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ARTICLES

Modern Seed-Fertiliser Technology and Adoption of Labour Saving Technologies in Rice Production: The Tamil Nadu Case

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INTRODUCTION

Modern rice varieties grown with fertiliser and chemicals have provided the major source of the increase in rice production in Tamil Nadu since the late 1960s. Yet, as much as about 30 per cent of rice area in unfavourable production environments is still planted to traditional varieties. Accumulated evidence indicates that environmental factors, especially irrigation and water control, represent the major constraints to the wider diffusion of modern rice technology (Barker and Herdt, 1985). Now, the fear has been widely expressed that the modern rice technology, due to differential adoption rates, accentuates the income disparities between the favourable and unfavourable areas. For example, in Tamil Nadu State, the areas which have a higher proportion of rice area irrigated and higher levels of fertiliser use and modern variety (MV) adoption rates, exhibit higher yields. In contrast, in areas where there is uncertainty in the availability of rain water, less reliable irrigation, poorly developed water control, lower rate of MV adoption, and consequently low use of fertilisers, the yields are observed to be lower.[1] In Tamil Nadu, the availability of irrigation water from canal and possession of pumpsets emerged as one of the key factors leading to higher rate of MV adoption and higher yields among all groups of cultivators (Prahladachar, 1983). It is observed that the spread of modern varieties (MVs) was followed by wider adoption of labour saving technologies, *i.e.*, tractors, threshers and direct seeding (Jayasuriya and Shand, 1985). Thus even though MV adoption increases labour use per hectare by increasing labour requirements for crop-care and harvesting, if MVs induce mechanisation and direct seeding, the net effect may well be labour saving, thereby adversely affecting the well-being of poor landless households. Did this happen in Tamil Nadu? One more issue, which is widely recognised, is the degree of complementarity among the various technologies which have been adopted over the years.

There have been many case studies on the adoption and impact of modern varieties, but most of them were conducted in favourable and progressive regions where the modern rice technologies were widely adopted. Relatively, little amount of research has been done on the adoption rates, determinants of adoption, complementarities among the technologies and the impact of technology across production environments comprising both favourable and unfavourable areas. This paper attempts to examine factors affecting adoption rates of MVs and explore their effects on fertiliser use and rice cropping intensity as well as adoption of labour saving technologies across different rice production environments.

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PRODUCTION ENVIRONMENT AND SAMPLE VILLAGES

The experience has reinforced the fact that the irrigation water has emerged as the most crucial constraint on all agricultural production activities. When the guaranteed water supply is restricted to a tank of uncertain reliability, land that can be regarded as potentially suitable for intensive and progressive agriculture is limited. In adapting to new economic opportunities in agriculture, the farmers have shown a strong sense of the importance to environmental constraints (Bradnock, 1983). Keeping in view the production environment as a key variable, the present analysis is undertaken covering a cross-section of 50 villages representing five different rice production environments in Tamil Nadu. The major variations in rice production environments could be accounted for by differences in sources of irrigation, their reliability and associated degree of water control. The five production environments were rainfed-tank irrigated, tank irrigated, tank-well irrigated, river-canal irrigated, and reservoir-canal irrigated rice areas. The rainfed-tank environment is located in a coastal area where semi-dry seeding of paddy with initial rains is common but subsequently the crop is irrigated by rain water stored in irrigation tanks. In the second environment, the rainfall is more reliable and storage of rain water in tanks is well established. The third situation, tank-cum-well irrigated environment, is a classic case of conjunctive use of tank and well irrigation for rice production. The supplementing nature of well irrigation imparts a high degree of reliability of irrigation. The fourth environment comprises the Cauvery river-canal irrigated delta region, the major rice growing region of Tamil Nadu State. The fifth environment characterised by a highly reliable water supply from a modern reservoir is most conducive for rice production, and is supported by good soils and adequate drainage. Thus the rainfed-tank irrigated situation represents the most unfavourable environment and the modern reservoir-canal irrigated area represents the most favourable environment, and other rice production environments lie in the order as listed above, between these two extremes.

