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Effect of modern rice varieties and irrigation on household income distribution in Nepalese villages

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ABSTRACT

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Since high-yielding modern rice varieties (MVs) are adopted only in favorable production environments, significant regional productivity differentials have emerged in Nepal. This study explores the distributional consequences of such differential MV adoption based on an intensive survey of favorable and unfavorable villages. We found that MV adoption increased returns to land but decreased family labor earnings from rice production, as it facilitated the substitution of hired for family labor. As a result, the differential MV adoption did not significantly worsen the household income distribution according to the results of the counterfactual Gini decomposition analysis.

INTRODUCTION

As in other Asian countries, the Green Revolution represented by the adoption of high-yielding modern rice varieties (MVs) took place only in the irrigated and favorable rainfed environments in Nepal (Barker and Herdt, 1985). Observing the differential adoption of MVs and the widening productivity differential between favorable and unfavorable rice production environments, several studies conclude that the Green Revolution worsened regional income distribution (Ruttan, 1977; Lipton and Longhurst, 1989).

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In order to analyze the distributional consequences of the Green Revolution in depth, it is essential to examine the impacts of MV adoption on the demands for and returns to hired labor, family labor, and land separately. A major source of hired labor is landless agricultural laborers, who belong to the poorest segment of the poor rural society. The landless are geographically mobile seeking profitable employment opportunities. According to a recent study of regional wage differentials in Nepal by Upadhyaya, Otsuka and David (1990), the differential adoption of MVs was followed by interregional migration of the landless from unfavorable to favorable areas, which significantly contributed to the equalization of the regional wages. Farmers (owner-cultivators and tenants) are wealthier and less mobile than the landless laborers. Thus, to the extent that MV technology increases the use of hired labor relative to family labor, the distributional impact of the Green Revolution may not be as inequitable as generally thought.

Since land is immobile and, hence, inelastic in supply, an increase in the demand for land due to MV adoption in favorable areas will result in an increase in returns to land in those areas, thereby creating the regional gap in land income. Moreover, its ownership distribution is much more skewed than the distribution of human resources. Therefore, the inter- as well as intra-regional income distribution may be significantly worsened by the increased returns to land in favorable areas. Whether and to what extent the differential adoption of MVs has inequitable impacts is an empirical question, depending critically on relative changes in hired and family labor income and returns to land.

This study attempts to analyze the distributional consequences of Green Revolution in Nepal. It is based on an intensive cross-sectional survey of farm and agricultural landless labor households in an irrigated (environmentally favorable) and unirrigated (environmentally unfavorable) village in the Nepalese Tarai. The hypothesis is that the introduction of MVs and development of irrigation has not significantly worsened income distribution because the income gains experienced by the owner farmers have been largely offset by increased labor earnings of the landless.

DESCRIPTION OF SAMPLE HOUSEHOLDS

After making a number of brief visits to various villages in the Western Terai region, we selected a typical rainfed and typical irrigated village for the study. Anandban, the irrigated village, is served by a farmer-managed gravity irrigation scheme whereas Ramapur, the unirrigated village, is predominantly rainfed. They are located 25 km apart. A complete enumeration survey of households in the two villages was first undertaken to serve

TABLE 1

Irrigated area, adoption of modern rice varieties, fertilizer use, cropping intensity, and crop yields in survey villages, 1987

	Anandban (irrigated)	Ramapur (rainfed)
No. of sample farm households	55	55
Area irrigated (%)	100	11
Adoption of MV rice (% area)	100	80
Fertilizer use in rice (kg NPK/ha)	43	14
Crop yields (t/ha)		
Rice	2.9	2.2
Wheat	1.7	0.9
Lentil	0.6	0.4
Mustard	0.4	0.3
Percent of total land planted to each crop		
Rice	100	98
Lentil	42	20
Wheat	38	20
Mustard	18	11
Others	11	8
Cropping intensity index [a]	209	157

t, metric tonne = 1000 kg.

