PN-AAN-591
ISN: 31722

THE CONSEQUENCES OF SMALL RICE FARM MECHANIZATION PROJECT

Working Paper No. 10

The Economics and Adoption of the Combine Harvester in the Muda Region of Malaysia

by

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October 1979

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.

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SUMMARY

The objectives of this paper was to provide basic information on the diffusion of the new mechanical harvesting technology in the Muda area of Malaysia. Primary data, obtained by means of personal interviews of farmers, machine owners and machine commission agents, were used. Cross-tabulation as well as multivariate techniques were employed to describe the pattern of combine harvester adoption in the Muda region. The analysis showed that large farms were more likely to adopt the machine compared with the small farms.

In the adoption process, those farmers who perceived the economic as well as technical superiority of the combine were not only more likely to adopt but adopted the machine earlier than those that did not perceive the machine's advantages.

Access of the new technology to an area increases the probability of a farmer using it. To be economical, the area harvested by a combine must be large and contiguous. Farms in Muda are typically small with an average of 1.6 ha. Hence it is necessary for neighboring farms to agree to harvest their crops together before a combine can be called upon to do the job.

The viability of the combine harvester as a private business project has been confirmed by another research worker. There is no doubt that the greater benefits of the new harvesting technology have accrued to the machine-owning class in the form of business profits. Another

direct beneficiary of the technical change is the group that act as "brokers" or commission agents. In so far as they are already big farmers, the introduction of the combine harvester furthers the interest of the large farms.

Farmers benefit from this new technology from the reduction of harvesting cost and timely operation which could well save a crop from torrential rain. An indirect benefit to farmers stems from the additional income obtained from part-time work on other farms not using the machine.

Complete mechanization of harvesting is not envisaged in the Muda area under the present state of the arts. Large areas of the region are still inaccessible to the machine and even in areas that are accessible, uneven ripening due to uneven planting dates prevent simultaneous harvesting of neighboring plots. A lodged crop is also rejected by the machine. For these farms, the manual harvesting will continue to be important.

THE ECONOMICS AND ADOPTION OF COMBINE HARVESTERS IN THE MUDA REGION OF MALAYSIA

INTRODUCTION

The construction of irrigation facilities in many parts of Asia has enabled a greater intensity of the use of land through the practice of multiple-cropping with the high-yielding varieties (HYV's) of rice. The higher yields that are achieved with the new cereal varieties have typically been achieved by the simultaneous application of a package of other inputs, including a heavier application of fertilizer, more effective control of weeds, insects and diseases and better management of water delivery and use. (Ruttan and Binswanger, 1978, p. 361). In many areas, the introduction of double-cropping with the HYV's has been associated with intensified mechanization. The Muda Irrigation Scheme of North Malaysia is one such area.

This paper is concerned with the economics and adoption of the rice combine harvester, a form of capital-intensive technology, in smallholding agriculture of the Muda region. The presence of the combine harvester in the Muda area appears to be a classic example of a direct transfer (Evenson and Binswanger, 1978, p. 166) of a mechanical technology from the developed economies to a developing country. Under this kind of technology transfer, a country merely screens and adopts the best techniques without modifying such techniques through adaptive research of its own, unlike the diffusion of the biological technology in the form of the HYV's.

Presently there are slightly over 100 units of the combine harvesters in the Muda area (Rayarappan, 1979). These combines range from the small Japanese type (32 HP, 4½ ft. cutterbar) to the huge European models (105 HP, 14 ft. cutterbar). The 30 small Japanese combines are owned by the Muda Agricultural Development Authority (MADA) while the remaining 80 large ones are privately owned by approximately 60 owners (Rayarappan, 1979, p. 7) who perform contract harvesting upon demand by farmers.

OBJECTIVES

The overall objective of this paper is to provide basic information on the circumstances surrounding the adoption of the combine harvester by paddy farmers in the Muda Irrigation Project area in Malaysia.

Specially the objectives of this paper are:-

1. To describe the institutional arrangement that has emerged to cater to the spread of the combine harvester in the Muda region;
2. To identify and measure the relative contributions of the factors that are associated with farmers' decision to adopt mechanical harvesting technology in the Muda scheme;
3. To explain the pattern of the diffusion of the combine harvester over time.