The distribution of sample villages among the five major production environments was predetermined to be equal. The sampling procedure was, in the first stage, to identify and select purposively two adjoining taluks in each district, typical of the production environments. In the next stage of sampling, a random selection of five villages in each taluk was effected. Thus we have sampled a total of ten villages in each environment. The study district included Ramanathapuram, Chengalpattu, North Arcot, Thanjavur and Coimbatore. In the village survey, the village level data on technology adoption, fertiliser use, productivity, wage rates, paddy prices, etc., pertaining to 1987-88 as well as socio-economic and physical characteristics were obtained through interviews with village leaders, knowledgeable farmers and development workers in each village. Besides, the Assistant Agricultural Officer and Village Administrative Officer provided required information from their records. In addition, we also obtained information on technology adoption in 1970 and 1980 in order to gain a historical perspective on the state of current technology.

Table I shows selected key characteristics of sample villages by production environments. The man-land ratio is lower in unfavourable rainfed-tank and tank irrigated areas, and high in areas endowed with more reliable irrigation. The population growth is higher in favourable areas and, apparently, it is due to larger net in-migration. Opportunities for higher income and employment in favourable areas act as a strong pull factor, which leads to more concentration of population. The labour migration to favourable areas may tend to

TABLE I. SELECTED CHARACTERISTICS OF SAMPLE VILLAGES

Characteristics	Production environments				
	Rainfed-tank	Tank	Tank and well	River-canal	Reservoir-canal
(1)	(2)	(3)	(4)	(5)	(6)
Man-land ratio	3.40	7.10	10.80	15.80	12.90
Farm size (ha)	1.37	1.68	0.79	1.54	0.98
Irrigation intensity (per cent)	101	114	152	163	171
Cropping intensity (per cent)	100	116	136	165	165
Rice area to gross cropped area (per cent)	72	65	48	77	40

equalise the wages across regions thus reducing the regional income disparities. The irrigation and cropping intensities, as one expects, are higher in favourable areas. However, the farm size and the proportion of rice area do not seem to show any conceivable pattern across production environments, indicating that the degree of favourableness across villages are not influenced by farm size and proportion of rice in gross cropped area.

ANALYTICAL FRAMEWORK

The technology adoption was examined by *(i)* looking at the trends in adoption of yield increasing and labour saving technologies for the period 1970 to 1987 and *(ii)* estimating technology adoption functions for different technologies. The data on adoption levels during 1970 and 1980 may be less reliable due to recall bias. This is only to gain an idea on the trends in the adoption rates. Care was taken to verify the data given by the villagers with the records maintained at the office of Agricultural Development Officers. Further, the results of some of the earlier studies (Ramasamy and Rajagopalan, 1973; Farmer, 1977) and data collected under the scheme, "Cost of Cultivation of Principal Crops" since 1970 covering all the regions of Tamil Nadu were cross-examined to confirm the results obtained by this approach. The yield increasing technologies are the ones, which by adopting them, will contribute positive increments to the yield. MVs, fertilisers and plant protection chemicals are considered as yield increasing technologies in the present study. This is land-augmenting type which relaxes the land constraint.

The labour saving technologies refer to the technologies which reduce the levels of employment of human labour in rice production. In this case, there exists a substitutability between the resources. The labour saving technologies, considered in this study, are the adoption of tractors, mechanical threshers and direct seeding. Complementarity may occur between the technologies. The adoption of MVs may have a positive influence on use of fertilisers. MVs may also speed up the tractorisation because short duration nature of MVs will increase the cropping intensity which may, in turn, require tractor services to quicken the operations such as land preparation in between seasons. Hence, an attempt is made here to examine the relationships between different technologies.

Adoption functions were estimated to analyse the effects of village specific environmental and market factors broadly determining the profitability of the new technology, the economic conditions as reflected in relative prices of inputs and outputs, and the institutional structures manifested in farm size and tenure patterns. The environmental variables include irrigation intensity (IRIG), which is defined as the ratio of gross irrigated to net irrigated area of the village, and the regional dummies for the five environments (RAIN-TAN, TANK, TAN-WELL, RIV-CAN, RES-CAN). Apparently, the irrigation intensity and regional dummies are the indicators of the well-being of the villages. TAN-WELL was kept as control dummy.

