Journal of Philippine Development
Number Twenty-One, Volume XII, No. 1, 1985

EFFECTS OF AGRICULTURAL MECHANIZATION ON FARM INCOME PATTERNS

Pilar C. Lim

INTRODUCTION

The introduction of new agricultural strategies has brought changes in the level and composition of resource use. Among these inputs is agricultural machinery. Mechanization of agricultural land has grown rapidly in the Philippines since the 1970's, particularly in the major rice producing areas such as Central Luzon and Laguna. Increased use of mechanical land preparation and threshing attests to the farm-level profitability of this new technology. It is important to determine the impact of mechanization on the overall level of living and welfare in these rural areas.

Mechanization, along with other new technology, has induced an upward shift in production by increasing output and decreasing costs. Furthermore, the cost of producing and using tractors and threshers has been reduced, thus encouraging higher adoption rates. The overall effect of increased production and reduced costs is increased incomes, assuming the price of rice remains constant.

On the other hand, mechanization, by its capital-intensive nature, has been divisive in its impact. Although incomes have increased in general, the large farmers and owners of mechanical power have been the prime beneficiaries. This, together with inequality in rates of adoption, has tended to produce greater inequality in the distribution of income.

This study attempts to measure the importance of mechanization as a source of income variation using cross-sectional results from the

Senior Research Assistant, Economics Section, Agricultural Engineering, The International Rice Research Institute, Los Baños. Paper presented at the Workshop on the Consequences of Small Rice Farm Mechanization Project, December 1-2, 1983, Develop-Academy of the Philippines (DAP), jointly sponsored by the National Economic and Development Authority (NEDA), Philippine Institute for Development Studies (PIDS), Ministry of Agriculture (MA), and International Rice Research Institute (IRRI).

Consequencues of Small Rice Farm Mechanization survey. In particular, it explores income differences across several dimensions including irrigation and mechanization. To permit a systematic analysis of the income impact of mechanization, the effect of confounding factors must be removed.

A stratified sample of 320 rice farm households from eight villages in Cabanatuan and Guimba was used. Stratification is by irrigation (rainfed, irrigated one-crop, irrigated two-crop) and mechanization (animal, two-wheel tractor, and four-wheel tractor). Irrigation is based on the type of water control. Mechanization is based on the type of power used for plowing.

Owing to gross shifts in type of power used from the wet season 1979 to the dry season 1980, a poststratification scheme was devised. For analysis by crop year, mechanization classes are categorized into the following: nonmechanized, partially mechanized, and fully mechanized. Rice farm households which used only animal power for the entire crop year were considered non-mechanized while those which used machines for land preparation during the crop year were defined as fully mechanized. The partially mechanized households included those which shifted from animal to machine or vice versa during the year. Irrigation levels are rainfed, pump, and gravity-irrigated. Pump irrigation is from deep wells and occurs in an otherwise rainfed area.

TABULAR ANALYSIS OF INCOME

The income measure used in this study is total household income which is the sum of on-farm, off-farm, and nonfarm earnings. On-farm income represents returns to crop and livestock production on the farmer's own farm. Off-farm earnings include income derived from agricultural work on other farms. Nonfarm earnings are derived from nonagricultural work such as services, commerce and industry or the practice of a profession.

Design-unbiased estimation procedures were used in the calculation of cell means. The method considers the sampling design to correct for the bias that is a result of the shifting across cells and the postsurvey stratification used. The procedure essentially involves estimating the total for a variable x in the subpopulation and the total number of units in the subpopulation. From the sample data, a

conceptual population is constructed which approximates the original population (see Lim 1982).

In the wet season, other things being equal, gross differentials indicate a 154 per cent income advantage for mechanized over nonmechanized farms, a 2 to 1 ratio between partially mechanized and nonmechanized farms and a slight advantage of ₱289 for mechanized over partially mechanized farms (Table 1). Using the irrigation strata, gravity-irrigated farms show an income superiority of ₱4,020 compared with ₱1,502 for rainfed and ₱2,544 for pump-irrigated farms, respectively. Cross-classifying by irrigation, the incomes of mechnized farms are higher than the nonmechanized at any given level of irrigation.

