PN-AAN-535
ISN 31739

THE CONSEQUENCES OF SMALL RICE FARM MECHANIZATION PROJECT

Working Paper No. 36

PRODUCTION EFFECTS OF MECHANIZATION

Yolanda Tan and John Wicks
The International Rice Research Institute

1981

The Consequences of Small Rice Farm Mechanization Project is supported by the United States Agency for International Development under Contract tac-1466 and Grant No. 931-1026.01 and is being implemented by the International Rice Research Institute and the Agricultural Development Council, Inc.

ABSTRACT

The impact of farm mechanization on output was assessed using decomposition analyses. An arithmetic decomposition technique was employed to disaggregate output differences, between mechanized and non-mechanized farms, yield, price, area and cropping intensity components. Results showed the most important factors were cropping intensity and yield. The yield effect of mechanization was then investigated by using a decomposition technique derived from a production function framework. Total yield differences were decomposed into the effects of neutral technological change, non-neutral technological change, and change in the use of inputs component. The results of the malysis showed that the major source of yield differences between the two farm types was brought about by non-neutral technical change, i.e., shift in the slope coefficients of the production functions. The cropping intensity effect of mechanization was further investigated using covariance analysis. Results of the test showed that this was modified by the impact of irrigation and credit availability. Even so mechanization increased cropping intensity significantly.

INTRODUCTION

The introduction of farm machinery to rice cultivation in less developed countries has resulted in many far-reaching economic and social changes. Not unexpectedly, two widely opposing views on the impact, and desirability, of farm machinery have evolved. One faction argues that mechanization permits faster, less laborious and hence more timely completion of farm tasks. This, it is claimed, results both in increased yields and greater intensity of land use. Mechanization is also argued to increase the productivity of labor and hence the wage rate. The alternative argument is that mechanization is a direct substitute for labor and is thus undesirable in areas with a surplus labor supply. Such situations are very common in less developed countries.

The development, introduction and use of agricultural machines in LDCs has produced a large and controversial literature covering technical, economic and socio-anthropological attempts to quantify, measure and evaluate the impact of mechanization on farm output, employment and income distribution. However, there appear to be few rigorous studies which demonstrate conclusively and convincingly the net effect of mechanization. In an attempt to rectify this situation a large study was initiated by the Engineering Department of IRRI in 1978. Four sites were selected for survey work. These were located in Nueva Ecija, Philippines; Supanburi, Thailand; West Java, Indonesia and South Sulawesi, Indonesia. A census was conducted for each site prior to sampling approximately 300 households at each site for more intensive survey work. Finally, approximately 50 households were selected from each site for daily recordkeeping.

In this study we attempted to quantify the effects of mechanization on total output and to investigate the reasons for these changes. This was done by modifying the decomposition procedure described by Binswanger (1978, 1979) to permit the partitioning of the differences in total observed output, between mechanized and non-mechanized farms, into changes caused by yield, area, cropping intensity and price.

DECOMPOSITION AS A METHOD OF ANALYSIS

Decomposition analysis, or component analysis, is a mathematical procedure for quantitatively partitioning an aggregate into its component elements, or explanatory factors. The variable to be decomposed may be either the change in the level of an input used or the change in the level of the output produced. Such allocation can be useful since it reduces complex relationships to an apparently simple basis and shows the relative importance of individual component effects. Thus the analysis may be able to identify the potentially most fruitful areas for further investigation.

Given such potential, it is not surprising to find that the concept of decomposition has been applied to a wide variety of problems. Early studies have applied decomposition to investigate the effects of technological change on output growth (Solow, 1957). Minhas and Vaidyanathan (1965) have used the technique to evaluate the reasons for yield increases which accompanied the spread of irrigation and adoption of better crop rotations. The reasons studied included the extension of cultivation to new areas, due to reclamation of virgin land and deforestation, and increases in cropping intensity.

More recent studies have used decomposition techniques to analyze the differences in output between farms using traditional and modern technologies (Bisaliah, 1977), between small and large farms (Binswanger, 1978; Rathore, 1979), the impact of shifts in relative prices and yields on growth due to technical change (Krishna, 1974) and to measure total change in employment between new and old technology farms (Bisaliah, 1978).

Decomposition Model I

The framework of the decomposition model used in this study is a synthesis of the formulations of Krishna (1974) and Binswanger (1978). Given the output identity:

$$Q = C \sum_i A_i P_i X_i \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (1)$$

where:

- Q is the value of total output in pesos;
- C is the cropping intensity defined as the gross cropped area divided by the operated area;
- A_i is the weighted proportion of gross cropped area under crop i;
- X_i is the yield of crop i in kg/ha; and
- P_i is the price of crop i in pesos/kg.

Classification of farms was on the basis of whether land preparation was done by tractor or carabao. Variables relating to the tractor farms (mechanized) are denoted by the superscript 1 and variables relating to the carabao farms (non-mechanized) are denoted by the superscript 0. The difference in output of the two groups of farms is given by:

$$Q^1 - Q^0 = C^1 \Sigma A_i^1 P_i^1 X_i^1 - C^0 \Sigma A_i^0 P_i^0 X_i^0 \quad \ldots\ldots\ldots\ldots\ldots\ldots (2)$$

Using the mathematical procedures explained in Tan (1981), and Tan Webster and Wicks, (1981), the decomposition model may be written as:

$$\Delta Q = \Delta C \Sigma A_i^1 P_i^1 X_i^1 + C^0 \Sigma \Delta A_i P_i^1 X_i^1 + C^0 \Sigma A_i^0 X_i^1 \Delta P_i + C^0 \Sigma A_i^0 P_i^0 \Delta X_i \quad \ldots (3)$$

Cropping intensity effect	Area effect	Price effect	Yield effect

where the symbol Δ is used to denote difference in the observed levels of variables for mechanized and non-mechanized farms, e.g. $\Delta Q = Q^1 - Q^0$.