The socio-economic variables specified in the adoption functions are farm size (FARSIZE), literacy (LITERACY), paddy price (PRICE), area under share cropping (TSCAREA), market distance (MARDIS), input prices, *viz.*, tractor rent (TRACRENT), thresher rent (THRERENT) and bullock wage (BULLWAGE), and production risk (RISK). The degree of risk in agricultural production varies considerably across villages. Consequently, risk variable will affect the adoption rates of modern rice production technologies. Risk was measured as the number of droughts[2] which occurred in each of the sample villages in the ten years preceding 1987. It is widely considered in the tenancy literature that share tenancy deters the adoption of new technology partly because share tenant may receive only a portion of productivity gains and partly because share tenancy is allocatively inefficient due to the disincentive effect of output sharing on tenant's work effort (Hayami and Otsuka, 1991). Thus the tenure was included in the equation. Since the observational unit, the village, is a relatively small and geographical area, purchased input and output prices were assumed exogenous. For the villages under investigation, wage rates were also assumed to be exogenous since they are largely equalised due to inter-regional labour migration (Ramasamy *et al.*, 1989). The adoption functions were estimated for MVs, fertilisers, tractor and thresher technologies.

MVs increase land productivity by raising yield per hectare per season and by increasing cropping intensity, which will be possible due to its shorter growth duration and photoperiod insensitivity. Hence, we analysed the impact of modern rice technologies on productivity by estimating rice yield and rice cropping intensity functions. The model specified to explain the variations in yield and rice cropping intensity, was essentially the same as in the MV adoption function except for the use of their adoption rate (MVs) as an explanatory variable. This procedure may be justified by the assumption of recursive system. The OLS procedure was used to estimate yield and rice cropping intensity equations.

The two-limit probit regression method developed by Rosett and Nelson (1975) was used to explain the rates of technology adoption. This model falls under the broad category of limited dependent and qualitative variables in econometrics. The preference of this model is justified, for the value of dependent variable can be observed in only some of the ranges. As against the tobit model, a censored normal regression model, which accommodates the specification of either lower or upper bound, the two-limit probit method is censored in both tails. With the technology adoption rates expressed either as a percentage of area or farmers (from 0 to 100) adopting technology, the method becomes handy to deal this kind of limited quantitative variable. This method that uses just the number of observations at the limits $L1i$ and $L2i$ and the number of observations between the limits will give consistent estimates of the parametres (Maddala, 1983). The model was estimated using the 'LIMDEP' econometric package developed by Greene (1985).

TECHNOLOGY ADOPTION

Yield Increasing Technology

The probability of adoption of a new technology will depend on the difference in profitability between the new and old technologies. The farmers' preference for high-yielding MVs of rice suggested that the level of adoption could be related to the income advantage achieved from improved yields of MVs over the traditional varieties. Trends in the adoption of yield increasing technologies such as MVs, use of fertilisers and plant protection chemicals and yields by production environments are presented in Table II. It is seen that, in the early phases of spread of technologies, no significant variations existed in the adoption rates across production environments. But the adoption of these yield increasing technologies were rapid and almost complete in the eighties in the favourable environments such as river-canal and reservoir-canal areas. Consequently, the average yield increase in rice has been very impressive in Tamil Nadu with the adoption of MVs and associated

TABLE II. TRENDS IN ADOPTION OF YIELD INCREASING TECHNOLOGIES AND LEVELS OF FERTILISER USE AND RICE CROPPING INTENSITY

Parameters	Production environments				
	Rainfed-tank	Tank	Tank-well	River-canal	Reservoir-canal
(1)	(2)	(3)	(4)	(5)	(6)
Area with MVs (per cent)					
1970	21	31	32	35	31
1980	43	50	92	85	87
1987	66	72	95	100	100
Farmers adopting chemical fertilisers					
1970	27	32	26	36	38
1980	41	44	95	79	66
1987	63	65	100	100	93
Farmers adopting plant protection chemicals (per cent)					
1970	22	21	24	15	27
1980	36	33	89	63	50
1987	62	63	100	100	79
Yield (tonnes/ha)					
1970	2.8	3.0	3.2	3.5	3.7
1980	3.0	4.2	4.7	4.8	5.7
1987	3.8	4.3	5.0	5.6	6.8
Fertiliser use:NPK nutrients (kg /ha)					
1987	70	62	158	163	188
Rice cropping intensity[a] (per cent)					
1987	100	100	164	151	195

a. Number of crops grown in a year in rice lands.

technologies. The major contributors for yield increases were identified as MVs, fertilisers and water control (Hazell and Ramasamy, 1986). Apparently, the yield increasing technologies were favoured in areas with assured and controlled water. As to be expected, the percentage of farmers using fertilisers and chemicals closely follow the pattern of MV adoption as the yield response of fertiliser is much higher with MVs. Fertiliser application in terms of sum of NPK was about 188 kg per ha in the favourable reservoir-canal irrigated areas but about 70 kg in the unfavourable rainfed-tank irrigated areas and about 158 kg. in the middle order tank-well irrigated areas in 1987. Chemical control of pests and diseases is also widely adopted in favourable villages as compared to unfavourable villages.