METHODOLOGY

Data sources

The data for this paper were obtained by means of a series of field interviews with paddy farmers, combine harvester brokers (commission agents), farm workers and government officials. A total of 858 farmers, (293 of them again on a second round) 315 farm workers, 38 machine owners and 59 machine brokers were interviewed. The respondents were randomly selected from three localities in the Muda area.

Analytical tools

Both descriptive and analytical techniques will be used, with the former setting forth the institutional aspects of the new technology and the latter quantifying the relationships between the adoption of the new technology and the ex-ante factors influencing adoption. The methods of cross tabulation as well as multivariate analysis will be used to analyze the data and test hypotheses. With the cross tabulation, the chi-square test will be used to test the presence of association between two categorical variables such as farm size and "earliness" in adoption of the harvester.

Multiple regression analysis was used to explain the adoption process over time and the extent of adoption by individual farmers. The two dependent variables here are the total number of seasons the farmer had used the service of the combine harvester (y_2) and the proportion (y_3) of the farmer's land that was harvested mechanically with the combine harvester. The ex-ante explanatory variables included were the farm

size, schooling in years, tenure status, fragmentation, sex, perception of the economic advantage, perception of the technical advantage (recovery of grain), the neighborhood factor, age, labor availability on the farm and full-time status of the farmer.

Ordinary least-squares regression was used to estimate the relationship. However, because of the non-normality of the disturbance term (since for a large number of the farmers interviewed, the dependent variable was zero), the usual t-tests of significance are not strictly appropriate. However, the OLS standard errors were calculated as though the classical assumptions of the linear model were satisfied.

The adoption of the combine harvester may also be regarded as the choice of technique. Here the dependent variable is dichotomous. It is equal to 1 if the farmer had adopted the machine in the survey season and 0 if he did not. The use of ordinary least squares based on the model

$$y_j = x_j' \beta + \varepsilon_j, \qquad j = 1 \ldots\ldots\ldots\ldots, n \qquad (1)$$

is clearly inappropriate here because the assumptions of OLS do not hold (Nerlove and Press, 1973, p. 5). Firstly, the error term does not have a constant variance, the variance being

$$\text{var}\,(y_i \mid x_j) = \text{var}\,(\varepsilon_j) = x_j' \beta(1 - x_j' \beta) \qquad (2)$$

Since var (ε_j) depends upon j, the ε_j's are heteroscedastic, and the use of OLS estimation will lead to inefficient estimators and imprecise predictions (Nerlove and Press, p. 5).

Furthermore, predictions based upon the OLS procedure could well give a negative value of the dependent variable or a value exceeding 1, whereas y_j is restricted to lie between 0 and 1, being the probability of the choice of the new technology.

Because of the above difficulties of using the OLS, one of the methods of analysis of binary dependent variable was used, namely the maximum likelihood logistic regression.

Let P be the probability that the farmer had used the combine harvester. Hence

$$\begin{aligned} P &= Pr\ (y_j = 1) \\ &= Pr\ (\varepsilon_j < X_j'\beta) \\ &= F\ (X_j'\beta) \end{aligned} \tag{3}$$

where F is the cumulative density function (cdf) of the random variable ε_j. Therefore $1 - p = Pr\ (y_j = 0) = 1 - F\ (X_j'\beta)$. With this specification P will lie between 0 and 1, being a property of the cdf (Meyer, 1965, p. 62), since $F\ (-\infty) = 0$ and $F\ (\infty) = 1$. The choice of the form of the cdf in empirical work is arbitrary (Maddala and Nelson, 1974, p. 3). A convenient form to use is the logistic function:

$$P_j = \frac{1}{1 + \varepsilon_j^{-X_j'\beta}} \tag{4}$$

Solving for the argument we get

$$X_j'\beta = \log \left(\frac{1 - P_j}{P_j} \right) \tag{5}$$

The right-hand side of (5) is known as the log-odds or logit of machine adoption.

The computational procedure for obtaining the estimates of the β's are given in Nerlove and Press (pp. 88-98). It involves the setting up of a likelihood function in the parameters, β, and the maximization of this likelihood function given the observations on a binary dependent variable and a set of independent variables. The likelihood of an observed binary sequence (Cox, 1969, p. 44) $y_1 \ldots\ldots, y_n$ is

$$\Pr(Y_1 = y_1, \ldots\ldots, Y_n = y_n) = \frac{\exp\left(\sum_{s=1}^{p} \beta_s t_s\right)}{\prod_{i=1}^{n} \left(1 + e^{x_i' \beta}\right)} \quad (6)$$

$$j = 1$$

where $t_s = \sum_{j=1}^{n} x_{js} Y_j$,

x_j is a row of independent variables and β a vector of unknown parameters.

