1	1.0725	1	1.2163	1
04	.9565	2	.9092	5	1.0473	3
26	.9487	3	.9434	2	1.0054	5
06	.9242	4	.8726	7	1.0516	2
36	.9072	5	.8690	9	1.0382	4
11	.8712	6	.8666	8	1.0045	6
13	.8484	7	.9231	4	.9253	12
29	.8119	8	.8523	12	.9595	9
34	.8020	9	.9306	3	.8714	19
70	.7393	10	.8572	11	.8821	17
09	.7187	11	.7252	31	.9935	8
03	.6942	12	.6941	34	1.0001	7
55	.6628	13	.9047	6	.7581	26
67	.6584	14	.7542	25	.9041	15
25	.6560	15	.7402	27	.9159	14
64	.6210	16	.7023	32	.9187	13
18	.6114	17	.7373	28	.8741	18
71	.5987	18	.7681	22	.8306	22
50	.5945	19	.7635	24	.8310	21
68	.5791	20	.7676	23	.8115	23
59	.5663	21	.7718	21	.7945	24
75	.5628	22	.7769	20	.7859	25
33	.5264	23	.8593	10	.6671	38
47	.5217	24	.7973	17	.7245	32
60	.5062	25	.7868	18	.7194	33
76	.5027	26	.7836	19	.7192	34
37	.4964	27	.5526	41	.9438	11
58	.4855	28	.6008	40	.8847	16
01	.4846	29	.5312	42	.9534	10
56	.4563	30	.7298	29	.7265	31
05	.4419	31	.6975	33	.7444	27
54	.4297	32	.7986	16	.6311	41
45	.3974	33	.6671	35	.7303	30
51	.3943	34	.6511	38	.7432	28
57	.3894	35	.7995	15	.5899	42
23	.3517	36	.8016	14	.5501	45
22	.3232	37	.7466	43	.5766	43
62	.3133	38	.6566	36	.6567	39
27	.2819	39	.7288	30	.5531	44
46	.2542	40	.4210	46	.8341	20
02	.1189	41	.6255	39	.4934	47
65	.1063	42	.8058	13	.3004	51
48	.0503	43	.6514	37	.3989	50
49	-.0873	44	.4505	45	.4623	49

Table 6 continued.

Site	Economic efficiency		Technical efficiency		Allocative efficiency	
	Rating	Rank	Rating	Rank	Rating	Rank
31	-.0093	45	.4985	43	.4922	48
20	-.1302	46	.1350	48	.7348	29
08	-.2262	47	.0734	49	.7004	35
14	-.2385	48	.2301	47	.5314	46
07	-.6646	49	-.3406	51	.6760	37
24	-.8512	50	-.5076	53	.6564	40
15	-.8924	51	-.5814	54	.6889	36
42	-.9295	52	-.0991	50	.1696	53
72	-1.1117	53	.4753	44	-.5870	54
35	-1.4269	54	-.5055	52	.0087	52
41	-3.0205	55	-.7902	55	-1.2303	56
44	-7.3800	56	-6.6591	56	-.7239	55

Table 7. Estimated yield gap and contribution of profit-seeking behavior, allocative and technical inefficiencies, Nueva Ecija, 1974 wet season to 1977 dry season.

Source	Grain yield (t/ha)			Average contribution (t/ha)		
	Farmer's behavior[a]	High input and efficiency[b]	Yield gap	Profit-seeking behavior	Allocative inefficiency	Technical inefficiency
		Wet Season				
Experiments	2.4	3.3	0.9	-	-	-
Function	2.6	3.5	0.9	0.1 (11)[c]	0.1 (11)	0.7 (78)
		Dry Season				
Experiments	4.4	6.4	2.0	-	-	-
Function	4.6	6.2	1.6	0.1 (6)	0.5 (31)	1.0 (63)

[a]For the experiments, the farmers' input plots; for the function farmers' input level with farmers' efficiency.

[b]Maximum yield, disregarding input costs, and with researchers' efficiency.

[c]Figures in parenthesis are percentage contributions.

Table 8. Regression analysis for explaining variation in technical efficiency rating.