Land Productivity

As a consequence of the differential adoption of the MV-fertiliser technology, significant yield differential has emerged across production environments. The gains of MVs, however, were smaller in less favourable environments, such as rainfed and tank irrigated rice areas with less assured water supply. In fact, the adoption rates of MVs in these two areas were 66 per cent and 72 per cent respectively, as against 100 per cent in other three favourable environments in recent periods. By 1987, the yield difference has widened between favourable and unfavourable environments (Table II). Since MVs have shorter growth duration and are photoperiod insensitive, they are expected to increase not only yield per hectare but also rice production per year through higher cropping intensity. The rice cropping intensity is higher in tank-well, river-canal and reservoir-canal irrigated favourable areas. It seems reasonable to hypothesise that variables reflecting technical superiority are relatively more important than socio-economic factors in explaining cross-sectional differences in the long-run equilibrium adoption of MVs, demand for fertiliser and increases in yields and rice cropping intensity.

Labour Saving Technology

A major question addressed by this paper is whether and, to what extent, the adoption of MVs caused adoption of labour saving technologies. The adoption of MVs leads to yield increases and helps crop intensification, which raises the demand for human and bullock labour. The mechanical technology emerges as a competing input which is cheaper, less hazardous and time saving. The spread of MVs may, thus, pave the way for increased mechanisation. But our results do not support this reasoning. Our village level data show an increase in adoption rate of tractors, mechanical threshers and direct seeding between 1970 and 1987 (Table III). In the case of tractors, adoption rates are lower than the corresponding rates of MV adoption, even though use of tractors is more pronounced in favourable environments. The rates of adoption of individual technologies do not show perceptible trends. For example, in tank-well irrigated environment, the use of tractors is very low whereas the threshers could make a dent. In river-canal irrigated areas, the mechanical threshers are not popular. The direct seeding is seen to be adopted to the extent of about 60 per cent in semi-dry situations of rainfed-tank and tank irrigated situations where the inadequacy of water at the time of sowing compels the farmers to adopt direct seeding, which requires less time and labour for crop establishment. Although the spread of MVs largely coincided with the increased adoption of mechanical technologies, comparisons of adoption levels between the two types of technologies by production environments do not strongly indicate that MVs caused the wider adoption of tractors, threshers and direct seeding. Evidently, MV adoption is not a major cause of adoption of labour saving technology. In another study, Duff (1978) reports that there is little evidence to indicate a strong causal relationship between the adoption of MVs and mechanisation, particularly tractors.

TABLE III. TRENDS IN ADOPTION OF TRACTORS, MECHANICAL THRESHERS AND DIRECT SEEDING

(per cent of farmers)

Parameters	Production environments				
	Rainfed-tank	Tank	Tank-well	River-canal	Reservoir-canal
(1)	(2)	(3)	(4)	(5)	(6)
Tractor					
1970	5	10	5	14	13
1980	9	19	11	51	41
1987	17	42	12	80	64
Thresher					
1970	1	4	2	4	2
1980	5	13	29	10	32
1987	13	18	77	18	66
Direct seeding					
1970	58	60	0	0	0
1980	60	60	0	0	0
1987	60	65	0	8	0

It is plausible that socio-economic factors such as tractor rent, bullock rent and tenure are relatively more important in explaining cross-sectional differences in tractor and thresher adoption. In the case of direct seeding, the physical environment appears to be a dominant factor influencing the adoption.