Taking a partial derivative of (4) one obtains the following relationship:

$$\frac{\partial p}{\partial x_j} = \beta_i (1 - p) \quad (7)$$

Equation (7) shows the rate of change of the probability of machine adoption with respect to the ith independent variable. Hence a positive β_i indicates a positive relationship between the independent variable in question and the probability of adoption. However it should be noted that the coefficient obtained from the regression output has to be multiplied by 2 in order to obtain the coefficients in the standard logistic form (Nerlove and Press, p. 90):

$$P(y) = \left[1 + \exp\{ - (x_j' \beta)\} \right]^{-1}$$

RESULTS

Comparison of farm size distribution for adopters and non-adopters

The survey reveals that 27.39 percent of the farmers interviewed had used the combine harvester in the last successful harvesting season while the remainder (72.61%) used entirely the traditional method of harvesting. In terms of area, 21.36 percent of the paddy land in the sample was harvested mechanically.

Experience with the combine harvester and farm size

The respondents were asked to state the number of seasons they have had used the combine harvester to harvest their crop. A cross-tabulation of the number of seasons the farmer had combined his crop and the farm size operated is given in Table 1.

The table shows, *inter alia*, that 24.1 percent of the farmers had used the combine harvester for the first time, 2.8 percent for the second time, 0.4 percent for the third time and a mere 0.23 percent for the fourth time.

The chi-square test gives a chi-square value of 390.6 (24 degrees of freedom) which is highly significant, statistically. The hypothesis of no association between farm size and the number of seasons the machine had been used is rejected at a very high confidence level (e.g. 0.01 level).

Pearson's rank correlation coefficient gives a value of 0.3024 suggesting a weak positive correlation between farm size and number of seasons the machine had been used, suggesting that the bigger farms have had a longer experience with the combine harvester.

Table 1. Number of previous seasons farmers have used combine harvester by farm size

Farm size class	Number of seasons 0	1	2	3	4	Row total
	Count					
0 - 3 ac	354	77	3	0	1	435
3 - 6 ac	200	77	14	2	0	293
6 - 9 ac	49	36	2	0	0	87
9 - 12 ac	15	10	3	0	0	28
12 - 15 ac	3	5	2	0	1	11
15 - 21 ac	0	2	0	1	0	3
GT 21 ac	0	0	0	1	0	1
Column Total (%)	621 (72.4)	207 (24.1)	24 (2.8)	4 (.5)	2 (.2)	858 (100)

Chi-square = 390.5790 (24 d.f.) Signif. = 0.0000

Pearson's R = .3024 Signif. = 0.0000

Date of first adoption and farm size

The date of first adoption was cross-tabulated with farm size, giving Table 2.

This table enables one to test the null hypothesis of no association between farm size class and date of first adoption. The chi-square value of 524.6 (42 degrees of freedom) is significant at the 0.01 level of probability. Pearson's R of -.29, which is also statistically significant, shows that the larger the farm, the earlier it will adopt the machine.

Characteristics of the sample based on the independent variables

Table 3 gives some general characteristics of the 858 farmers interviewed, based on 12 independent variables. Table 4 provides a comparison between the adopters and non-adopters based on this set of characteristics.

Farm size. The smallest farm encountered was only .07 ha. and the biggest was 11.5 ha. The mean farm size for all respondents was 1.50 ha. The mean farm size for adopters was 2.03 ha., which is substantially higher than 1.30 for non-adopters.

Tenure status (OWN, TEN). Forty-five percent of the farmers interviewed operated only their own paddy land. However, a larger proportion of the non-adopters (49.7%) operated only their own land while 34.6 percent of the adopters operated only what they own.

Slightly over 29 percent of the non-adopters were strictly tenants compared with 35 percent of the adopters belonging to the pure-tenant class (Table 4).