Clearly equation (2) contains a mixture of variables at the levels observed for mechanized and non-mechanized farms as well as differences between levels. The exact combinations may be manipulated by the mathematical procedures used to derive the decomposition relationship. We have therefore extended the decomposition model to eliminate all terms specific to mechanized farms and hence to exclude the possibility of more than one formula. We describe the revised formulation as decomposition with interactions, since some of the elements contain expressions of more than one difference. The relationship for decomposition with interactions is:

$$\Delta Q = \Delta C \Sigma A_i^0 P_i^0 X_i^0 + C^0 \Sigma A_i^0 P_i^0 \Delta X_i + C^0 \Sigma \Delta A_i P_i^0 X_i^0 + C^0 \Sigma A_i^0 \Delta P_i X_i^0$$

cropping intensity effect	yield effect	area effect	price effect

$$+ \{\Delta C \Sigma A_i^0 P_i^0 \Delta X_i + \Delta C \Sigma \Delta A_i P_i^0 X_i^0 + \Delta C \Sigma A_i^0 \Delta P_i X_i^0$$

$$+ C^0 \Sigma \Delta A_i \Delta P_i X_i^0 + C^0 \Sigma \Delta A_i P_i^0 \Delta X_i + C^0 \Sigma A_i^0 \Delta P_i \Delta A_i \}$$

(first-order interaction terms)

$$+ \{\Delta C \Sigma \Delta A_i P_i^0 \Delta X_i + \Delta C \Sigma \Delta A_i \Delta P_i X_i^0 + \Delta C \Sigma A_i^0 \Delta P_i \Delta X_i + C^0 \Sigma \Delta A_i \Delta P_i \Delta X_i \}$$

(second-order interaction terms)

$$+ \Delta C \Sigma \Delta A_i \Delta P_i \Delta X_i \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (4)$$

(third-order interaction term)

This is an extension of the decomposition without residual model outlined by Binswanger (1979). The degree of the interaction terms expresses the number of component elements that are allowed to change simultaneously in the model. The first-order interaction terms will refer to the simultaneous effects of the component elements taken two at a time. The second-order interaction terms will mean three components are changing simultaneously and the third-order interaction reflects the effect of changing simultaneously all the four components.

Decomposition Model II

Studies in Thailand (Inukai, 1970), Nepal (Thapa, 1979) and Philippines (Antiporta and Deomampo, 1979) have shown that output from mechanized farms is higher than from non-mechanized farms. These differences may be related to any of the components isolated in the first decomposition. However other studies (e.g., Minhas and Vaidyanathan, 1965; and Sagar, 1977) have indicated that increased yield is the most important factor associated with the introduction of new technology. Increased yields may arise from improvements in the quality of an input or from increases in the quantity of the inputs used.

In the second part of this study we use an alternative decomposition model to disaggregate the difference in yield per hectare into the effects of technical change (both neutral and non-neutral) and changes in the levels of inputs used. Estimation of this model is a two-stage process.

First we must determine if there is a difference in the structural form of the production functions for mechanized and non-mechanized farms, i.e., are the intercept and slope coefficients equal for mechanized and non-mechanized technology? If a structural difference does exist we may determine the extent to which it is due to changes in the efficiency parameter (intercept) of the production functions and changes in the output elasticities (slope parameters) of the inputs.

The theoretical framework for the decomposition of yield per hectare is a modification of Bisaliah (1977) and derived from the Cobb-Douglas production function. The production function is specified as:

$$Y = \beta_0 e^{D\alpha_0} F^{(\beta_1+D\alpha_1)} L^{(\beta_2+D\alpha_2)} C^{(\beta_3+D\alpha_3)} P^{(\beta_4+D\alpha_4)} e^{U_i} \quad \ldots\ldots (5)$$

where:

Y is the yield of palay in kilograms per hectare;

L is the pre-harvest labor used in planting, care and cultivation of the crop, except land preparation, in manhours per hectare. Activities included were seeding of seedbed, pulling of seedlings, transplanting, irrigating, fertilizer application, weeding and applying weedicide and insecticide;

F is the total amount of fertilizer used converted to kilograms of nitrogen per hectare;

C is the total amount of crop protection used in pesos per hectare. These include insecticide, fungicide, herbicide, weedicide and rodenticide;

P is the total amount of machine/animal services used in land preparation measured in man-machine/animal hours per hectare; 3/

D dummy for mechanization. It is equals to 1 for farms that are mechanized and 0 for non-mechanized farms;

β_0 is the scale parameter;

3/ For mechanized farms, P is measured in man-machine hours, and for non-mechanized farms, it is in man-animal hours. In order to decompose the structural differences, the variable P must be made comparable for both types of farm. This was done by comparing the average amount of animal hours and the average amount of machine hours needed to plow, harrow and level a hectare of land. The estimated ratio was 3.3:1. To make them comparable the number of man-machine hours were multiplied by 3.3.

$\beta_1 - \beta_4$ are the output elasticities;

α_o is the intercept shiftor;

$\alpha_1 - \alpha_4$ are the slope shiftors,

e^{U_i} is the error term with e defined as the mathematical constant and U normally distributed

Taking logarithms of both sides the production function becomes

$$\log Y_i = \log \beta_o + D\alpha_o + \beta_1 \log F + \beta_2 \log L + \beta_3 \log C + \beta_4 \log P + \alpha_1 D \log F + \alpha_2 D \log L + \alpha_3 D \log C + \alpha_4 D \log P + U_i \quad \ldots\ldots (6)$$

The structural difference of the production functions between the two farm types can be investigated using the dummy variable test (Gujarati, 1970). So long as the coefficients of the dummy variables (either the intercept or the slope dummies) are significant, the decomposition model can be estimated.