[a] Sum of percent of total land planted to each crop.

as the basis for selecting the sample farm and landless households. Two rounds of surveys of randomly selected farm and landless labor households were conducted covering the wet and dry seasons of 1987. The farm household questionnaire collected detailed information on technology adoption, yields, input use, prices, tenurial arrangements, assets, and income by sources. The landless household questionnaire focused on employment, assets, and income by sources.

Selected indicators of technology adoption and cropping patterns in the study villages are shown in Table 1. The two villages differed significantly in terms of area coverage under irrigation. All farms were irrigated in Anandban whereas only 11% of the total area was irrigated in Ramapur. Average rice yield per hectare was higher in Anandban than in Ramapur mainly due to a higher adoption of MVs and a higher level of fertilizer use per hectare. In the predominantly rainfed village of Ramapur, there are essentially three rice-farming conditions. In about one-tenth of total cultivated area in this village, MVs are grown under irrigated conditions where rice yields are comparable with those in the irrigated village. Traditional varieties (TVs) are grown under unfavorable rainfed conditions in about one-fifth of the total area, whereas MVs are grown in the rest of the rainfed area.

TABLE 2

Farm size, ratio of landless households, person–land ratio, and tenure patterns in survey villages, 1987

	Anandban (irrigated)	Ramapur (rainfed)
Farm size (ha)	2.02	2.07
Ratio of landless households (%)	22	21
Person–land ratio (No./ha)	3.2	3.1
Tenure (% of area)		
Owner	70	94
Share tenancy	15	4
Fixed-rent tenancy	15	1

The cropping intensity index (sum of the percent of total land planted to each crop) was significantly higher in Anandban (209%) than in Ramapur (157%). While percent of land planted to rice was comparable between villages, percent of land in the dry season crops like lentil, wheat and mustard was much higher in the irrigated village. This can be explained by the difference in water availability during the dry season between the two villages and by the fact that second crop of rice cannot be grown in these study villages during the dry season because of insufficient availability of irrigation water for rice. Thus, there is practically no substitutability between rice and non-rice crops in these villages. Also note that the yields of non-rice crops such as wheat, lentil and mustard, are significantly higher in Anandban than in Ramapur, because of the better production environments in the former village during the dry season.

Farm size, the ratio of landless households, and person–land ratio are similar in both villages (Table 2). Although one would normally expect a higher person–land ratio in the irrigated village, technology-led migration in the case of Nepalese Tarai is primarily seasonal rather than permanent (Upadhyaya, Otsuka and David, 1990). [1] Owner cultivation is the dominant form of land tenure in both villages, although the incidence of both share and fixed rent tenancy is significantly higher in Anandban than in Ramapur. More specifically, area under share and fixed-rent tenancy each constituted 15% of total cultivated land in Anandban. In Ramapur, the corresponding percentages were 4% and 1%, respectively. Most landlords reside in villages and their landholdings range from 8 to 14 ha. They are,

[1] However, permanent migration is also pervasive in Nepal from the hills to Tarai, which is reflected in the relatively higher ratio of landless households in the Tarai than in the hills.

however, not included in our sample primarily because of the difficulty in obtaining reliable information on the amount and sources of their income.

LABOR USE IN RICE PRODUCTION

The effect of new rice technology on employment has an important bearing on income distribution, because labor is the mobile factor and the main income earning resource for the poorest of the rural population. Several studies have shown that the adoption of new rice technology is associated with greater employment of hired labor (Thapa, 1989; Barker and Cordova, 1978). In this section, we will estimate labor use functions to quantify the effect of modern technology on the use of hired and family labor.

Comparative figures for total labor use in rice production per hectare by activity are shown in Table 3. In Ramapur 17 of the farmers sampled were growing both MVs and TVs. Since it was not feasible to collect accurate data on labor use separately for plots growing MVs and TVs, Table 3 shows for this village labor use by variety using data from nine farms growing TVs on more than 50% of the farms. All other farms were classified as MVs. On average, farmers in Anandban employed more labor per hectare in rice production than in Ramapur in all activities except in land preparation. Lower labor use for land preparation in Anandban can be explained by a substantially higher tractor use for this activity in this village than in Ramapur.