Table 2. Date of first adoption of combine harvester by farm size class

Year and season	0 - 3 ac	3 - 6 ac	6 - 9 ac	9 - 12 ac	12 - 15 ac	15 - 21 ac	GT 21 ac	Row Total
1974-II	0	0	0	0	0	1	0	1
1975-II[a]	0	0	0	0	1	0	0	1
1976-I	0	1	0	0	0	0	0	1
1976-II	1	6	0	0	1	0	1	9
1977-I	13	16	9	3	1	1	0	43
1977-II	66	67	28	10	5	1	0	177
1978-I	1	3	1	0	0	0	0	5
Never adopted	354	200	49	15	3	0	0	621
Column total	435	293	87	28	11	3	1	858

Chi-square = 524.6 (42 d.f.) Significance = 0.0000

Pearson's R = -.29 Significance = 0.0000

[a] No farmer first adopted in 1975-1

Table 3. Descriptive statistics of explanatory variables

Variable	Mean	Minimum	Maximum
FSIZE (ha.)	1.50	0.07	11.5
OWN	0.45	0.0	1.0
TEN	0.31	0.0	1.0
FMN	3.18	0.25	15.00
SEX	0.06	0.0	1.00
ECON	0.41	0.0	1.00
RCV	0.17	0.0	1.00
NHBR	0.54	0.0	1.00
AGE (years)	43.30	17.0	99.00
MEQ	2.09	0.0	5.34
FUL	0.88	0.0	1.00
SCH (years)	3.97	0.0	15.00

Key:

FSIZE = Farm size
TEN = Tenure: Tenure
SEX = Sex
RCV = Perception of better grain recovery
AGE = Age
OWN = Tenure: Owner
FMN = Fragmentation
ECON = Perception of economic advantage
NHBR = Neighborhood effect
MEQ = Labor availability
SCH = Schooling

Table 4. Comparison of means of explanatory variables between adopters and non-adopters

Variable	Mean for		
	Non-adopters	Adopters	Overall
FSIZE (ha.)	1.30	2.03	1.50
OWN	0.497	.346	0.45
TEN	0.292	.350	0.31
FMN	4.607	3.810	3.18
SEX	0.069	0.043	0.06
ECON	0.330	0.641	0.41
RCV	0.141	0.293	0.17
NHBR	0.389	0.944	0.54
AGE (years)	43.490	42.910	43.30
MEQ	2.095	2.071	2.09
FUL	0.853	0.966	0.88
SCH (years)	3.861	4.261	3.97

Key:

FSIZE = Farm size
TEN = Tenure: Tenant
SEX = Sex
RCV = Perception of better grain recovery
AGE = Age
FUL = Full-time status
OWN = Tenure: Owner
FMN = Fragmentation
ECON = Perception of economic advantage
NHBR = Neighborhood effect
MEQ = Labor availability
SCH = Schooling

Fragmentation index (FMN). Based on the formula FMN = FSIZE/PCL where PCL is the number of parcels of paddy land operated, the fragmentation index measures the average parcel size. This ranged from 0.07 ha. to 4.31 ha. with a mean value of 0.91 ha.

Sex of respondents (SEX). Six percent of the heads of households interviewed were women. They were either divorced or widowed. Among the non-adopters, 6.9 percent were women while in the adopter group only 4.3 percent were women.

Perception of economic advantage (ECON). Table 3 shows that 41 percent of the respondents believed it was cheaper to harvest paddy with the combine harvester. The proportion of adopters and non-adopters who perceived the economic advantage of using the machine was 64.1 percent and 33.0 percent, respectively. Thus a much higher proportion (twice) of the adopters perceived the economic advantage of the machine.

About 27 percent of the non-adopters and .43 percent of the adopters did not know about the relative economic advantage of the two techniques. About equal proportions of both categories of farmers (28.4 and 28.9%) did not see any difference in the relative cost of the two methods. Only 6.81 percent of the adopters thought that the traditional method of harvesting cost less and yet chose the more expensive method, perhaps because of the time-saving element of the combine harvester.

The cost of harvesting paddy by a mechanical harvester at present ranges from US$78 to US$104 per hectare while to harvest by

hired labor it may cost anywhere between US$87 to US$122 per hectare. On top of this, the farmer often has to add expenses for workers' meals, and snacks and, in the case of migrant workers from Thailand and Kelantan, sleeping quarters. Additional expenses and labor are also incurred in transporting the harvest from the threshing area to the bunds. This in-field transportation is provided free by the combine harvester.