Independent variables	Symbol	Regression coefficient	Standard error	Beta coefficient
Constant	A	1.23700		
Total area	A	-2.78588***	0.27992	-0.93372
Information index	I	0.11182[a]	0.08225	0.11848
Age of farmer operator	AO	-0.01315*	0.00785	-0.15995
Years education	E	-0.02580	0.02491	-0.10589
Gross family income	GFI	0.00002**	0.00001	0.28574
Number of days off farm	ND	0.00290***	0.00093	0.24375
Technical knowledge score	TK	0.07216	0.09459	0.06386
Dummy for share tenants	DST	-0.22748	0.62377	-0.02885
Dummy for rainfed farms	DI	-0.00450**	0.00220	-0.15724
Dummy for not enough labor	DL	0.24156	0.25709	0.07155

R^2 = .772 $\bar{R}^2$ = .720 F =14.884

[a]is significant at the 20% level (t = 1.303)
* is significant at the 10% level (t = 1.684)
** is significant at the 5% level (t = 2.021)
***is significant at the 1% level (t =2.704)

Table 9. Regression analysis for explaining variation in allocative efficiency rating.

Independent variables	Symbol	Regression coefficient	Standard error	Beta coefficient
Constant		1.74900		
Total area	A	-3.07312***	0.32179	-0.96246
Information index	I	0.17134*	0.09512	0.16964
Age of farmer operator	AO	-0.00913	0.00890	-0.10383
Years education	E	-0.24185	0.20146	-0.10477
Gross family income	GFI	0.00003***	0.00001	0.36792
Number of days off farm	ND	0.00256**	0.00123	0.20128
Technical knowledge score	TK	0.03969	0.09701	0.03283
dummy for share tenants	DST	-0.28356	0.34569	-0.08391
Dummy for rainfed farms	DI	-0.00750***	0.00234	-0.24500
Dummy for not enough labor	DL	0.02492	0.27287	0.00690
Dummy for no credit	DC	-0.43693**	0.20552	-0.17314
Dummy for risk factor	DR	-0.13019	0.20028	-0.05640

R^2 = .772 $\bar{R}^2$ = .707 F = 11.880

* is significant at the 10% level (t = 1.684)
** is significant at the 5% level (t = 2.021)
***is significant at the 1% level (t = 2.704)

Table 10. Impact of allocative efficiency on input use and yield, 1974 wet season to 1977 dry season, Nueva Ecija.

Item	Irrigated status (DI)		Credit status (DC)		Total area (ha) (A)		Gross family income (GFI)		Days off-farm (ND)	
	Irrigated	Rainfed	With loan	Without loan	Less than 3	Greater than 3	Less than ₱20,000	Greater than 3 ₱20,000	Less than 4	Greater than 4
Number of farms	47	9	40	16	41	15	40	16	44	12
Technical efficiency rating	.6605	3334	.5654	.7115	.6996	.3627	6312	.7242	.5867	.7346
Allocative efficiency rating	.7344	6788	.7744	.6031	.7662	.6141	7096	.8662	.7072	.7247
Insect control cost (₱/ha)	157	74	155	114	136	166	132	170	135	102
Weed con trol cost (₱/ha)	104	42	90	104	104	66	100	78	64	102
Fertilizer (kg/ha):										
Nitrogen	78	52	82	50	123	70	29	73	77	60
Phosphorous	34	12	36	20	32	30	29	34	34	24
Potassium	1	2	1	0	1	0	1	2	1	2
Yield (t/ha)	3.4	2.7	3.0	2.8	-	-	-	-	-	-