TABLE 1
MEAN HOUSEHOLD INCOME, BY FARM TYPE AND SEASON, IN EIGHT VILLAGES OF CABANATUAN AND GUIMBA, NUEVA ECIJA, CROP YEAR 1979/80

Irrigation	*Season*	*Mechanization class*			
		Non-mechanized	*Partially mechanized*	*Mechanized*	*All*
		Pesos			
Rainfed	WS	1,302	1,910	3,951	1,502
	DS	1,885	2,301	673	2,007
	WS-DS	3,187	4,211	4,623	3,509
Pump	WS	2,018	3,655	–	2,544
	DS	3,110	4,762	–	3,641
	WS-DS	5,128	8,417	–	6,185
Gravity	WS	1,821	4,474	3,732	4,020
	DS	3,521	7,277	6,485	6,752
	WS-DS	5,342	11,751	10,217	10,772
Mean	WS	1,469	3,446	3,735	2,662
	DS	2,204	5,185	6,415	4,151
	WS-DS	3,673	8,631	10,150	6,813

Source: Consequences of Small Rice Farm Mechanization (CSRFM) data.

Dry season incomes are generally higher than wet season incomes. Without cross-classifying, income differentials have the same trends as the wet season data, with mechanized farms having a 191 percent advantage over their nonmechanized counterparts. The incomes of the partially mechanized and mechanized classes are consistently higher than those of nonmechanized farms for the pump and gravity-irrigated farms though not for the rainfed class. This last result appears because only a single household belonged to the rainfed mechanized class after poststratification. Hence, inferences regarding it are extremely hazardous.

The crop year income differences among the mechanization classes are even more pronounced. The mechanized farms show a 176 per cent differential advantage over the nonmechanized farms. Though not significantly different from the mechanized farms, the partially mechanized farms earn less. At given levels of irrigation, the partially mechanized and fully mechanized households show consistently higher mean incomes than the nonmechanized farms. Comparing irrigation classes, as expected, the gravity-irrigated farms perform better than pump-irrigated and rainfed farms. The benefits of an assured water supply are clearly seen.

DISTRIBUTION OF INCOME

Tables 2 and 3 illustrate the differences in income inequality among the mechanization classes. Both household incomes and per capita incomes are distributed unequally. The modal household income bracket is ₱2,000-3,999 for both nonmechanized and partially mechanized households while the modal bracket for mechanized households appears to be ₱10,000-11,999. The bulk of the nonmechanized farm households are clustered in the three lowest income groups (Table 2). About 80 per cent of the nonmechanized households have an annual per capita income of less than ₱900 while more than 60 per cent of the mechanized households are characterized by an annual per capita income of over ₱1,300 (Table 3). Figure 1 shows the cumulative income distribution for each mechanization class. The vertical axis is the cumulative probability that household income is less than or equal to an amount indicated on the horizontal axis. The cumulative income distribution of the sampled population of nonmechanized households rises steeply, which is strongly indicative of income inequality. The flat portion of the nonmechanized

TABLE 2
DISTRIBUTION OF RICE FARM HOUSEHOLDS ACROSS ANNUAL INCOME GROUPS, BY MECHANIZATION CLASS, IN EIGHT VILLAGES OF CABANATUAN AND GUIMBA, NUEVA ECIJA, CROP YEAR 1979/80

Annual household income group (In pesos)	*Mechanization class*		
	Nonmechanized	*Partially Mechanized*	*Mechanized*
		per cent	
Below 0	7.0	1.8	3.1
0-1,999	28.3	16.2	13.6
2,000-3,999	33.9*	20.3*	6.8
4,000-5,999	11.2	13.0	9.3
6,000-7,999	8.6	8.9	7.4
8,000-9,999	3.0	8.8	11.1
10,000-11,999	3.7	6.2	19.1*
12,000-13,999	1.9	4.7	7.4
14,000-15,999	0.5	6.8	3.1
16,000-17,999	1.3	4.1	6.8
18,000-19,999	0.0	2.9	1.2
20,000 & over	0.5	6.2	11.1

*Modal income bracket.
Source: CSRFM Data.

curve implies that a small percentage of households receives the highest incomes. In comparison, the cumulative distributions of the partially mechanized and mechanized classes rise relatively uniformly, denoting less income inequality.

The differences in income inequality can be explained by the fact that most mechanized farms are situated in Cabanatuan. Cabanatuan is predominantly irrigated and mostly mechanized. It has a wider resource base and a host of suitable technologies that facilitate income generation. In contrast, nonmechanized households are located in Guimba which is predominantly rainfed and less well-endowed than Cabanatuan. As a result, it is uncertain whether income inequality can indeed be attributed to mechanization or to a conglomerate of other factors.