Grain recovery (RCV). Only 17 percent of the farmers interviewed believed that grain recovery of the combine harvester was superior to traditional methods. The corresponding figures for adopters and non-adopters are 29.3 and 14.1 percent, respectively.

Grain losses by the combine harvester can originate (Phills, 1967:541) from:

(1) Failure of the cutting mechanism to cut all the grain;

(2) Failure of the threshing mechanism to remove the seed from the head or pod;

(3) Failure of the separating mechanism to separate the seed from the straw;

(4) Cracking of the seed in the threshing process or the seed being blown away in the cleaning process.

On the other hand, shattering losses in manual harvesting may originate from several stages of the harvesting operation - during cutting and transportation to the threshing area, during threshing and also during winnowing. Inexperienced workers may not thresh the crop completely, often leaving plenty of stubborn grains intact on the panicle.

Neighborhood effect (NHBR). Fifty-four percent of the respondents reported that their neighbors had used the combine harvester in the last successful harvesting season. Of these, 47.9 percent adopted the machine themselves; and of those who reported that neighbors did not use the machine only 3.3 percent adopted the machine.

The substantial difference in these proportions provide a *prima facie* evidence of the importance of the NHBR variable in influencing the adoption of mechanical harvesting in the Muda area.

Age of respondents (AGE). The youngest respondent in the sample was 17 years old while the oldest was 99 years old. The mean age of the farmers was 43.3 years. Non-adopters were slightly older than the adopters although the difference appears to be quite negligible, i.e. 0.58 year.

Labor availability (MEQ). Family labor availability was measured in male-equivalents of full-time family members available to participate in harvesting work. It was immaterial whether they did actually participate or not. The measure on this variable ranged from 0 to 5.34 with a mean of 2.09 male-equivalents. The non-adopters had a slightly higher mean than the adopters although the difference was small.

Full-time farmers (FUL). Eighty-eight percent of the farmers interviewed may be considered as full-time farmers. For the adopters, 96.6 percent were full-time paddy farmers, while in the case of non-adopters, 85.3 percent were full-time farmers.

Schooling (SCH). The average length of school attendance for the sample was 3.97 years. The adopters had a slightly longer school attendance than the non-adopters.

Reasons for and against the choice of the combine harvester

Machine adopters were asked to give reasons for their choice of the machine in harvesting while the non-adopters were asked why they did not harvest by machine.

Nearly 84 percent of the adopters indicated the great speed of the machine as their reason for employing the machine. A second reason (40.4%) was the difficulty of finding manual labor to do the work. A third reason closely related to the second was "shortage of man-power" on the farm.

For the non-adopters, the most popular answer (49%) was that the farm was "too small" to justify mechanical harvesting. The second most important reason for not adopting the machine (43.3%) was the fact that the crop did not ripen "evenly" - meaning that it either ripened too early or too late in relation to neighboring fields. This involves the questions of accessibility and economics. If a plot of paddy ripens too early, there is probably no way in which a combine can get to it. If it ripens too late, it will not be economical for a combine to come and harvest it. Hence the farmer who is out of schedule will often not be able to harvest mechanically.

The logistic of machine adoption

Table 5 presents the maximum likelihood regression coefficients with the asymptotic standard errors, t-ratios and significance levels. If we accept an asymptotic t-ratio of 1 or more as a reasonable critical level for hypothesis testing, as Demir (1976) did, then six independent variables are statistically significant in Table 5. These variables are FSIZE, TEN, ECON, RCV, NHBR and FUL. The positive coefficient of .0792 for farm size indicates that the probability of a farmer in Muda adopting the combine harvester increases as the farm size increases.

Another interesting result of the logistic regression is that the probability of adoption is also influenced to a large extent by the availability of the machine in an area. NHBR is supposed to indicate the availability of the machine in a village since if a farmer reported that his neighbor had used the machine, there could be no doubt that the machine was available. The "neighborhood" variable is also intended to show the "influence" of neighbors in the acceptance of a new technology. Thus, it may be concluded that the adoption of the harvesting machine in Muda is facilitated by neighboring conditions. This is not a startling conclusion if it is realised that mechanical harvesting of paddy is often done on a cooperative basis at an informal level. What usually happens is that a machine will harvest a certain tract of land belonging to several neighboring farmers in one "run" after which the harvest is divided among the owners on a *pro rata* basis based on the actual area covered. However the neighboring crops have to ripen simultaneously.