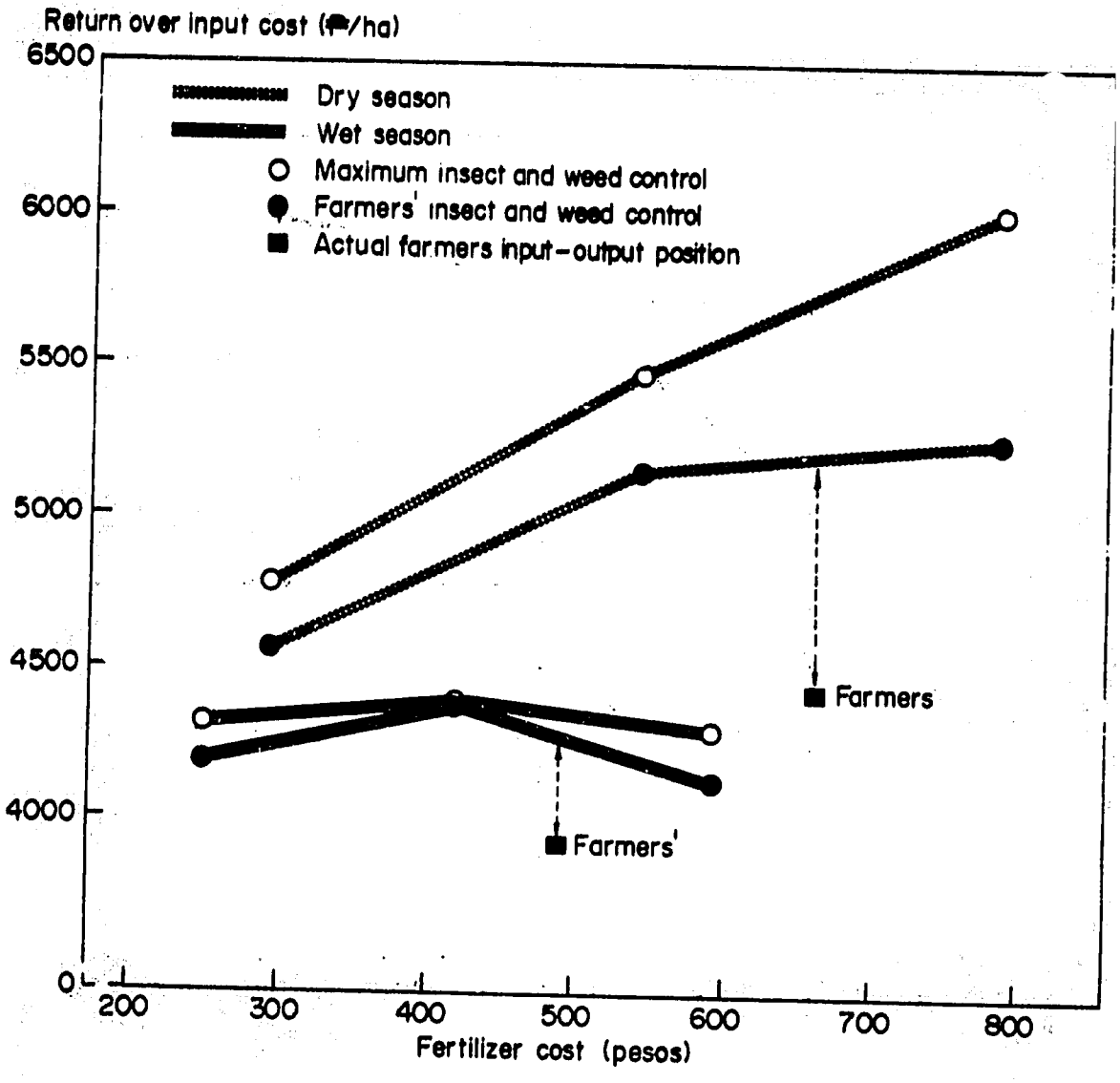

Fig. 1. Return over cost of variable inputs for four levels of fertilizer inputs and two levels of weed and insect control inputs, average of nine experiments in farmers' fields, Nueva Ecija, 1977.