TABLE 3

Labor use in rice production (person days per ha) and adoption of labor-saving technology (percent) in survey villages, 1987

	Anandban (irrigated)	Ramapur (rainfed)		
		MV	TV [a]	Average
Land preparation	21	32	28	31
(% area using tractor for land preparation)	(69)	(15)	(0)	(13)
Transplanting	27	24	21	23
Crop care	33	24	13	22
Harvesting and threshing	47	40	30	38
Total labor	128	120	92	114
(% hired labor)	(63)	(607)	(41)	(54)
Number of Households	55	46	9	55

[a] Farmers growing TVs on 50% or more of their land.

Overall, the total labor use and the proportion of hired labor were higher in Anandban than in Ramapur. The relatively greater employment of hired labor in the irrigated village suggests that the modern rice technology creates greater income and employment opportunities for the landless laborers. In Ramapur the total labor use, labor use in major activities, and the proportion of hired labor were higher for MVs than for TVs.

Table 4 presents the results of labor use functions for hired and family labor per hectare of rice production. We chose linear specification and applied a Tobit (censored regression) model for hired and family labor use because several observations had zero values for dependent variables. We applied an ordinary least squares model (OLS) for the total labor use

TABLE 4

Estimation results of hired, family and total labour use functions (days per ha) in rice production, 1987

Independent variables	Hired labour (Tobit)	Family labour (Tobit)	Total labour (OLS)
IRG [a]	53.57 **	−15.13	44.84 **
	(2.71)	(−0.97)	(4.76)
FRF [b]	41.29 *	−21.36	26.80 **
	(2.02)	(−1.29)	(2.71)
Farm size (ha)	4.15 **	−8.23 **	0.66
	(3.62)	(−3.35)	(0.92)
Schooling [c]	2.32 **	−2.21 **	0.38
	(2.57)	(−2.88)	(0.85)
Share tenancy	−24.17 *	12.69	−7.89
	(−2.57)	(1.15)	(−1.49)
Fixed rent tenancy	2.15	6.38	5.41
	(0.20)	(0.67)	(0.97)
No. of family workers	−3.95 *	4.74 *	−0.11
	(−2.42)	(2.51)	(−0.12)
Tractor use dummy	−2.90	−4.51	−9.60 *
	(−0.34)	(−0.58)	(−2.17)
Intercept	21.81	74.55	86.92
R^2 (log-likelihood)	(−505.87)	(−493.45)	0.30
F-value (chi-squared)	(52.69)	(41.98)	5.42

Tobit, Tobit (censored regression) estimation.
OLS, Ordinary least squares estimation.
Numbers in parentheses are t-values.
* Indicates significance at 5% level; ** at 1% level.
[a] Ratio of irrigated area planted to MVs.
[b] Ratio of rainfed area planted to MVs.
[c] Years of schooling of the household head.

function. Explanatory variables included technology factors, farm size, tenure, number of family workers between ages 15 and 65, schooling of household head, and tractor use dummy. Since the adoption of MVs is complete in the irrigated areas of both villages, it is very difficult to identify the separate effects of MVs and production environment on labor use using our cross-section data. Therefore, MVs are not included as a separate variable in our model. We specified technology factors in terms of production environments implicitly interacted with MV adoption; irrigation ratio (IRG) represents farming conditions in Anandban and some parts of Ramapur where MVs have been fully adopted under irrigated conditions, and favorable rainfed ratio (FRF) represents farming conditions in a large part of Ramapur where MVs are grown under rainfed conditions. The omitted technology variable which acts as control refers to unfavorable rainfed areas planted to TVs which are found only in Ramapur. Tenure variables include dummies for share and fixed-rent tenancy. Wage rates and other input and output prices were not included because they are largely uniform within and between villages. In order to account for the possible difference in labor use between tractor using and animal using farms, we included a tractor use dummy, which assumes the value of unity if a farm household uses tractors and zero otherwise.