TABLE 3
DISTRIBUTION OF RICE FARM HOUSEHOLDS ACROSS ANNUAL PER CAPITA INCOME GROUPS, BY MECHANIZATION CLASS, IN EIGHT VILLAGES OF CABANATUAN AND GUIMBA, NUEVA ECIJA, CROP YEAR 1979/80

Annual per capita income group (In pesos)	*Mechanization class*		
	Nonmechanized	*Partially Mechanized*	*Mechanized*
		per cent	
Below 100	13.3	5.3	9.1
100-299	19.4	15.6	7.9
300-499	23.7	8.5	6.1
500-699	9.3	8.5	2.4
700-899	13.6	5.9	0.0
900-1,099	5.1	14.1	3.0
1,100-1,299	4.2	9.1	7.3
1,300-1,499	4.8	5.6	10.9
1,500-1,899	2.1	7.1	14.5
1,900-2,299	2.4	6.8	12.7
2,300-2,799	0.5	4.7	12.7
2,800-3,199	0.3	0.6	5.4
3,200 & over	1.3	8.2	7.9

Source: CSRFM data.

Income and Farm Size

An assessment of the income impact of mechanization is not complete unless we consider the farm size issue. Rice farm households were allocated to farm size categories on the basis of area cultivated per season. The size classes used were: below 1.00 ha., 1.00-2.49 ha., and 2.50 ha. and over. Since there exists a fairly active land rental market, not all farms stay in the same category each season. Tables 4 and 5 give mean incomes by farm size and mechanization class. In both the wet and dry seasons, farms below 1.00 ha. showed no significiant differences among the mechanization classes. The distinction between "1.00-2.49 ha." farms and "2.50 ha. and over" farms is accompanied by a significant difference between nonmechanized and their mechanized counterparts. No

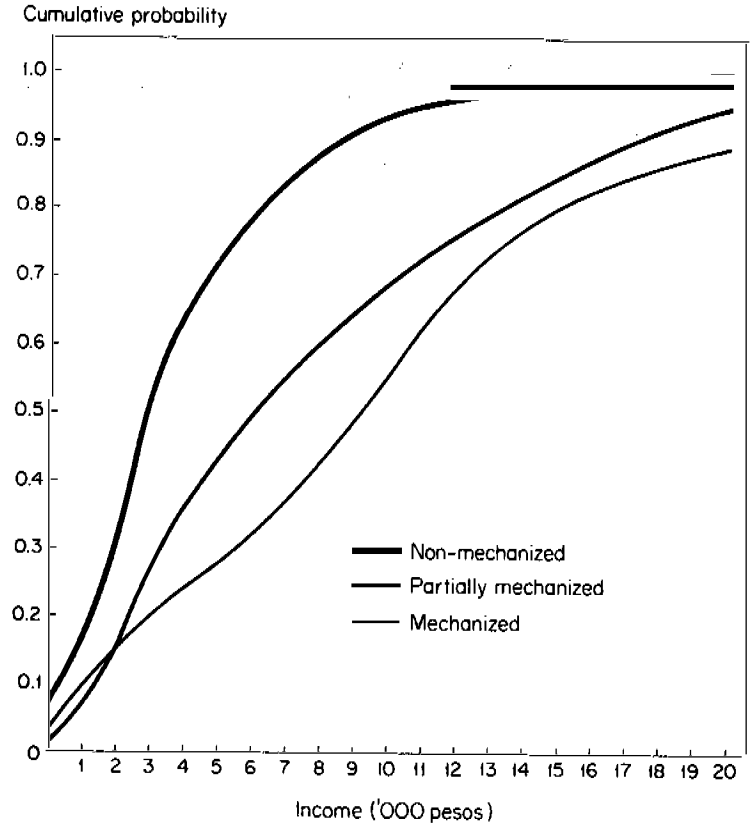

FIGURE 1
CUMULATIVE INCOME DISTRIBUTION BY MECHANIZATION CLASS

difference appears to exist between partially mechanized and fully mechanized households. Whether this is evidence of a mechanization effect is not definitive. In general, increasing farm size translates into higher incomes for all mechanization classes.

On a per capita basis, the same mechanism is at work. For farm sizes over one hectare, the partially mechanized and fully mechanized households retain a significant per capita income superiority of as much as 171 per cent over the nonmechanized households. This suggests, among other things, that the effect of mechanization on income is significant for fairly large farm sizes. There seem to exist economies of scale in the use of machines on these farms.