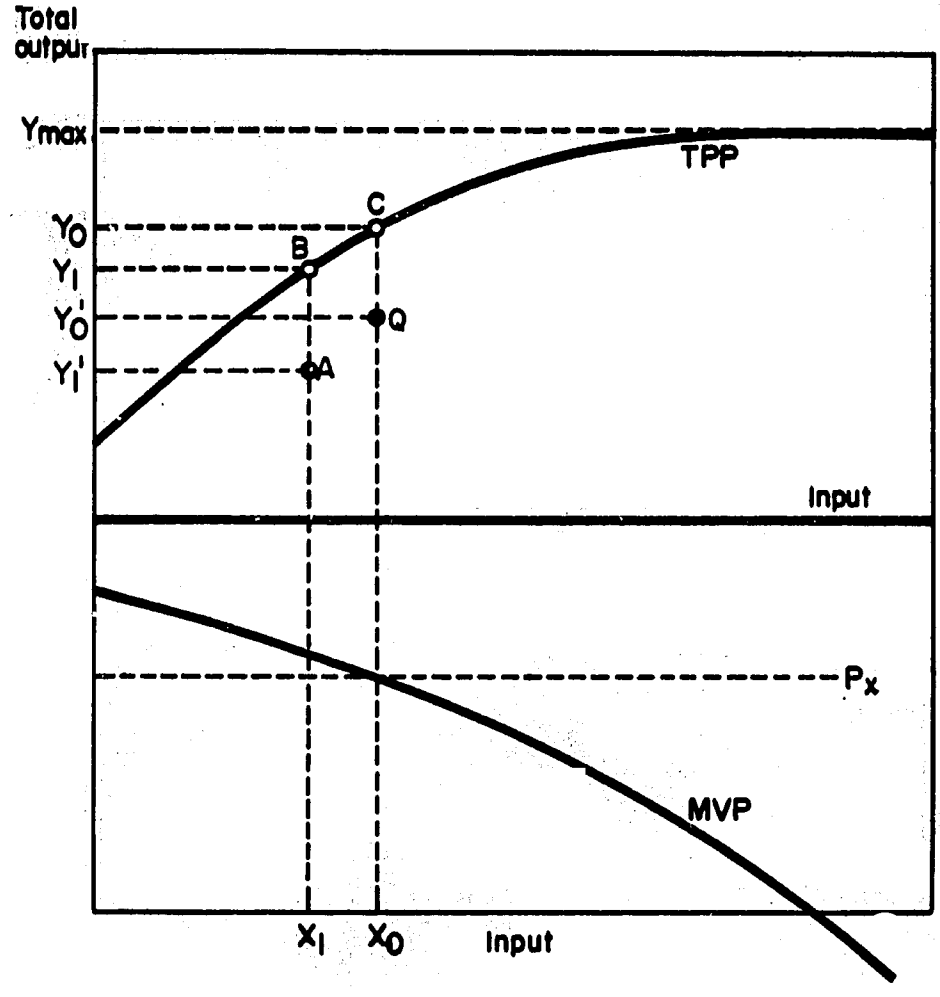

Fig. 2. Basic model used to measure constraints imposed by technical and allocative inefficiencies.