REGRESSION RESULTS

Yield Increasing Technology

Regression results of MV and fertiliser adoption functions are presented in Table IV. The environmental factors, represented by irrigation intensity and regional dummies, emerge as significant variables in both the equations. Irrigation intensity representing reliability and better water control favours the adoption of MVs. This is reasonable in the present context in Tamil Nadu where the rice production is critically dependent on irrigation water. This is particularly supported by the negative and significant coefficients of unfavourable regional dummies RAIN-TAN and TANK where unfavourable physical environment prevails. Paddy price is not significant. Consistent with the findings of many earlier studies neither farm size nor tenure significantly affected adoption of MVs (Barker and Herdt, 1985; Hazell and Ramasamy, 1986). However, it was reported that the much discussed scale-neutrality of the new technology is belied by the greater access which the larger cultivators have to the crucial factors of production involved – cash, pumpsets and fertilisers (Chinnappa, 1977). The results of the present study suggest that the scene has changed in the later years with small farmers catching up with their large farmer counterparts in adopting modern varieties. The fairly comprehensive study of National Council of Applied Economic Research (1978), covering a sample of 25,000 farmers spread over 17 Indian States conducted in 1975-76, did not provide any clear evidence of relationship between farm size and rice area in MV in 14 of the 17 States. These findings suggest that MV adoption is neutral to scale and insensitive to tenure farms. The risk variable bears a negative and significant coefficient. The higher production risks occurring in unfavourable environments act as a deterrent for adopting MVs. One of the concerns expressed during the early phase of green revolution was the lack of fine grain MVs which fetch high prices in the market. The second generation varieties with the fine grain characters are, however, successful in overcoming this problem.

TABLE IV. REGRESSION RESULTS OF MV AND FERTILISER ADOPTION FUNCTIONS[a]

Parameters (1)	MV (two-limit probit) (2)	Fertiliser (two-limit probit) (3)
IRIG	0.46*	0.82*
	(1.89)	(2.24)
MV	-	0.40**
		(3.12)
FARSIZE	-0.54	-0.03
	(-0.43)	(-0.62)
LITERACY	0.01	-0.02
	(0.20)	(-0.18)
PRICE	-0.01	-0.01
	(-0.31)	(-0.21)
TSCAREA	0.04	0.03
	(0.32)	(0.22)
MARDIS	-0.08	0.03
	(-0.19)	(1.74)
RISK	-0.07*	-0.86*
	(-1.68)	(-1.92)
RAIN-TAN	-24.78**	-14.58*
	(-6.28)	(-2.28)
TANK	-18.62**	-23.86**
	(-5.22)	(-10.72)
RIV-CAN	4.96	5.08*
	(0.48)	(2.04)
RES-CAN	4.12	4.46*
	(0.84)	(1.94)
Intercept	92.42**	78.48**
	(7.86)	(6.45)
R^2	-	-
Log-likelihood	-140.00	-169.78
(Chi-square)	(120.54)	(142.62)

a. Estimated using two-limit probit approach.
Figures in parentheses are 't'-statistics.
** indicates significance at 1 per cent level; * at 5 per cent level.

In fertiliser adoption function, IRIG and MV are highly significant.[3] Similarly, the coefficients of regional dummies are significant in all four environments. Expectedly, the negative signs of dummies for unfavourable environments clearly show that all farmers have not ventured to apply chemical fertilisers. This is mainly due to less favourable physical environmental conditions and use of traditional varieties. In both absolute and relative terms, fertilisers are used less intensively with traditional varieties of rice than modern varieties of rice (Datta *et al.*, 1986). The story is just the opposite in favourable environments for which the coefficients of regional dummies are positive and significant. Both MVs and better irrigation provide a strong basis for increased use of fertilisers by large number of farmers. Needless to say, management of fertiliser application should assume greater importance in unfavourable areas. Marginal cost of additional application of fertiliser should exceed marginal returns in areas which are characterised by high level of risks in the supply of crucial inputs such as irrigation water. As in MV adoption function, farm size, tenure, literacy and price of paddy are not significant. Seemingly, even the share tenants and farmers with even poor literacy are aware of the improved cultural practices and adopted them accordingly. It is plausible that the risk is negatively associated with the use of fertilisers. Market distance shows expected negative sign but not significant.

Yield and Cropping Intensity Functions

Table V shows the estimation results of yield and rice cropping intensity functions. The coefficients of irrigation intensity (IRIG) and favourable village dummies RIV-CAN and RES-CAN are positive and significant in yield equation, implying that there is clear productivity difference between favourable and unfavourable areas. The results demonstrate that 'assured irrigation' is significant in explaining the variations in yield across the villages. It strongly supports the hypothesis that the degree of water control has a decisive influence on the rice yield. Unexpectedly, the coefficient of MV is not significant. This will be partly due to the fact that the MV adoption rate and irrigation intensity are positively correlated. Among the regional dummies, RIV-CAN and RES-CAN have positive and significant

TABLE V. ESTIMATION RESULTS OF YIELD AND RICE CROPPING INTENSITY FUNCTIONS[a]