The decomposition model was derived by taking the difference of the predicted linearized production functions for both mechanized and non-mechanized farms using average values for each variables (Tan, 1981). The decomposition Model II, using the fitted production function is specified as follows:[4/]

$$\begin{aligned}\{\log Y_M - \log Y_N\} &= \{\alpha_o\} \\ &+ \{\alpha_1 \log \bar{F}_N + \alpha_2 \bar{L}_N + \alpha_3 \log \bar{C}_N + \alpha_4 \log \bar{P}_N\} \\ &+ \{(\beta_1 + \alpha_1)(\log \bar{F}_M - \log \bar{F}_N) \\ &+ (\beta_2 + \alpha_2)(\log \bar{L}_M - \log \bar{L}_N) \\ &+ (\beta_3 + \alpha_3)(\log \bar{C}_M - \log \bar{C}_N) \\ &+ (\beta_4 + \alpha_4)(\log \bar{P}_M - \bar{P}_N)\} \\ &+ \{U_M - U_N\} \quad \ldots\ldots (7)\end{aligned}$$

[4/] This specification is tailored to the production function using dummy variable for mechanization and is a modification of the original model (Tan, 1981) which used the Chow's test.

Since the mean values of logarithms of the error terms are zero, the error term in (7) is zero. This decomposition model provides an approximate measure of the allocation to various components of differences in output between mechanized and non-mechanized farms.[5/]

The decomposition models formulated in this section are designed to assess the possible impact of mechanization on the output of small, rice farms. They were designed to obtain a fairly complete impression of the sources of output growth which might be attributed to mechanization. Clearly further, more intensive, research will be required to confidently establish causability

STUDY AREA AND CHARACTERISTICS OF THE SAMPLE FARMS

Source of Data

The data used for this study were collected as part of the Philippine component of a study entitled "The Consequences of Small Farm Mechanization on Rural Employment, Incomes and Production in Selected Countries of Asia"[6/]. The study involves an extensive survey of over 300 rural households, each of which is interviewed at the beginning and the end of every season and a more intensive farm record-keeping component in which daily records are maintained for approximately 50 households. The data used for the current analysis were for the cropping season 1979/80.

The Study Area

The surveys are being conducted in the municipalities of Cabanatuan City and Guimba, in the province of Nueva Ecija. Four sample barrios were randomly selected from each of the municipalities.

In Cabanatuan, the barrios included were: San Isidro, Lagare, Kalikid Sur and Caalibangbangan, and in Guimba they were Galvan, Narvacan I, San Andres and Bunol. The number of households included for each barrio is shown in table 1.

[5/] The statement here is one of association and not causality. Before causality may be assumed we must be confident that the effects of all other variables, which are likely to confound the results, have been eliminated.

[6/] Moran P., and Unson D. "Farm Survey and Recordkeeping Procedures for the Consequences of Small Rice Farm Mechanization Project: Operation Handbook" IRRI/USAID, May 1980.

This study area was selected to ensure that there would be sufficient representation of mechanized vs. non-mechanized farms and irrigated vs. rainfed farms to permit a detailed analysis. Even so some minor complications with the sample were discovered during data collection.

Sample Farms and their Characteristics

Farms were classified according to the type of power used in land preparation, comprising plowing, harrowing and levelling. Non-mechanized farms were defined as those using carabao power alone for land preparation, while mechanized farms were defined as those using only tractors for land preparation. The tractors being used were either 2-wheel, or 4-wheel or a combination. Other farmers used a combination of carabao and tractor.

There were 368 sample households in the survey. One hundred thirty one of these were classified as non-mechanized, 86 were purely mechanized and 105 used tractor and carabao combinations. Of the mechanized farms, one was rainfed and 85 were irrigated. Of the non-mechanized farms, 48 farms were irrigated and 83 were rainfed (Table 2). The remaining 46 respondents were landless field workers.

Those households using a combination of carabao and tractor were eliminated from the study because of the problems associated with defining the extent of mechanization. The 4-wheel tractor and 2-wheel/4-wheel tractor combination farms were also eliminated due to their small samples. This means that rainfed farms had to be eliminated, there being only one mechanized farms.

The average age, number of years in school and experience in farming, of the household heads, is shown in Table 3. Three of the observations had to be eliminated at this stage because of incomplete information. There was very little difference in these characteristics between the two groups.

Average farm characteristics are shown in Table 4. Mechanized farms were, on the average, 1.22 times larger than non-mechanized farms while yield per hectare was more than 1.5 times higher on the mechanized than on the non-mechanized farms.

Pre-harvest labor excluding land preparation did not vary much between the farm types. Post-production labor, which includes harvesting, threshing and winnowing, was higher on the carabao farms. This was due to the wide use of threshers by the mechanized farms, as compared to manual threshing by the non-mechanized farms. Land preparation hours showed a sharp drop from the average 96.79 man-animal hours for the non-mechanized to 29.52 man-machine hours for the mechanized farms.

Fertilizer use and crop protection, i.e., use of insecticides, weedicides and rodenticides were higher on the mechanized than the non-mechanized farms.

Short-term loans for seasonal farm expense per hectare was higher for the mechanized than the non-mechanized farms. Likewise, long-term loans used for agricultural investment, i.e., purchase of farm machines, carabao and irrigation pumps, was higher on the mechanized than the non-mechanized farms.

Cropping intensity was lower for the non-mechanized farms, with a value of 1.36 as compared to 1.92 for the mechanized farms.

RESULTS

The first stage in the analysis was to test the wet and dry season data for significant differences between the means of area, yield and price of paddy for mechanized as compared to non-mechanized farms. The differences in average levels of input use were also tested for the wet season data as these were to be used in one of the subsequent decomposition analyses. Given that the variables to be compared were considered highly unlikely to be normally distributed we opted to use a non-parametric test rather than the more frequently encountered parametric tests. The Kruskal-Wallis one-way analysis of variance by ranks (Siegel, 1956) was selected because of its relative efficiency[7/]. The results of the tests are shown in Table 5.