The coefficients of IRG and FRF indicate that irrigated and favorable rainfed farms growing MV rice employ, on average, 54 and 41 more hired labor days per hectare, respectively, compared to unfavorable rainfed farms growing traditional varieties (TVs). This result supports the hypothesis that modern rice technology is biased towards using hired labor. Another interesting result is the negative coefficients of IRG and FRF in the family labor use regression, even though the coefficients are not significant. These results suggest that the MV technology increased hired labor by increasing the peak season demand for labor due to the shorter growth duration of MVs. Also important may be the income effect on family labor generated by the new technology which facilitated the substitution of hired for family labor. Similar results have been reported elsewhere by previous studies (Roumasset and Smith, 1981).

The coefficient of schooling was significant and positive in the hired labor use function, but significant and negative in the family labor use function. Farm size had a significant and negative effect on family labor use. Share tenants, who are generally poorer than the owner-operators or fixed rent tenants, used significantly smaller amounts of hired labor per hectare. These results further support the importance of income effect in labor resource allocations. As expected, the coefficient of the number of family workers was significant and negative in the hired labor use function but positive in the family labor use function. The tractor use dummy had a negative but non-significant coefficient in both hired and family labor use functions, although it had a negative and significant coefficient in the total labor use function.

The results of labor use functions indicate that the new rice technology increases hired labor use. This may be due to the effect of technology bias and income effect which have positive effects on hired labor use as family labor is substituted by hired labor. Since hired laborers are mostly landless workers, usually the poorest in the village, the impact of the new rice technology on labor use appears to have a desirable effect on household income distribution (Thapa, 1989).

FACTOR SHARES IN RICE PRODUCTION

Changes in factor payments and factor shares in rice production will have significant impact on household income distribution, because rice production constitutes a major source of household income in the study villages. The purpose of this section is to identify the effect of MV technology on factor shares and factor payments.

A standard technique in functional income distribution analysis is to compare shares accruing to different factors and earners before and after technological change (Herdt, 1987; Hayami and Kikuchi, 1981; Ranade and Herdt, 1978). If a higher share of the increased output goes to poorer segments of society, then technological change contributes to an equitable distribution of income. On the other hand, if the increased benefit is captured by landlords, then technological change may accentuate income disparity. Because of the lack of benchmark data in our study, it is not possible to make comparisons of factor shares before and after the technological change. Instead, a comparison of factor shares between two villages characterized by different technologies but similar market conditions is attempted.

The average factor payments and relative factor shares per hectare of rice production in Anandban and Ramapur are shown in Table 5. The gross value of output in Anandban is significantly higher than in Ramapur. The factor payments to different inputs are also higher in absolute terms in the irrigated village, indicating that the adoption of modern rice varieties leads to higher returns to all factors of production. The relative share of labor in Ramapur, where technology adoption has been limited by the lack of irrigation, is higher than in Anandban, where new technology has been widely adopted. This suggests that the new rice technology as a whole, including biological and mechanical innovations in combination with better production environment, has a labor-saving effect.

TABLE 5

Factor payments (Rs.) and factor shares (%) in rice production per ha, 1987 [a]

	Anandban (irrigated)	Ramapur (rainfed)	Inter-village difference (%)
Gross value of output	9776	6723	45
	(100)	(100)	
Current inputs [b]	644	281	129
	(7)	(4)	
Capital [c]	1702	1056	61
	(17)	(16)	
Labor	2349	2020	16
	(24)	(30)	
Family [d]	1011	914	11
Hired	1338	1106	21
Residual	5081	3366	51
	(52)	(50)	
Land rent			
Fixed rent	3065	2902	6
Share rent	3894	3508	11
Surplus [e]			
Fixed rent	2016	464	334
Share rent	1187	−142	–

Rs., Rupees.
[a] Figures in parentheses are the factor shares.
[b] Includes seed, fertilizer, and pesticides.
[c] Includes animal and machine use.
[d] Imputed labor cost using average daily wage rates.
[e] Residual minus fixed or share rent.