TABLE 4
MEAN HOUSEHOLD AND PER CAPITA INCOME, BY FARM SIZE, MECHANIZATION CLASS AND SEASON, IN EIGHT VILLAGES OF CABANATUAN AND GUIMBA, NUEVA ECIJA, WET SEASON 1979, DRY SEASON 1980

Farm size class	*Mechanization class*					
	Nonmechanized		*Partially mechanized*		*Fully mechanized*	
	Wet season	*Dry season*	*Wet season*	*Dry season*	*Wet season*	*Dry season*
	Pesos					
Below 1.00 ha.						
Household income	1,470	1,868	1,320	2,225	962	1,970
Per capita income	280	308	226	348	262	515
	(31)	(277)	(31)	(122)	(12)	(15)
1.00-2.49 ha.						
Household income	883	3,150	2,695	4,825	2,417	4,256
Per capita income	167	542	468	791	450	795
	(203)	(82)	(170)	(146)	(71)	(70)
2.50 ha. and over						
Household income	2,320	3,748	4,844	10,847	5,336	9,172
Per capita income	371	576	744	1,298	840	1,562
	(140)	(13)	(141)	(74)	(81)	(80)

Note: Figures in parentheses are estimated population numbers.
Source: CSRFM data.

Multiple Covariance Analysis of Income

Differences between household incomes are confounded by many factors. The analysis can be improved if these confounding factors can be partitioned out in advance. Analysis of covariance is suited for this purpose. It eliminates the effect of the confounding factors by regressing income levels against them and considering the residuals. If these residuals vary significantly from class to class, this is evidence of a mechanization effect distinct from the dependence of income on the confounding factors.

Apart from possible irrigation and mechanization effects, household income is likely to depend on factors such as household size. Ceteris paribus, one would suspect that households with large families would have higher incomes than those with smaller families. Cropping intensity may also explain income variation as it measures the number of times a parcel of land is planted during the year. Differences in area cultivated must also be considered. In general, larger farm sizes translate into higher incomes. Finally, nonfarm earnings are included to account for income variation resulting from nonagricultural activities. There is reason to believe that nonfarm earnings may not be influenced by mechanization and could be an important source of inequality in income distribution.

TABLE 5
MEAN ANNUAL HOUSEHOLD AND PER CAPITA INCOME, BY FARM SIZE AND MECHANIZATION CLASS, IN EIGHT VILLAGES OF CABANATUAN AND GUIMBA, NUEVA ECIJA, CROP YEAR 1979/80

Farm size class	*Mechanization class*		
	Nonmechanized	*Partially mechanized*	*Fully mechanized*
	Pesos		
Below 2.00 ha.			
Household income	2,828	3,274	2,924
Per capita income	501	545	844
	(158)	(59)	(13)
2.00-4.99 ha.			
Household income	3,907	6,615	6,620
Per capita income	618	1,049	1,240
	(172)	(189)	(70)
5.00 ha. and over			
Household income	5,930	15,970	14,309
Per capita income	1,076	2,265	2,365
	(43)	(95)	(82)

Note: Figures in parentheses are estimated population numbers.
Source: CSRFM data.

It is also believed that the regression of income against factors within different irrigation and mechanization classes does not produce estimates of a common within-class regression. Hence, the model used estimates of separate slopes for the ovariates within each level of class variables. The class variables for the analysis are irrigation and mechanization and the covariates are the factors cited above. The dependent variable in the study is the natural logarithm of household income expressed in pesos. The necessity for transforming the data arises because the income variable is nonnormal, and nonnormality invalidates the standard tests of significance. Only households with positive incomes were considered for the analysis.

Table 6 provides the results of the multiple covariance analysis for all farms. The marginal *F*-values which evaluate the individual predictive power of each effect adjusted for the effects of other variables are indicated. Significant irrigation and mechanization effects are evident after correcting for the effect of the covariates.

Cropping intensity appears significant in explaining variation in the logarithms of income. Nonfarm earnings also appear significant and the absence of interaction with either irrigation or mechanization suggests a parallel relationship between incomes and nonfarm earnings from class to class.

TABLE 6
MARGINAL F-VALUES FOR MULTIPLE COVARIANCE ANALYSIS ON THE NATURAL LOGARITHMS OF ANNUAL HOUSEHOLD INCOME IN EIGHT VILLAGES OF CABANATUAN AND GUIMBA, NUEVA ECIJA, CROP YEAR 1979/80

		Irrigation	*Mechanization*
Class effects		3.5*	11.6*
Confounding factors		*Interactions*	
Cropping intensity	4.3*	<1	2.2
Farm size	29.0**	13.4**	6.2**
Nonfarm earnings	24.1**	<1	2.0
Household size	15.1**	7.4**	4.7**

Note: **Significant at 1% level.
*Significant at 5% level.