Results of the analysis using the Decomposition Model I (the arithmetic decomposition scheme) are presented in Table 6. The decomposition of output differences between the mechanized and non-mechanized farms showed that the component which contributed the largest percentage to the output difference is the yield effect (31.40%) followed by cropping intensity effect (26.01%) and area effect (11.22%). The price effect only contributed 4.96%.

Among the interaction terms, the first-order interaction of cropping intensity and yield contributed the largest percentage (12.93%) in the output difference. Other first-order interactions as well as the second-order and third-order interactions provided very minor contributions.

The decomposition analysis suggested that the two most important factors explaining output differences between mechanized and non-mechanized

---

[7/] When all of the assumptions of the F test are met the Kruskal-Wallis test has an asymptotic efficiency of 95.5%. Hence, even if our expectations are erroneous, the probability of incorrectly stating that there is no significant difference between the means of two sets of variables is sufficiently low.

farms were yield and cropping intensity. The two other factors, area and price bear little significance in bringing about productivity differences. These results, identify variables which need to be investigated further to evaluate the impact of mechanization.

Yield Effect

Yield, as the major component explaining differences in output between mechanized and non-mechanized farms was further investigated using the second decomposition model. This disaggregated the differences in paddy output per hectare into the effects of technical change (neutral and non-neutral technological change) and changes in the levels of inputs used.

The estimated coefficients of the Cobb-Douglas production functions for mechanized and non-mechanized farms, are presented in Table 8. The coefficients were consistent with respect to expected signs, though not all variables turned out to be significant. Of the independent variables for mechanized farms, fertilizer use and power showed significant coefficients while, for the non-mechanized farms, only crop protection turned out to be significant (Table 8). The production elasticity for labor, although non-significant in both production functions, was higher in the mechanized farms than the non-mechanized farms.

The production elasticity for fertilizer use was higher for the mechanized farms while the non-mechanized farms had the higher production elasticity for crop protection. In the case of the power variable, mechanized farms showed a higher production elasticity.

The structural difference of the production functions between the two farm types was tested using the dummy variable approach. Since the slope dummies for fertilizer and crop protection were highly significant, Decomposition Model II was estimated using the average level of inputs. The results are shown in Table 9.

Technical change which affects output by shifting either the intercept or the slope coefficients, was found to increase yield by 48.71%. Disaggregating technical change into neutral and non-neutral technical effects indicates a negative contribution (-9.35%) from the shift in the scale parameter. The contribution of non-neutral technical change was estimated to be 58.06%. This means that production on the mechanized farms was higher than mechanized farms because of different responses to the inputs used.

Total change in yield due to differences in the levels of inputs used was estimated to be 4.13%. The highest contributor was fertilizer which amounted to 7.03%, followed by capital services with 2.74% share. Post-tillage labor and crop protection registered a negative contribution of 0.44 and 0.28 percent respectively.

This decomposition analysis indicated that the major source of the structural difference between the mechanized and non-mechanized farms was non-neutral technical change. Computing for the individual terms of this component showed that the difference in the slope coefficients of labor for the two farms accounted for 22.7%. The difference in fertilizer coefficients amounted to 65.1%, in the power coefficient 35.77% and crop protection, -65.5%. These results indicate that the major source of the structural difference in the production functions is the difference in the response of yield to fertilizer and crop protection.

Cropping Intensity Effect

Cropping intensity, the second major component explaining differences in output between mechanized and non-mechanized farms was briefly examined. Table 10 summarized the cropping intensities of the sample farms by type of irrigation and source of power for land preparation. It shows that farms using dam or gravity irrigation have consistently higher cropping intensities than farms that are rainfed or use deep wells. Farms were grouped for each of the irrigation categories, according to whether they use tractor, carabao or a combination and cropping intensities were compared. Tractor farms and tractor/carabao combination farms had higher cropping intensities than the carabao farms by 17.4% and 19.9% respectively.

Under deep well irrigation, the cropping intensity of the carabao/tractor combination was 8.4% higher than for carabao farms. For rainfed farms, cropping intensities of the carabao farms and tractor combination farms showed no difference suggesting a water, rather than power constraint.

This brief comparison of cropping intensities of the different groups of farms by degree of mechanization and irrigation suggests that mechanization has potential for increasing cropping intensity. However, the comparative mean values in table 10 do not separate the effects of other variables such as tenure, farm size and loan from that of mechanization and irrigation. To compare cropping intensities between mechanized and non-mechanized farms more accurately by accounting for interactive effects of these factors, a covariance model was used.

$$CI = \beta_o + \beta_1 FS + \beta_2 M + \beta_3 I + \beta_4 L + \beta_5 T + \beta_6 MI + \beta_7 ML + \beta_8 MT + \beta_9 MFS + \mu$$

where:

CI - cropping intensity

FS - farm size

M - a mechanization dummy with value equal to 1 for mechanized farms and o for non-mechanized farms.

I - an irrigation dummy with value equal to 1 for gravity irrigated farms and o for farms that used deep well.

T - a dummy for tenurial status with value equal to 1 for farms that are rented and o for farms that are owned.

L - a dummy for loans with value equal to 1 for farms that have short term loans in the dry season for seasonal farm expenses and o for farms that do not have such loans.

MI - interaction of mechanization and irrigation dummy

MT - interaction of mechanization and tenure dummy

ML - interaction of mechanization and loan dummy

MFS - interaction of mechanization and farm size

The above model included nonadditive effects which measure the interactive influence of mechanization on irrigation, tenure, loans, and farm size on cropping intensity. To test the significance of these interaction effects, a constrained version of the above model was fitted with the following restriction: $\beta_6 = \beta_7 = \beta_8 = \beta_9 = 0$, such that the constrained model is specified as follows:

$$CI = \beta_o + \beta_1 FS + \beta_2 M + \beta_3 I + \beta_4 L + \beta_5 T + V$$

The restrictions on the coefficients of the interaction terms were tested using an F-test. The test showed that the interactive effects were statistically significant at the 5% level. However, the only significant interaction term was mechanization and irrigation. Subsequent examination of the correlation matrix showed that these variables were too highly correlated for the results to be considered meaningful. Therefore the remainder of this description covers the model without interactions.