Since the household income distribution is more closely related with actual payments to owners of factor inputs, the factor payments to labor are divided into those accruing to hired and family labor, and the factor payments to land are divided into actual average rent and surplus to farm operators. The share accruing to land as measured by the residual constitutes as high as 52% and 50% of gross value of output in Anandban and Ramapur, respectively. In contrast, the share accruing to hired labor is only about 15% of gross revenue in the study villages. The estimated surplus, which is defined as residual minus fixed or share rent, is significantly higher in Anandban than in Ramapur, partly because leasehold rents are fixed at the similar levels in two villages by land reform law. This policy works to the great advantages of those who own irrigated land. [2]

[2] Share rents seem to have been adjusted to the level of leasehold rents prescribed by law in both villages.

The analysis of factor shares clearly shows that employment opportunities for hired labor in rice production are relatively limited and that the important sources of farm operators' income from rice are the residual returns to land and the surplus. As a consequence, a farm operator's total income share from capital, family labor, and land per hectare far exceeds that of hired labor, even though the share of family labor is lower than that of hired labor in rice production. This clearly shows that landless workers will be much worse-off than farmers, unless remunerative employment opportunities are available outside rice production.

HOUSEHOLD INCOME BY SOURCE

Household income in our study villages consists of income from rice, non-rice crops, livestock and non-farm sources. Table 6 shows the estimates of average annual incomes of farm and landless households by source in

TABLE 6

Structure of average annual incomes of farm and landless households (Rs. 1000) in survey villages, 1987

	Farm households		Landless households	
	Anandban (irrigated)	Ramapur (rainfed)	Anandban (irrigated)	Ramapur (rainfed)
Rice production	11.47	9.24	4.73	2.49
Labor income	1.53 [a]	1.34 [a]	4.73 [b]	2.49 [b]
Capital income [c]	3.23	2.40	–	–
Land income [d]	6.71	5.50	–	–
Nonrice production	17.43	7.39	4.97	5.95
Farm [e]	11.84	4.48	3.89	1.58
Nonfarm [f]	5.59	2.91	1.08	4.37
Total income	28.90	16.63	9.70	8.44
Household size	6.7	7.2	5.3	4.0
Per-capita income	4.31	2.31	1.83	2.11
No. of households	55	55	15	15

[a] Includes family labor income imputed by using appropriate market wage rates for different tasks.
[b] Includes labor earnings from rice production.
[c] Includes returns to owned machineries and bullocks imputed by using prevailing custom rates.
[d] Residual for owner-cultivators and surplus (residual minus actual rent payments) for tenants.
[e] Includes income from nonrice crops and livestock, off-farm labor earnings, and actual rental earnings.
[f] Includes labor earnings from nonfarm employment, remittances, pensions, and income from self-employed petty trade.

the survey villages. For both categories of households, non-rice farm income and non-farm income account for significant shares of total income. [3] Average income of farm households was significantly higher in Anandban than in Ramapur. Much of this can be explained by the fact that Anandban has a much higher level of farm income from non-rice crops grown during dry season, which can be attributed largely to the presence of irrigation.

Rice income is divided into the earnings of the household's owned labor, capital, and land (or tenancy right) from rice production. Labor income refers to returns to family labor which are imputed by applying appropriate market wage rates for different tasks. Similarly, capital income refers to returns to owned capital used in own farm which are imputed by using prevailing custom rates. Land income for owner-operators is the residual, whereas for tenants it is the surplus, i.e., the residual net of rent payments. Note that the residual represents not only the returns to land but also returns to management and errors in imputing income of family labor and family owned capital.

Among farm households, income from rice production is higher in Anandban than in Ramapur primarily because of higher yield, since farm size and percent of area planted to rice are similar between villages. The difference in the average land incomes is not as much as the difference in the rice yields, because larger fractions of farmers in Anandban were tenants. Since even greater differences in non-rice income exist between villages, both total and per capita incomes are substantially higher in Anandban than in Ramapur.