The household size component is also significant and interacts with mechanization and irrigation. Again, the interaction with mechanization implies varying effects on income for different household sizes. Larger household sizes possibly denote more intensive employment of family labor in farm and off-farm activities. The presence of mechanization could enhance the income generating capacity of a fairly large household. A mechanized farm appears to require very much less family labor input as compared with a non-mechanized farm. If household size represents the household labor available, the suggestion can be put forth that mechanization requires fewer labor inputs, and hence releases labor to be used for other work. The extent of the latter effect has yet to be assessed.

Of expected significance is farm size which is really a proxy for wealth, aside from being a management variable. Area cultivated interacts significantly with irrigation and mechanization. The interaction suggests that the magnitude of the mechanization effect on income is not the same for farms of different sizes. This supports the hypothesis of economies of scale associated with mechanized farming. Tables 4 and 5 also indicate a similar result, as no significant differences were detected across mechanization classes for small farm sizes. There may be few mechanization effects for small farms and considerable mechanization effects for larger farms. This suggests a threshold level above which mechanization translates into greater profits or higher incomes. It would be interesting to determine this threshold level which ensures profitable mechanization.

Finally, after removing the confounding effect of variables that affect incomes singly and jointly, income differences are still substantial since the model has not accounted for a substantial portion of the variability in the logarithms of income. The remaining portion unaccounted for by the model could arise from any one of a number of reasons. Differences could reflect price variations since prices of inputs and other goods are, in general, higher in Guimba than in Cabanatuan. Although similar wages are paid for similar services so that the labor market appears in approximate equilibrium, wages in Cabanatuan are a little higher than in Guimba. Lastly, measurement errors, in addition to purely stochastic variability, could have been contained in the residuals.

To quote from Lipton: "Income data are notoriously difficult to collect, and are not very reliabile unless gathered during a considerable period of residence in the village over a time-span which

allows for seasonal fluctuations. Few village surveys take such precautions, hence the value of much income information is severely reduced."

SUMMARY AND CONCLUSIONS

The paper presents statistical results to evaluate the income impact of mechanization.

The findings have policy implications. The present research supports the view that mechanization has had an effect on income variation. At the micro level, the effects are confined to certain levels of farm size. Household size as a gauge of family labor input interacts with mechanization in its income effect. Mechanization requires fewer labor inputs and presents the potential for releasing labor which can be used for other work. Cropping intensity contributes significantly in explaining income variation across the sample of farms but fails to do so when standardized for irrigation technique. Farm size as a proxy for wealth is most important. The significant farm size/mechanization interaction suggests that, beyond a certain farm size, mechanization effects are more pronounced. To make mechanization profitable, farmers may have to consolidate landholdings or cooperatives may have to be formed to realize the economies of machinery.

The low income levels, especially in the case of the non-mechanized households, exacerbate the problem of lack of access to credit, a major constraint in the adoption of new technologies, particularly capital intensive inputs such as most farm machines. An attempt should be made to supply new production inputs plus credit, marketing, extension, and education relating to new technologies, particularly in less well-endowed areas. This would enable small farmers to benefit as well from new technology, thereby reducing income inequality.

The analysis as presented here is only exploratory. To proceed to definite policy prescriptions requires a more dynamic model of income. In place of the conventional univariate analysis of income, more realistic insight[5] concerning income inequality could be gained with the use of multivariate analysis employing several dependent variables such as production and employment variables aside from income. Multivariate analysis would utilize the relationship among the dependent variables and incorporate this in the analysis of

possible mechanization effects. Another direction for research on the income issue might include factor share analysis to take account of the distribution of ownership within each mechanization class of land, labor, and capital in addition to intermediate inputs.

REFERENCES

Cornell, J., and Lipton, Michael. "Village Surveys Rearing on Labour Utilization: Scopes and Aims." In *Assessing Village Labor Situations in Developing Countries.* Delhi: Oxford University Press, 1977.

Lim, P.C. "Estimation and Significance Test Concerning a Subpopulation Mean Using Survey Data." Paper presented at the Third National Convention on Statistics, December 13-14, 1982, Philippine International Convention Center, Manila.

Yotopoulos, P., and Nugent, J. "Income Distribution, Poverty and Dualism." In *Economics of Development.* New York: Harper and Row Publishers, 1976.