The dummies for mechanization, irrigation and short term credit were found to significantly increase cropping intensity (Table 11). Irrigation had the largest impact on cropping intensity and this clearly affected the simple means of mechanized and non-mechanized farms. Also it is also true that tractor farms are often better endowed with productive capital or have better access to credit markets which enable the farmers to buy the inputs required for a second crop. Even so the mechanized farms tend to have a higher cropping intensity, and this has been shown to be significant.

SUMMARY AND CONCLUSION

The main objective of the study was to quantify the impact of mechanization on small-scale rice production. It aimed to isolate the sources of output differences between mechanized and non-mechanized farms by using decomposition analyses. They were designed to obtain a fairly complete picture of the sources of output growth which may be attributed to mechanization.

The first model used an arithmetic decomposition scheme to disaggregate the output difference between the mechanized and non-mechanized farms into the following components:

a. pure yield
b. price
c. area
d. cropping intensity
e. interactions

One of the limitations of this model is that although it involves heavy (but simple) computational work, it is wasteful of information, being based on means rather than actual data. Another is that it is considered an ad hoc method for analyzing the impact of mechanization since no rigorous methodological framework underlies its formulation. It is simply an accounting method. This does not mean that the results are barren of meaningful interpretation. The manner in which output growth was decomposed in the models are expected to bring out the important factor(s) that are affected by mechanization. The technique attempts to address the question of the source of the major differences in output between the mechanized and non-mechanized farms. This provides direction for evaluating the impacts of mechanization on yield, cropping intensity, cropping pattern and price. It leads one to ask precisely why such an effect arises and hence, the possible source of the effect.

The results of the analysis showed that the most important factors accounting for output differences between the mechanized and non-mechanized farms were yield and cropping intensity.

The possible impact of mechanization on yield is extremely complex since it may involve many factors. A second decomposition model, based on a Cobb-Douglas production function, was used to investigate the yield effect further. The model permitted the decomposition of total yield differences, between mechanized and non-mechanized farms, into a technical change component and a change in inputs used component.

The results suggested that the major explanators of increased yields were non-neutral technical changes associated with use of fertilizers and crop protection chemicals.

Mechanization also appears to have an impact on cropping intensity. The covariance analysis, however, showed that this effect is dominated by the impact of irrigation. We must, therefore, exercise caution in attributing the increased cropping intensity to mechanization since there are confounding factors, including credit availability, which could prevent production of a second crop.

The overall results which we have obtained to date are much less clear than we had initially hoped, and should be treated with some caution. To suggest a direct link between mechanization and the productivity of fertilizer and chemical inputs would be very premature. We are currently obtaining soil samples from each of our respondents and will integrate these and other data into subsequent analyses. It should be possible, in this way either to eliminate many of the other potential causes of increased yield and cropping intensity, or to establish that these, and not mechanization, are the real causal agents. To take any fixed stance at this point in the analysis would be to prejudge the situation.

If we can eventually unravel the consequences of mechanization, it will be possible to provide meaningful guidelines to policy makers involved in farm mechanization.

REFERENCES

ABERCROMBIE, K. C. "Agricultural Mechanization and Employment in Developing Countries," Effects of Farm Mechanization and Employment, FAO/OECD, Rome, 1975, pp. 35-49.

ABRAMOVITZ, M. "Resources and Output Trends in the United States Since 1870". American Economic Review, Vol. 46, May 1956, pp. 5-23.

ALMARIO, E. S. "A Historical Approach to Agricultural Mechanization in the Philippines". Paper presented at the workshop on the Consequences of Small Rice Farm Mechanization, IRRI, 1979.

ANTIPORTA, D. B. and Deomampo, N.R., "Employment Impact of Mechanization of Rice Production Processes", SEARCA Professorial Chair Lecture, U. P. at Los Baños, September 1979.

BINSWANGER, H. Economics of Tractors in South Asia, A., New York and ICRISAT, Hyderabad, India, 1978.

BISALIAH, S. "Effects of Technological Change on Output, Employ- and Functional Income Distribution in Indian Agriculture, A Case Study of the Punjab Wheat Economy". Ph. D. Dissertation, University of Minnesota, November 1975.

BISALIAH, S. "Decomposition Analysis of Output Change Under New Production Technology in Wheat Farming: Some Implications to Returns to Investment in Research:. Indian Journal of Agricultural Economics, Vol. 32, No. 1, Jan-March, 1977.

BISALIAH, S. "Decomposition Analysis of Employment Change under New Production Technology in Punjab Agriculture" Indian Journal of Agricultural Economics, Vol. 33, No. 2, April-June, 1978.

BRADY, Nyle C. The Nature and Properties of Soils, 8th edition MacMillan Publishing Co. Inc, New York, 1974, p. 538.

CHOW, G. C., "Tests of Equality Between Sets of Coefficients in Two Linear Regressions", Econometrica, Vol. 28, No. 3, July, 1960, pp. 591-605.

DUFF, B. "Output, Employment and Mechanization in the Philippine Agriculture", Effects of Farm Mechanization and Employment, FAO/OECD, Rome, 1975. pp. 111-152.

DUFF, B. "Mechanization and Use of Modern Rice Varieties", Economic Consequences of the New Rice Technology", IRRI, Los Baños, Philippines, 1978.

FOLLOSCO, C. "Farm Mechanization and Its Economic Impacts" Agricultural and Industrial Life. Vol. 28, September, 1966.

GUJARATI, D. "Use of Dummy Variables in Testing for Equality Between Sets of Coefficients in Two Linear Regressions: A Note" The American Statistician, February 1970, pp. 50;52.

INUKAI, I. "Farm Mechanization Output and Labor Input: A Case Study in Thailand" International Labour Review. CI, 5 (May 1970) pp. 453-473.