Landless households, whose major source of income is labor earnings, have considerably lower total income than that of farm households mainly because of the difference in land income in rice and non-rice crop production. Landless households in Anandban had higher income from the crop sector. However, total household as well as per capita income are not significantly different between villages because landless households in Ramapur had significantly higher non-farm income than in Anandban. Since employment in the crop sector in Ramapur is limited during the dry season, landless households found employment in the non-farm sector like carpentry, brick-making, petty trade, etc.

[3] Several studies have reported that non-farm income constitutes a significant proportion of total income for agricultural households in other developing countries (e.g., Chin, 1979; Anderson and Leiserson, 1980; Shand, 1987).

INCOME DETERMINATION FUNCTIONS

Household income determination functions were estimated by income component to identify the determinants of household income for different components of household income. Theoretically, the estimated functions are reduced form equations derived from the utility maximization behaviors of households with respect to allocations of labor, land, and other family owned resources for different uses (Otsuka and David, 1989). Explanatory variables included production environments, farm size, tenure status, value of non-land fixed assets, number of family workers between ages 15 and 65, and schooling of household head. A village dummy variable was also included to represent other factors which affect factor returns and allocations. A linear functional form was again adopted in estimating income determination functions. [4] Variables representing production environments (IRG and FRF) and tenure variables have been specified as interaction terms with farm size, because component incomes are expressed on per farm basis. [5]

Table 7 shows regression results of household income determination functions by income component. Dependent variables measures annual income in Rs. 1000. It is evident that the estimation results conform to a priori expectations. Technology and tenure variables have significant coefficients in the land income regression. The coefficients of FS × IRG (interaction between farm size and ratio of irrigated area which is all planted to MVs) and FS × FRF (interaction between farm size and ratio of favorable rainfed area planted to MVs) imply that land income per hectare in irrigated and favorable rainfed areas planted to MVs is higher by Rs. 5300 and Rs. 2600, respectively, compared to unfavorable rainfed areas planted to TVs. The coefficient of farm size suggests that land income in unfavorable rainfed areas planted to TVs is close to zero which is not necessarily an implausible result, in view of the extremely low yield per ha in this environment. [6]

[4] The log-linear form could not be estimated because several observation had negative values of land income, zero labor earnings from rice production and zero non-farm incomes. We chose ordinary least squares model for land, capital and nonrice farm income and Tobit model for labor and non-farm incomes, because several households had zero labor and non-farm incomes.

[5] We obtained basically similar results when component incomes were expressed on per-ha basis and explanatory variables like IRG, FRF, share tenancy, and fixed-rent tenancy variables were specified as separate variables with no interaction with farm size.

[6] Significant yield differences were observed among unfavorable rainfed, favorable rainfed, and irrigated production environments in the study villages. Their corresponding paddy rice yields are 1.07, 2.29, and 2.90 metric tonnes per ha.

TABLE 7

Estimation results of farm household income determination functions, 1987

Rice income				Nonrice farm income (OLS)	Nonfarm income (Tobit)
Independent Variables	Land (OLS)	Labor (Tobit)	Capital (OLS)		
Farm size (FS)	−0.55	0.99 **	1.41 **	−0.78	−2.23
	(−0.49)	(4.07)	(4.04)	(−0.68)	(−0.70)
FS×IRG [a]	5.27 **	−1.05 **	0.64	4.77 **	−0.40
	(4.23)	(−3.45)	(1.65)	(3.73)	(−0.11)
FS×FRF [b]	2.61 *	−1.24 **	0.27	1.27	2.01
	(1.85)	(−3.84)	(0.61)	(0.88)	(0.51)
FS×Share tenancy	−2.63 **	0.71 **	−0.64 *	−0.38	0.02
	(−2.96)	(3.73)	(−2.32)	(−0.42)	(0.01)
FS×Fixed-rent tenancy	−2.31 **	1.06 **	−0.29	0.41	−2.95
	(−3.37)	(9.63)	(−1.38)	(0.58)	(−0.69)
Schooling [c]	0.10	−0.08 *	−0.03	−0.12	0.94 **
	(0.77)	(−2.10)	(−0.83)	(−0.88)	(3.21)
No. of Family workers	−0.03	0.39 **	0.06	−0.76 *	1.51
	(−0.09)	(6.81)	(0.69)	(−2.49)	(1.66)
Fav. Village dummy	−3.55 **	0.17	0.52	−0.73	6.29 *
	(−2.83)	(0.51)	(1.33)	(−0.57)	(2.03)
Asset	0.01 *	0.00	0.00	0.05 **	0.03 *
	(2.10)	(0.04)	(−0.59)	(9.67)	(1.99)
Intercept	1.21	−0.12	−1.03	2.20	−10.28
R^2 (log-likelihood)	0.81	(−161.93)	0.91	0.87	(−227.66)
F-value (chi-squared)	47.37	(116.14)	107.06	72.35	(38.60)