Table 5. A logistic regression of machine adoption in Muda

Indep. variable	Coefficient	Asymp. std. error	Asymp. t-Ratio	Asymp. significance
FSIZE	.0792*	.0190	4.156	.324E-4
OWN	-.0309	.1255	.246	.806
TEN	.1444	.1323	1.0912	.275
FMN	.0002	.0307	.007	.995
SEX	-.0782	.2194	.357	.721
ECON	.3050*	.0982	3.105	.002
RCV	.1263	.1217	1.038	.299
NHBR	1.575*	.154	10.212	.17E-23
AGE	-.0025	.0046	.553	.580
MEQ	-.0051	.0595	.086	.931
FUL	.462*	.2136	2.165	.030
SCH	.015	.018	.842	.400
Const.	-2.6563*	.3808	6.975	.30E-11

No. of iterations = 15 N = 858

* Coefficients with extremely low asymptotic standard errors.

Key:

FSIZE = Farm size in "relong" (1 rel. = .29 ha.)
OWN = 1 if full-owner, 0 otherwise
TEN = 1 if full-tenant, 0 otherwise
FMN = Fragmentation index (average parcel size)
SEX = 1 if female, 0 if male
ECON = 1 if machine perceived to be cheaper than traditional method, 0 otherwise
RCV = 1 if machine perceived to recover more grain than old method, 0 otherwise
NHBR = 1 if farmer reported neighbor had used the machine, 0 otherwise
AGE = Age of head of household in years
MEQ = Number of male-equivalents
FUL = 1 if paddy provides more than 50% of farmer's income, 0 otherwise
SCH = Schooling in years

Farmers who perceived the economic advantage of the combine harvester (ECON) have a higher probability of adopting the machine than those farmers that did not. Hence the conclusion is that farmers in Muda are rational in their decisions in that they strive to reduce their cost of production whenever possible.

Calculating the conditional probability of adoption: an example

Let us now take a farmer at the means of those variables that are measured on an interval scale (FSIZE = 5.22, FMN = 3.18, AGE = 43.4, MEQ = 2.09, SCH = 3.97) (see Table 4) and calculate the probability of adopting a combine harvester given that the farmer is a full-time farmer, male, full-owner and who responded affirmatively to ECON, RCV and NHBR. Thus ECON = RCV = NHBR = OWN = FUL = 1. Hence the probability of machine adoption for this hypothetical farmer is obtained by substituting the values of the x_i's in the following equation:

$$\begin{aligned}\log\left(\frac{p}{1-p}\right) = 2\{ & -2.66 + .079x_1 - .031x_2 + .144x_3 \\ & + .0002x_4 - .078x_5 + .305x_6 \\ & + .126x_7 + 1.57x_8 - .0025x_9 \\ & - .005x_{10} + .462x_{11} + .015x_{12}\}\end{aligned}$$

or in this equation:

$$p\,(y_1 = 1 \mid x) = \left[1 + \exp\{-2(a + \sum_{i=1}^{12} b_i\, x_i)\}\right]^{-1}$$

Plugging those values of the independent variables we get:

$$p\,(y_1 = 1 \mid x) = 0.57$$

Thus the conditional probability that the "average" farmer with the given responses to the categorical variables will adopt the combine harvester is 0.57. To obtain the partial effect of any variable at its means on the probability of machine adoption we use the relationship:

$$\frac{\partial p}{\partial x} = bp\ (1-p)$$

For instance, in the case of farm size, x_1:

$$\frac{\partial p}{\partial x_1} = bp\ (1-p) = .158\ (.57)\ (1-.57)$$

$$= .158\ (.57)\ (.43) = 0.0387$$

This means that an increase of 1 *relong* in the farm size, increases the probability of machine adoption by 0.0387, *ceteris paribus*.

The elasticity, ξ, with respect to farm size (x_1) is given by:

$$\xi_1 = b\ (1-p)\ \bar{x}_1$$

$$= (.158)\ (.43)\ (5.22)$$

$$= 0.3546$$

The interpretation of this is that, an increase of one percent in the farm size, will increase the probability of adopting the machine by 0.3546 percent.