Parameters (1)	Yields (tonnes/ha) (2)	Rice cropping intensity (3)
IRIG	0.96**	1.26*
	(3.93)	(1.81)
MV	0.17	0.68*
	(0.14)	(1.86)
FARSIZE	0.07	0.02
	(1.00)	(0.80)
LITERACY	-0.13	-0.01
	(-0.27)	(-1.02)
PRICE	0.69	-0.01
	(0.25)	(-0.58)
TSCAREA	0.06	-0.01
	(0.72)	(-0.64)
MARDIS	-0.01	0.01
	(-1.01)	(0.68)
RISK	-0.04*	-0.02
	(1.69)	(-0.94)
RAIN-TAN	-0.33	-0.28
	(-0.78)	(-0.52)
TANK	0.02	-0.30
	(0.07)	(-0.41)
RIV-CAN	0.78**	0.58**
	(3.58)	(3.26)
RES-CAN	1.10**	0.57**
	(6.08)	(3.86)
Intercept	3.20*	0.92*
	(2.31)	(1.86)
R^2	0.87	0.64

a. Estimated using OLS procedure.
Figures in parentheses are 't'-statistics.
** indicates significance at 1 per cent level; * at 5 per cent level.

coefficients suggesting that favourable environments positively influence yield. Risk variable has a negative and significant influence on yield, which is quite reasonable in that paddy producers in unfavourable areas may be hesitant to adopt modern technologies to a sufficient extent and hence the negative impact on yield. Share tenancy, distance to the market, literacy, rice price and farm size did not play significant roles in determining the rice yield.

The rice cropping intensity is, to a significant extent, influenced by irrigation, MV adoption and favourable environmental factors (Table V). It is seen that complete adoption of MVs will result in 68 per cent increase in the rice cropping intensity. Greater development of irrigation and shorter duration and photoperiod insensitivity of MVs are important to increase rice cropping intensity. Good soils of rice land and improved infrastructural facilities, represented in regional dummies, have also played a significant role in enhancing rice cropping intensity. The economic variable such as incentive prices for rice may induce investment on irrigation which may, in turn, increase cropping intensity. But it may be a necessary but not a sufficient condition as physical and technical constraints would impose restrictions.

To summarise, our analysis on determinants of yield increasing technology adoption confirm accumulated evidence that farm size, tenure and other social and institutional factors have not significantly affected adoption of MVs and associated increase in fertiliser use (Lipton and Longhurst, 1989; Barker and Herdt, 1985). As in other studies, environmental factors, especially, the reliability of irrigation and MV adoption are the most important variables in explaining the productivity gap between favourable and unfavourable areas. It may be inferred that the differential adoption of MV technology has inequitable direct effects on regional income distribution.

Labour Saving Technology

Our interest in adoption rates of labour saving technologies relates primarily with our concern for the employment impact of technological innovations. Econometric results shown in Table VI lend support that the adoption of MVs does not bear any significant relationship with adoption of tractor technology. Irrigation, however, significantly affects tractor adoption. Tractor rent is found to affect tractor use inversely. It is seen that all of the regional dummies bear positive coefficients and three of them are significant. These results may be explained by the fact that the control environment (tank-well) has low adoption rate of tractors, which can be attributed to the ownership of more bullocks in this region. Farm size is not found to be significant in the adoption of tractors, which suggests that economies of scale do not play a role in tractorisation. It should be emphasised at this point that, in Tamil Nadu, with the larger availability of tractors for custom hiring, the technology becomes divisible which facilitates the small farmers to hire tractor services. Competitive market structure for tractor services keep the tractor rent also competitive. Production risks did not seem to influence the tractorisation process.

It is found that the adoption of thresher technology is not affected by the irrigation intensity and the extent of MV adoption as well (Table VI). Further, it is surprising to find that the adoption of threshers is the highest in tank-well irrigated control environment in contrast to the lowest adoption of tractors in this region. In fact, this makes all the coefficients of regional dummies to be negative and significant. In accordance with *a priori* expectation, the bullock wage does show a positive relationship with thresher use, because bullock threshing competes with machine threshing. Analogous to the case of tractor services, threshers are increasingly available on custom hiring basis. The ownership of threshers by the farmers is not common, and small private entrepreneurs own the threshers and let out for custom hiring. The share cropping tenants use threshers to a lesser extent as evidenced from negative and significant coefficient of TSCAREA. As in the case of tractor adoption, risk has an insignificant role in the adoption of threshers.