KENDRICK, D. A. Productivity Trends in the United States. Princeton: Princeton University Press, 1961.

KRISHNA, R. "Measurement of the Direct and Indirect Employment Effects of Agricultural Growth w/ Technical Change" Employment in Developing Nations. Edited by Edgar O. Edwards, Columbia University Press, 1974.

McMENNAMY, J. A. "Machinery Development Program at the International Rice Research Institute". Paper presented at the Meeting of the Indian Society of Agricultural Engineers, Hyderabad, India, January 1976.

MINHAS, B.S. and Vaidyanathan A. "Growth of Crop Output in India, 1951-1954 to 1958-1961". Journal of the Indian Society of Agricultural Statistics, Vol. 17, No. 2, 1965.

MISRA, V. N. "Growth of Crop Output in Gujarat: A Component Analysis" Anvesak, Vol. 1, No. 1, June, 1971.

MORAN, P. and Unson D. "Farm Survey and Recordkeeping Procedures for Consequences of Small Rice Farm Mechanization Project: Operation Handbook" IRRI/USAID, May 1980.

PATEL, N. T. "Farm Tractorization, Its Impact on Agricultural Inputs and Outputs", Economic Times, India, October 20, 1980.

PIPUTSITEE, C. "An Economic Analysis of Manufacturing and Distribution Activities in the Farm Machinery Industry in the Philippines" M.A. thesis, UP, 1976.

RATHORE, M.S. "Factor Combination and Resource Use Efficiency on Small and Large Farms - A Comparative Study of Hill Agriculture and the SAT", Ph.D. Dissertation, Himachal Pradesh University, Simla, 1979.

SAGAR, V. "A Component Analysis of the Growth of Productivity and Production in Rajasthan: 1956-61 to 1969-74" Indian Journal of Agricultural Economics, Vol. 32, No. 1, January-March, 1977.

SANTOS, G. "Mechanization Farming in the Philippines". M.A. Thesis. University of Sto. Tomas, 1946.

SIEGEL, S. Nonparametric Statistics for the Behavioral Sciences, McGraw-Hill Kogakusha, Ltd. 1956.

SOLOW, R.M. "Technical Change and the Aggregate Production Function", Review of Economics and Statistics, Vol. 39, August 1957, pp. 312-320.

SONDHI, R. and Singh K. "Component Analysis of Foodgrain Economy of India", Journal of Social and Economic Studies, Vol. 3, No. 2, September, 1975.

TAN, Y. L. "The Impact of Farm Mechanization on Small-scale Rice Production", Unpublished M.S. thesis, UPLB, March 1981.

TAN, Y. L., Webster, J.P. and Wicks, J.A. "The Decomposition of Differences in Output Between Two Groups of Farms." The Consequences of Small Rice Farm Mechanization Project, Working Paper No. 14, 1981.

TENNENT, R. M. Science Data Book, Longman Group Ltd., London 1975.

THAPA, G. B. "The Economics of Tractor Ownership and Use in Selected Districts of the Nepal Terai." M.S. Thesis, UPLB, 1979.

Table 1. Distribution of sample farms by municipality and barrio, Nueva Ecija, Philippines, 1979.

Municipality/Barrio	Number of Sample Household
Cabanatuan	
San Isidro	49
Lagare	47
Kalikid Sur	24
Caalibangbangan	76
Guimba	
Galvan	35
Narvacan I	39
San Andres	45
Bunol	53

Table 2. Distribution of sample farms by type of power used in land preparation and irrigation, Nueva Ecija, Philippines, Wet Season, 1979.

Power	Irrigation			
	Gravity	Deep well	Rainfed	Total
Carabao	11	37	83	131
2-wheel tractor	62	1	1	64
4-wheel tractor	2	-	-	2
2-wheel/4-wheel tractor combination	20	-	-	20
2-wheel/carabao	27	3	26	56
4-wheel/carabao	9	10	12	31
2-wheel/4-wheel/ carabao	15	1	2	18
Total	146	52	124	322

Table 3. Demographic characteristic of sample farms by type of mechanization, Nueva Ecija, Philippines, Wet Season, 1979.

Characteristics	Carabao farms	2-wheel tractor farms
Number of households	46	62
Average age of the household head (years)	44	49
Average education of household head (years)	4	4
Average experience in farming of household head (years)	19	22

Table 4. Characteristics of sample farms by type of mechanization, Nueva Ecija, Philippines, Wet Season, 1979.

Operation	Carabao farms	2-wheel tractor farms
Area (hectares)	1.95	2.39
Production (kilograms)	5089.50	7710.85
Yield per hectare (kgs.)	2610.00	4013.36
Price of paddy (₱/kg.)	1.06	1.17
Total pre-harvest labor (m-hrs/ha)	247.02	223.28
Total post-production labor (m-hrs/ha.)	244.41	207.34
Total land preparation hours (man-machine or man-animal hours/hectare)	96.79	29.52
Level of fertilizer (kg.N/ha)	40.13	57.98
Value of crop protection (₱/ha)	96.69	186.44
Loan for seasonal farm expense per hectare	1023.44	1215.35
Long term loan for agricultural investment per hectare	1954.87	2484.56
Cropping intensity*	1.36	1.92

*Cropping intensity = $\frac{\text{gross cropped area in a given crop year}}{\text{Operated area per crop}} \times 100$

- computed for wet and dry season data

Table 5. Test for differences of variable between tractor and carabao farms using the Kruskal-Wallis one-way analysis of variance by ranks.

Variables	Value of H*** for 2-wheel tractor farms vs. carabao farms
Area (wet season)	-5.81 n.s.
Area (dry season)	30.58**
Yield (wet season)	18.57**
Yield (dry season)	3.31 n.s.
Price (wet season)	9.88**
Price (dry season)	0.43 n.s.
Fertilizer use (wet season)	5.61*
Level of crop protection (wet season)	13.99**
Total pre-harvest labor (wet season)	-5.65 n.s.
Land preparation hours (wet season)	32.03**

n.s. - not significant

* - significant at 5% level

** - significant at 1% level

Table 6. Decomposition analysis (with interaction terms) of output differences between 2-wheel tractor and carabao farms.