Summary of findings from logit analysis

The decision to use the combine harvester in Muda appears to be influenced to a large extent by the farm size, availability of the machine in an area, farmers' perception of the cost-reducing advantage

of the machine vis-a-vis traditional harvesting methods and whether paddy farming was a full-time occupation or not.

With double-cropping of paddy, there is great urgency in completing the harvesting operation on time in readiness for the next crop. This urgency naturally increases with the farm size. In addition, the calamity of unpredictable rain which could destroy the harvest may be another underlying reason for the importance of farm size in influencing the decision to use a combine harvester in Muda.

The evidence also indicates that adoption of the technology is contingent partly upon its availability. If a neighbor had used the machine, then this indicates that it was available in the area. As long as it is available, few obstacles are in the way to prevent farmers from using its service, other things equal.

The results also indicate the rationality of Muda farmers in that once an innovation is perceived to be cost-reducing, even though it may not be output-augmenting, the innovation will be readily acceptable. There were only a few farmers in Muda who would "knowingly waste resources", to quote Welch (1970).

The full-time farmer in Muda appears to be more inclined to use the machine than the part-time farmer. This is consistent with the belief that full-time farmers may regard paddy farming as a small business rather than a subsistence occupation; hence any improvement in technique of production "which saves the relatively more expensive factor is welcome."

A priori we expect a farmer facing a labor shortage in the household would tend to use the machine and those with ample labor would tend to behave differently. However the logistic analysis failed to provide sufficient evidence to support this expectation. Labor availability, as measured by the variable MEQ, turned out to have no statistical significance in "explaining" adoption. This implies that the so-called "labor shortage" in Muda is really "unwillingness" on the part of the available family labor to perform the harvesting operation. Thus, having the necessary labor is no guarantee that these labor will be utilized to do manual cutting and threshing of the paddy crop. Eventually this "idle" labor will probably migrate to urban employment as unskilled or semi-skilled workers.

Age appears to be of little consequence in the adoption of the new technology in the whole sample although two localities studied displayed contradictory, significant, results. In one locality, age had a positive influence while in the other it had a negative effect. This appears to be consistent with the conclusion reached by Rogers and Shoemaker (1971:185-86).

On the whole, pure tenants seem to have a greater tendency to adopt the new technology than pure owners or part-owners. We may explain this by the greater desire of tenants to reduce costs of production than any other group, since the rental on land constitutes a major portion of fixed costs on tenanted farms.

Factors affecting level of mechanization

To determine factors that might influence the level of mechanization, an OLS regression was run with the proportion of land harvested by machine as the dependent variable, which was regressed against the same set of explanatory variables as was used in the logit analysis.

Table 6 gives the results of this regression run. The independent variables altogether explain about 23 percent of the variation in the dependent variable. Variables that have relatively low OLS standard errors include farm size, schooling, perception of economic advantage, the neighborhood variable and the dummy variable relating to full-time farming. The signs of these coefficients appear to be consistent with *a priori* expectations. Thus as farm size increases, *ceteris paribus*, a greater proportion of the land will be harvested by machine. Furthermore, a farmer who sees the economic advantage of the machine is likely to harvest a greater proportion of his land by machine than another farmer who does not. It is also evident that farmers who reported having neighbors using the machine harvested a larger proportion of his land by machine. Full-time farmers also achieved a higher level of mechanization than part-time farmers.

Pattern of adoption over time

The diffusion of the combine harvester in Muda over time was analyzed by regressing the number of seasons the farmer had used the machine against the same set of independent variables. However, because

Table 6. Extent of mechanization in all FDAs

Variables	Coefficient	OLS standard error
FSIZE	.45E-2	.0036*
SCH	.51E-2	.0035*
OWN	.29E-2	.0260
TEN	.24E-1	.0278
FMN	.19E-2	.0063
SEX	.55E-2	.0420
ECON	.97E-1	.0213*
RCV	.25E-1	.0265
NHBR	.2518	.0204*
AGE	-.39E-3	.0009
MEQ	.35E-2	.0116
FUL	.52E-1	.0315*
CONST.	-.99E-1	

R^2 = .2446 $\bar{R}^2$ = .2339

$S_{\hat{y}}$ = .2817 N = 858

* Low standard errors

the dependent variable has a lower limit of zero for a large proportion of the respondents, the assumption of normality and homoscedaticity of the error term does not hold. Hence strict application of the t-test is inadmissible. However, the OLS coefficients and their standard errors are presented as crude estimates of the population parameters. Table 7 gives the OLS regression results.