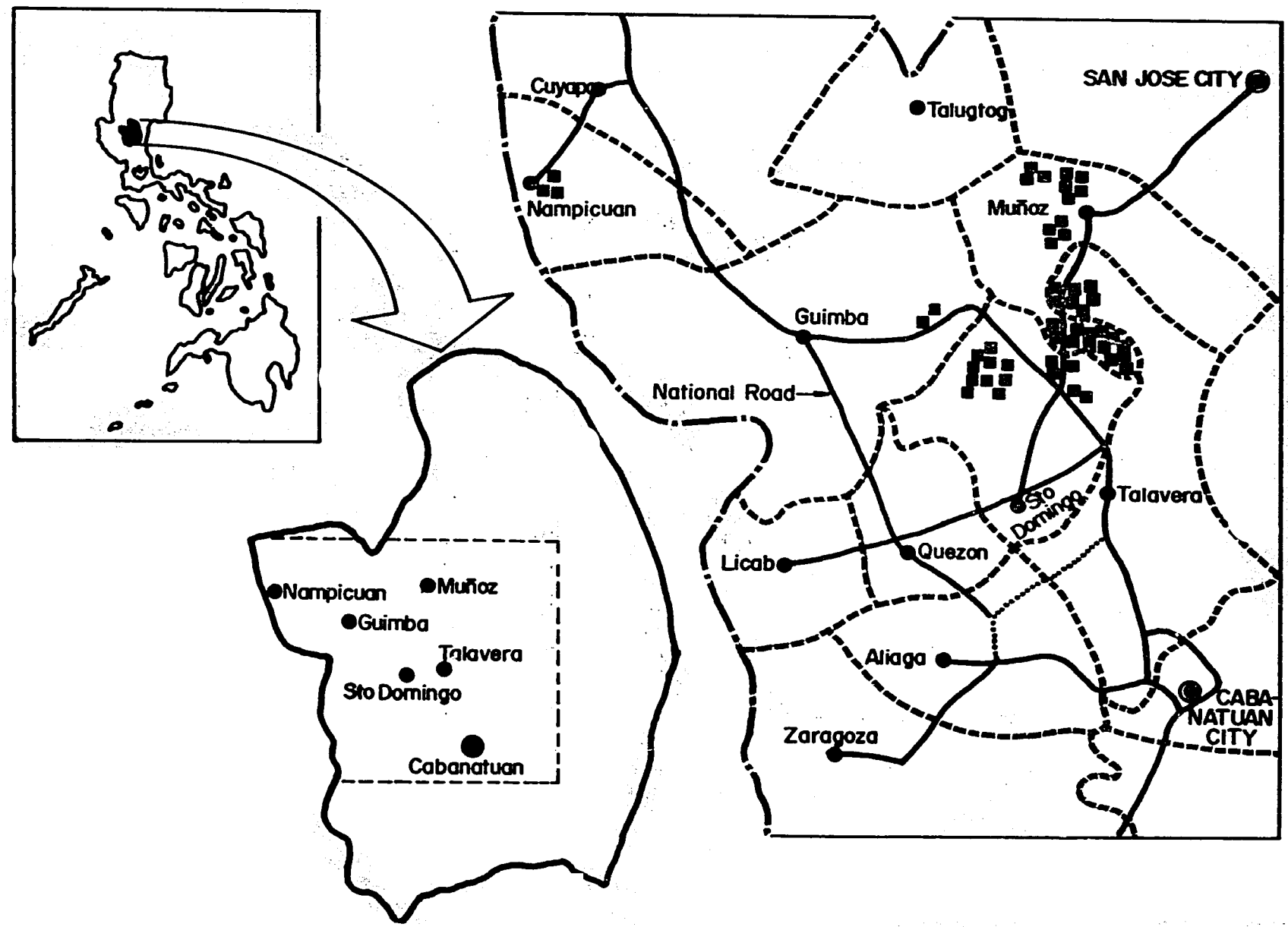

Fig. 3. Location of farmers' field experiments, 1974 wet season to 1977 dry season, Nueva Ecija.