Numbers in parentheses are t-values.
Dependent variables measure annual income in Rs. 1000.
OLS = ordinary least squares estimation.
Tobit = Tobit (censored regression) estimation.
[a] FS×IRG refers to the interaction term between farm size and the ratio of irrigated area which is all planted to MVs.
[b] FS×FRF refers to the interaction term between farm size and the ratio of favorable rainfed area planted to MVs.
[c] Years of schooling of the household head.

The estimated coefficients of two interaction terms between tenancy dummies and farm size are significant and negative. These coefficients indicate that land income under both share and fixed rent tenancy is lower than that under owner cultivation because of rent payments to landlords.

In the labor income regression, adoption of MVs in irrigated and favorable rainfed areas seems to have decreased labor income of farm households from rice production significantly. Such result suggests that the MV adoption reduced the family labor income partly because of income effect as better-off households would prefer leisure and partly because family labor in rice production is substituted by hired labor because of the sharper peak demand for labor. Labor income of both share and fixed-rent tenants is estimated to be significantly higher than those of owner-operators. This result is also expected given the income status of tenants and the positive income effects on leisure. The coefficient of farm size is significant and positive in labor and capital income functions as expected. It is interesting to note that the coefficient of schooling of the household head is positive and significant in the non-farm income function but negative and significant in the labor income function from rice production. This may be explained by the larger effect of education on non-farm wages and employment opportunities than on labor earnings from rice production. While the best educated obtain the non-farm jobs, the others are left behind to work in the paddy fields.

The estimated coefficient of interaction term between farm size and the ratio of irrigated area is significant and positive in non-rice farm income function. This can be explained by significant and positive effect of irrigation on the yields of non-rice crops and, thus, on income from these crops in the irrigated village. As is shown in Table 6, the non-rice farm income of farm households in the irrigated village was two and half times higher than in the rainfed village. As expected, in the non-farm income function, the coefficient of the farm size–irrigation interaction term is not significant.

The coefficient of favorable village dummy is significant and negative in the land income regression. This may be due to the advantage of the unfavorable village arising from factors other than irrigation or MV adoption, e.g., the better soil structure and water holding capacity in Ramapur than in Anandban. In the case of labor income, capital income, and non-rice farm income regressions, the coefficient of village dummy is not significant, suggesting no particular locational advantages or disadvantages in income earning opportunities from both rice and non-rice sources between study villages unaccounted for by environmental variables. The significant and positive coefficient of village dummy in the non-farm income regression can be explained by the easier access of the irrigated village to non-farm employment opportunities in nearby towns. The current value of non-land fixed assets has a significant and positive coefficient in the land income regression. This may be due to the fact that households with more fixed assets have greater access to credit which positively affects profitability from rice production. This variable also has a significant and positive coefficient in the non-rice farm income regression. This can be explained in part by the greater access of rich households to credit and in part by the fact that this variable includes values of livestock and poultry which positively affects the amount of income from this source. The significant and positive coefficient of this variable in the non-farm income