The earlier adopters of the combine harvester were those farmers operating bigger farms, who were full tenants and who perceived the economic as well as technical advantage of the machine. The negative sign associated with the regression coefficient of FMN (the average parcel size) indicates that farmers operating bigger parcels adopted later than those operating smaller parcels. One possible reason for this perverse relationship between "earliness" and average parcel size could be the confounding effect of the farm size.

The institutional arrangement

The institutional arrangement that has emerged to cater to the spread of the combine harvester is the contractual system which is similar to the tractor contractual system. Under this system, a machine owner appoints a few trustworthy and respected farmers to act as his agents in the villages. These agents are often large paddy land owners who will make contacts with other farmers wishing to harvest their land by the combine harvester. For their services, these agents receive a commission ranging from US$3.47 to US$17.35 per hectare harvested. A broker could arrange as much as 200 ha. to be harvested by machine in a season, although an average broker achieved about 50 ha. in a season.

Table 7. Earliness of mechanization in Muda

Variables	OLS coefficient	OLS standard error
FSIZE	.4975E-1	.00612*
SCH	-.3819E-2	.00598
OWN	-.1488E-4	.04411
TEN	.7681E-1	.04718*
FMN	-.2447E-1	.01068*
SEX	-.3546E-1	.07135
ECON	.1062	.03616*
RCV	.8963E-1	.04500*
NHBR	.4340	.03463
AGE	-.1170E-2	.00151
MEQ	-.1899E-1	.01970
FUL	.5772E-1	.05343
CONST.	-.1218	

R^2 = .3166 $\bar{R}^2$ = .3068

$S_{\hat{y}}$ = .4783 N = 858

Total earnings from commission during the surveyed season ranged from US$37.50 to US$1,250 with a meanof US$381. Clearly, the new technology has meant an additional source of income to these commission agents.

Combine harvester ownership and operation

Based on information supplied by the 38 machine owners interviewed, by and large the machines were operated on a partnership basis. Nearly 70 percent of the owners reported a partnership arrangement involving from two to six persons.

All machines were bought on hire-purchase basis from internationally based firms having subsidiaries in Malaysia (Rayarappan, 1979, p. 26). Loans were obtained mainly from private lending institutions based in the township of Alor Setar. The interest rate charged was around 10 percent. Table 8 shows repayment schedule for loans extended by these lending institutions.

Economics of ownership

Jegatheesan (1978, personal communication) reported that the capital invested in purchasing a combine harvester (14 ft. cutterbar) was fully recovered in three harvesting seasons. Rayarappan (1979) made an in-depth study on the profitability of harvester ownership. Specifically, he made a cost-benefit analysis of the private ownership of the machine. Based on an assumed salvage value of 25 percent of the cost of the machine, an economic life of eight years, and a discount rate of 10 percent, an average annual income of M$55,000 per machine, etc. he calculated the net present value to be M$1,902, indicating that

Table 8. Repayment schedule for loans

	Brand	
	X (M$)	Y (M$)
Cash price	152,000	144,905
Down payment	52,000	38,000
Balance	100,000	106,000
Interest (@ 20% for 24 months)	20,000	21,000
Balance in 24 monthly instalments	120,000	127,000
Monthly instalment	5,000	5,300

Source: Rayarappan (1979, p. 27)

the 'project' of owning the machine was indeed profitable (US$1 = M$2.13). The B/C ratio was found to be 1.04 (Rayarappan, p. 58). Rayarappan (p. 57) also calculated the internal rate of return of combine operation and the figure of 12.44 percent was obtained. Rayarappan (p. 61) also found the annual break-even area to be 227 ha. Since on the average, a machine could harvest about 375 ha. a year, the excess over the break-even hectarage should result in profits. Rayarappan (p. 61) estimated these profits to be M$11,490 per machine per annum.

Machine servicing and maintenance

Servicing of the machines is provided by the machine dealers as well as other private foundries found all over the Muda area. Rayarappan (p. 38) reports that some contractors complained about the long delay (sometimes as long as six months) in obtaining spare parts. They were also unhappy with diesel "rationing" practised by the sundry shop owners who acted as diesel agents around the Muda area.

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