Effect	Absolute change	Percentage share
Sources of output differences		
A. Individual effects		
pure yield effect	4356.54	31.40
area effect	1556.92	11.22
cropping intensity effect	3608.66	26.01
price effect	688.63	4.96
B. First-order interaction effects		
yield and price	397.33	2.86
area and price	-71.52	-0.52
area and yield	388.99	2.80
cropping intensity and yield	1793.87	12.93
cropping intensity and price	283.55	2.04
cropping intensity and area	641.08	4.62
C. Second-order interaction effects		
cropping intensity, price and area	-29.45	-0.21
cropping intensity, price and yield	163.61	1.18
cropping intensity, yield and area	160.17	1.15
price, yield and area	-46.54	-0.34
D. Third-order interaction effect		
cropping intensity, price, yield and area	-19.16	-0.10
Total	13872.70	100.00

Table 7. Estimated coefficients of the Cobb-Douglas production function using dummy variable for mechanization.

INDEPENDENT VARIABLES	DEPENDENT VARIABLE (Yield per hectare)
Intercept	5.39**
Intercept dummy	1.01 (0.1460)
Power	0.20*
Fertilizer	0.44**
Labor	0.01 (0.1531)
Crop protection	0.01 (0.8859)
Slope dummy for power	-0.18 (0.1901)
Slope dummy for fertilizer	-0.406**
Slope dummy for labor	-0.095 (0.4426)
Slope dummy for crop protection	0.33
N	96
R^2	0.64

Figure in parentheses are probabilities of $|T| > 't'$ statistic.

* significant at 5% level.

** significant at 1% level.

Table 8. Estimated coefficients of the Cobb-Douglas production functions for the 2-wheel tractor and carabao farms

Independent Variables	Farm types	
	Carabao farms	2-wheel tractor farms
Intercept	6.4**	5.16**
Power	0.02 (0.8702)	0.20*
Fertilizer use	0.034 (0.8064)	0.44**
Labor	0.005 (0.9622)	0.10 (0.1467)
Crop protection	0.34**	0.01 (0.8836)
R^2	0.33	0.65
N	46	62

Figure in parentheses are probabilities of $|T| > 't'$ statistic

* significant at 5% level

** significant at 1% level

Dependent variable - yield per hectare

Table 9. Decomposition analysis of per hectare yield differences between 2-wheel tractor and carabao farms.

Component	Percentage Share
Sources of yield differences	
A. Technical change	
Neutral technical change	-9.35
Non-neutral technical change	58.06
Total due to technical change	48.71
B. Change in inputs	
Power	-2.74
Fertilizer	7.03
Labor	-0.44
Crop protection	0.28
Total due to input difference	4.13
Total due to all sources	52.84

Table 10. Cropping intensity of sample farms by type of power used in land preparation and irrigation, wet season, 1979 and dry season, 1980.

Power	Irrigation		
	Gravity	Deep well	Rainfed
Carabao farms	182%	119%	103%
Tractor farms	191%	191%	-
Tractor-Carabao combination	193%	129%	101%

- no observation in the sample

Table 11. Covariance analysis of the effects of mechanization on cropping intensity.

INDEPENDENT VARIABLES	DEPENDENT VARIABLE Cropping Intensity (Percentage) Additive Model	With interaction Effect
Intercept	126.05**	120.55**
Land (FS)	-4.80*	-5.21 (.11)
Mechanization Dummy (M)	27.01**	79.22**
Irrigation Dummy (I)	35.53**	45.67**
Tenure Dummy (T)	8.07 (0.19)	12.90 (0.13)
Short term loan for dry season dummy (L)	15.11*	24.80*
M X I	-	-56.61*
M X T	-	-3.56 (0.77)
M X L	-	17.96 (0.13)
M X FS	-	1.37 (0.74)
R^2	0.644	0.685
N	102	102

* significant at 5% level.

** significant at 1% level.

Figure in parentheses are probabilities of |T|>'t' statistic

CONSEQUENCES OF SMALL RICE FARM MECHANIZATION PROJECT

Working Papers

1 Juarez, F. and B. Duff. The Economic and Institutional Impact of Mechanical Threshing in Iloilo and Laguna. October 1979.

2. Pathnopas, R. The Economics of Rice Threshing Machines in Thailand: A Case Study of Chachoengsao and Supanburi Provinces. October 1979.

3. Gardezi, J., A. Rauf, M. Munir, K. Altaf, Q. Mohd-ud-Din, and B. Lockwood. A Study of Mechanical and Traditional Wheat Threshing in Multan District, Punjab, Pakistan: Some Preliminary Results. October 1979.

4. Habito, C. and B. Duff. A Simulation Model to Evaluate Mechanization of Rice Postharvest Operations in the Philippines. October 1979.

5. Chapman, J. The Potential of Mechanization for Crop Intensification in a Rainfed Area - Iloilo, Philippines. October 1979.

6. Thapa, G. The Economics of Tractor Owernship and Use in the Nepal, Terai. October 1979.

7. Jongsuwat, N. Productivity Growth and Farm Machinery Adoption in Thai Agriculture. April 1980.

8. Bernsten, R.H. and R. Sinaga. A Methodology for Identifying Lowland Rice Farms that Would Benefit from the Mechanization of Land Preparation. October 1979.

9. Bernsten, R. H. and A. Rochim. Labor Shortage as a Constraint to Increasing Cropping Intensity. Revised March 1980.

10. Ayob, A.M. The Economics and Adoption of the Combine Harvester in the Muda Region of Malaysia. October 1979.

11. Lubis, R. Impact of Cropping Pattern Technology on Income, Employment and Production: A Case Study on Expanded Crop Production in Lampung. October 1979.