TABLE VI. TRACTOR AND THRESHER ADOPTION FUNCTIONS[a]

Parameters (1)	Tractor (2)	Thresher (3)
IRIG	1.36*	16.42
	(1.78)	(-0.52)
MV87	0.05	-0.36
	(0.14)	(0.56)
FARSIZE	0.74	0.42
	(0.79)	(0.38)
LIT80	0.26	0.48
	(1.22)	(1.56)
PRICE	-0.22	0.17
	(-1.00)	(1.21)
TSCAREA	-0.08	-1.22*
	(-0.32)	(-2.18)
MARDIS	-0.66	0.46
	(-0.32)	(0.74)
RISK	0.18	0.43
	(0.28)	(0.32)
TRACRENT	-0.66*	-
	(1.94)	
BULLWAGE	0.58	1.60*
	(1.28)	(1.74)
THRERENT	-	0.58
		(1.21)
RAIN-TAN	2.22	-92.88*
	(0.16)	(-3.46)
TANK	38.43**	-76.14*
	(3.72)	(-4.87)
RIV-CAN	84.57**	-86.31*
	(8.21)	(-5.67)
RES-CAN	46.58	-14.62
	(8.98)	(-1.52)
Intercept	23.47	45.32
	(1.21)	(0.74)
R^2	-	-
Log-likelihood	-162.74	-92.42
(Chi-square)	(46.47)	(24.62)

a. Estimated using two-limit probit approach.
Figures in parentheses are 't'-statistics.
** indicates significance at 1 per cent level; * at 5 per cent level.

To recapitulate, there is no evidence to indicate that the MV adoption caused the subsequent adoption of labour saving mechanical technologies, not to speak of direct seeding technology. On the other hand, irrigation and other environmental factors as well as factor prices seem to play more important roles in the adoption of these labour saving technologies. Considering the fact that the adoption of MVs significantly increased labour demand in the context of Tamil Nadu (Ramasamy *et al.*, 1989), we may conclude that the MV technology is labour using, even if we consider its possible indirect effects on the adoption of labour saving technologies.

SUMMARY AND CONCLUSION

In this paper we examined long-run adoption behaviour of selected major innovations in Tamil Nadu rice sector in a unified analytical framework. We focused on the degree of complementarity between adoption rates of MVs vis-a-vis fertiliser use, rice yield, rice cropping intensity and adoption of labour saving technologies. Cross-sectional differences in adoption of MVs are explained mainly by environmental rather than socio-economic factors. It appears that the adoption of MVs has helped to increase rice cropping intensity in favourable areas, thus expanding the employment prospects. Irrigation was an important determinant of MV and fertiliser adoption. The second generation MVs now in use, which have greater resistance to various pests, better tolerance to less favourable production conditions, and shorter growth duration have promoted adoption of MVs in wider areas. It should be also emphasised that environmental factors seem to affect fertiliser use mainly through its impact on MV adoption.

Despite the cross-sectional nature of our data set, it is clear that relative factor prices are important determinants of adoption of labour saving technologies. We did not find any indication that MVs, directly, induced adoption of tractors, threshers and direct seeding. But irrigation has directly induced adoption of tractors which could, along with MVs, have been an important factor in inducing higher rice cropping intensity. With increased cropping intensity in favourable areas, labour use per hectare per year may be increased even though tractors are adopted.

The fact that MVs have been effectively adopted in favourable areas may indicate the need for developing new MVs for unfavourable environments with lesser degree of water control. Scientifically, however, it is more difficult and hence, more costly to develop MVs for unfavourable areas. Moreover, environments in unfavourable areas are so diverse that the adoption area of a specific MV is likely to be limited. Thus such research strategy may result in the stagnation of technology in the rice sector as a whole. In other words, there is a trade off between efficiency and equity associated with the development of MV technology. One of the recent criticisms against the MV technology is that it facilitates the adoption of labour saving technologies, thereby depriving the poor of employment opportunities. Major implication of our analysis is that MV technology is not as inequitable as such common view assumes.

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NOTES

1. The areas are seen in Chengalpattu and Ramanathapuram districts.
2. Drought year was defined as the year in which the shortfall in the normal rainfall is 25 per cent and above.
3. Although MV adoption rate is an endogenous variable, we use it as an explanatory variable in this function as well as other functions estimated under the assumption of pair-wise recursive equation systems.

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