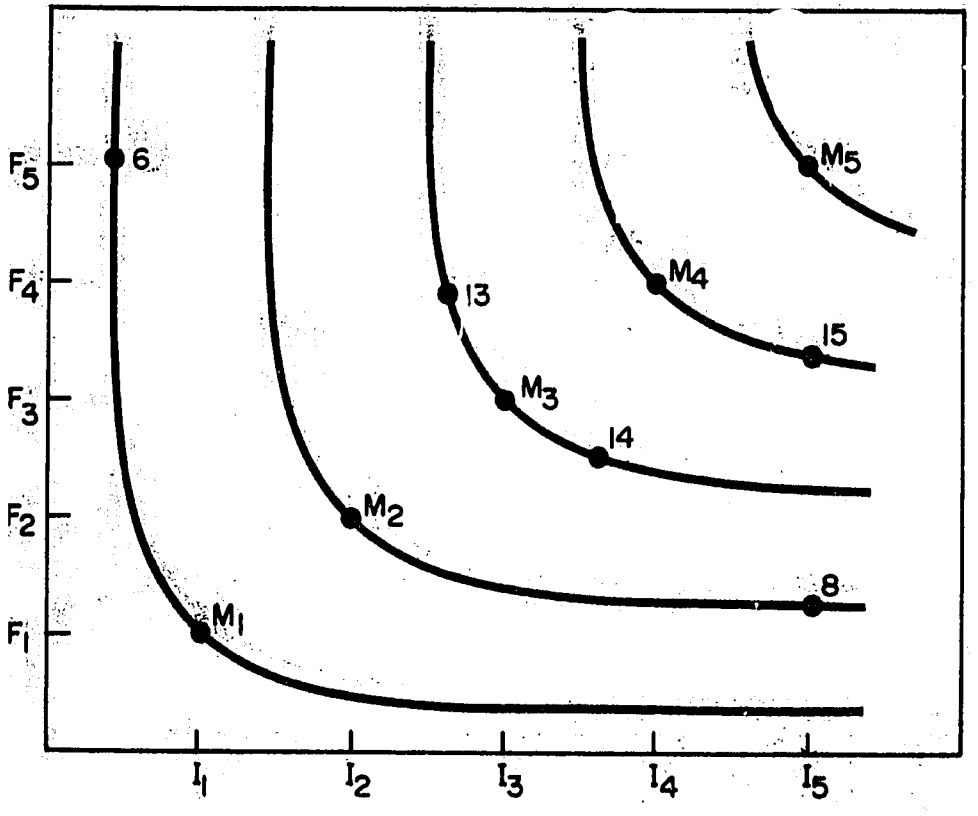

Fig. 4. Treatments M_2-M_5 as points in the expansion path.

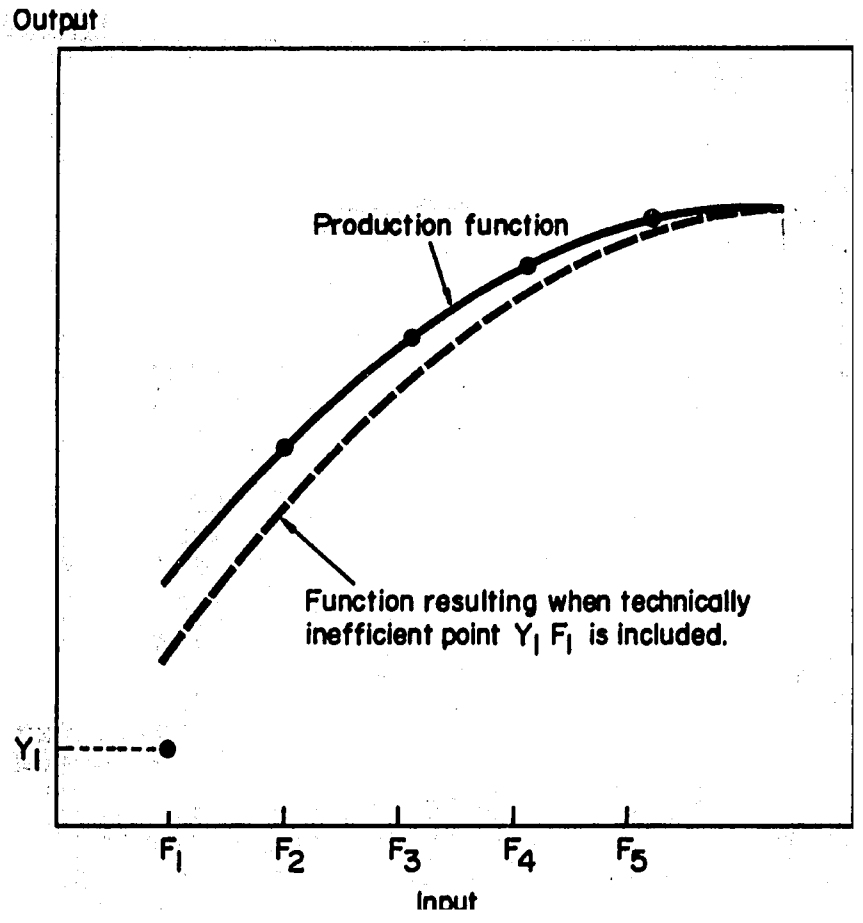

Fig. 5. The unadjusted function and the production function. (The unadjusted function wouldn't go through Y_1 F_1 because other points would pull it up.)