12. Wicks, J. A. Modelling the Consequences of Future Mechanization: An Outline of Possible Procedures. October 1979.

13. Khoju, M.R. and J. A. Wicks. Economics of Pump-Irrigation in Eastern Nepal. August 1980.

14. Tan, Y. L., J.P.G. Webster and J. A. Wicks. The Decomposition of Differences in Output Between Two Groups of Farms. Revised 1981.

15. Herdt, R. W. Mechanization of Rice Production in Developing Asian Countries: Perspective, Evidence, and Issues. September 1981.

16. Lantin, R. M. Mechanization Policy and the National Agricultural Mechanization Council - Philippines. September 1981.

17. Lockwood, B. Farm Mechanization in Pakistan: Policy and Practice September 1981.

18. Wiboonchutikula, P. The Total Factor Productivity Growth of the Three Digit Manufacturing Industries in Thailand. September 1981.

19. Ahammed, C. S. and R. W. Herdt. A General Equilibrium Analysis of the Effects of Rice Farm Mechanization in the Philippines. September 1981.

20. Mikkelsen, K. and N. Langam. Technology Change in the Philippine Agricultural Machinery Industry. September 1981.

21. Boughton, D. Energy Use in Alternative Rice Production Systems in Nueva Ecija, Central Luzon, Philippines. September 1981.

22. Hurun, A. Financial Analysis of Power Tiller Ownership in Mariuk Village, West Java, Indonesia. September 1981.

23. Hafsah, J. The Economics of Tractor Operation and Use in South Sulawesi, Indonesia. September 1981.

24. Maranan, C. L. A Comparative Analysis of Tractor Contract Operations in Nueva Ecija, Philippines, 1972 and 1980. September 1981.

25. Monge, V. S. and B. Duff. Analysis of the Demand for Farm Power for Small Rice Farm Agriculture in Nueva Ecija, Philippines. September 1981.

26. Munir, M. An Evaluation of the Farmers' Decision-Making for Investment in Farm Machinery. September 1981.

27. Jabbar, M. A., Md.S. R. Bhuiyan and A. K. Maksudul Bari. Causes and Consequences of Power Tiller Utilization in Two Areas of Bangladesh. September 1981.

28. Juarez, F. and R. Pathnopas. A Comparative Analysis of Thresher Adoption and Use in Thailand and the Philippines. September 1981.

29. Ahmed, J. U. Labour Use Pattern & Mechanization of Paddy Postharvest Processing in Bangladesh. September 1981.

30. Colter, J. M. The Impact of Handtractors on Income and Employment Opportunities of Migrant Laborers in Java. September 1981.

31. Santoso, K. The Potential for Agricultural Mechanization and Labor Markets in East Java. September 1981.

32. Bernsten, R. H. Effects of Mini-Tractor Mechanization on Employment and Labour Use Intensity, Sidrap and Pinrang, South Sulawesi, Indonesia. September 1981.

33. Collier, W. Improved Cropping Patterns, Labor Absorption and Small Farm Mechanization in Indonesia. September 1981.

34. Moran, P. B. and E. Camacho. Consequences of Farm Mechanization Project Site Description: Philippines. September 1981.

35. Generalla, A. C. and A. Aguilar. Effects of Mechanization on Intensity of Land Use. September 1981.

36. Tan, Y. and J. A. Wicks. Production Effects of Mechanization. September 1981.

37. Sison, J. F. and P. B. Moran. Farm Labor Utilization and Employment in Two Selected Municipalities in Nueva Ecija - A Preliminary Analysis. September 1981.

38. Saefuddin, Y. Site Description: Mechanization Consequences Project in West Java, Indonesia. September 1981.

39. Handaka, S. Effects of Mechanization on Intensity of Land Use, West Java, Indonesia. September 1981.

40. Handaka, S. A Technical and Economic Evaluation of Rice Mills in West Java, Indonesia. September 1981.

41. Sinaga, R. Effects of Mechanization on Productivity: West Java, Indonesia. September 1981.

42. Sinaga, R. Effects of Mechanization on Productivity: South Sulawesi, Indonesia. September 1981.

43. Sri-Bagyo, A. The Impact of Mechanization on Production and Employment in Rice Areas of West Java, Indonesia. September 1981.

44. Maamun, Y. Site Description: Mechanization Consequences Project in South Sulawesi. September 1981.

45. Sarasutha, I. G. P. and R. Bernsten. Effect of Mechanization on Intensity of Land Use, South Sulawesi, Indonesia. September 1981.

46. Bockhop, C. W. and M. Nafziger. The Impact of Economics upon the Design of Machinery at IRRI. September 1981.

47. Wattanutchariya, S. Economic Analysis of Farm Machinery Industry and Tractor Contractor Business in Thailand. September 1981.

48. Hussain, K. A. An Assessment of Capacity of Workshops and Farmers To Repair and Maintain Farm Machinery in District Faisalabad: Summary of Major Findings and Policy Recommendations. September 1981.

49. Gonzales, L. A. and R. W. Herdt. Evaluating the Sectoral Impact of Mechanization on Employment and Rice Production in the Philippines: A Simulation Analysis. September 1981.

50. Khoju, M. R. The Economics of Pump Irrigation in Eastern Nepal. September 1981.

51. Sudaryanto, T. The Effect of Tubewell on Income and Employment: A Case Study in Three Villages in Kediri, East Java, Indonesia. September 1981.

52. Santoso, K. Economics of Pumpsets in East Java. September 1981.

53. Wicks, J. A. and M. A. Sumiran. Data Management for Analyzing the Consequences of Mechanization. September 1981.

54. Webster, J. P. G. An Evaluation of Mechanization Data Using the FAO's Management Data Collection and Analysis System (FMDCAS). September 1981.

55. Lingard, J. Measuring the Impact of Mechanization on Output. September 1981.

JW/hhr