TABLE 8

Estimation results of landless household income determination functions, 1987

Independent variables	Rice income (OLS)	Nonrice farm income (OLS)	Non-farm income (Tobit)
Schooling [a]	−0.25 **	−0.05	1.62 **
	(−2.81)	(−0.47)	(2.99)
No. of family workers	0.97 **	1.77 **	−2.29
	(4.08)	(6.42)	(−1.47)
Asset	−0.01	−0.01	0.08 **
	(−0.97)	(−0.76)	(5.70)
Village (irrigated)	0.89	0.58	2.49
	(1.53)	(0.86)	(0.94)
Intercept	1.51	−1.77	−2.12
R^2 (log-likelihood)	0.68	0.70	(−33.40)
F-value (chi-squared)	13.18	14.72	(53.87)

Numbers in parentheses are t-values.
* indicates significance at 5% level; ** at 1% level.
Dependent variables measure annual income in Rs. 1000.
OLS, ordinary least squares estimation.
Tobit, Tobit (censored regression) estimation.
[a] Years of schooling of the household head.

regression can be explained by its positive effect on rental income earnings from work animals and tractors.

Estimation results of household income determination functions for landless households are presented in Table 8. An important finding is that the coefficient of schooling is significant and positive in the non-farm income regression but negative in the rice income regression. Though unreported here, the net effect of schooling on total income is bound to be positive, which would imply that human capital is an important determinant of the income of the landless particularly because of the high pay-offs to human capital in non-farm jobs. The coefficient of number of family workers is significantly positive in rice and non-rice farm income functions, which is a plausible result since income here refers to labor earnings from rice or non-rice crop production. As expected, the value of non-land fixed assets, which include animals and buildings for petty trade is an important explanatory variable in the non-rice income regression.

We cannot specify the household specific technology variables for the landless household income determination functions. Therefore, we consider the village dummy to capture, at least partly, the effects of environments and technology differences between the two villages. According to the estimation results, the estimated coefficients of village dummy are not significant in any income regressions. [7] Such result is consistent with the finding of Upadhyaya, Otsuka and David (1990) that agricultural wage rates are largely equalized between favorable and unfavorable areas in the Tarai primarily because of the seasonal migration of the landless laborers from unfavorable to favorable areas. It seems that benefits of increased hired labor due to the adoption of modern rice technology in favorable areas are shared by the landless laborers at large.

GINI DECOMPOSITION ANALYSIS

Several previous studies of the impact of new technology on income distribution have used the Gini coefficient analysis in comparing income inequality with and without technological change using cross-section data (Raju, 1976; Shand, 1987). These studies do not consider the impact of technology on various income components nor do they control the effects of factors other than technology. In this analysis, we compare Gini coefficients for total and component incomes based on actual data and counterfactual incomes which are computed from the estimated income determination functions assuming that there had been no introduction of modern rice technology.

The adoption of MVs affects various income components differently. Therefore, it is essential to quantify the relative importance of each income component in analyzing the issue of income inequality. In this paper, we follow the specific decomposition procedure derived by Fei, Ranis and Kuo (1978) and later elaborated by Pyatt, Chen and Fei (1980).

In this framework, the exact decomposition of the Gini coefficient for total income is given by:

$$G(Y) = \sum S_k R(y, x_k) G(x_k)$$

where S_k is the share of the kth income source in total income, $R(y, x_k)$ a rank correlation ratio, $G(x_k)$ the Gini coefficient for the distribution of individual income source, x_k. Rank correlation is defined as:

$$R(y, x_k) = (\mathrm{Cov}(x_k, r(y))/(\mathrm{Cov}(x_k, r(x_k))$$

where $\mathrm{Cov}(x_k, r(y))$ the covariance between income from individual source and the rank of household with respect to total income, and Cov $(x_k,$

[7] The result may appear to be consistent with the estimation results of the family labor use functions (Table 4) where the coefficient of IRG (irrigated land) and FRF (favorable rainfed land) were found to be insignificant. However, family labor was engaged mostly in non-peak season activities for which market wages were relatively lower.

TABLE 9

Income shares, Gini coefficients, rank correlation ratios, and contributions of income components to the overall Gini coefficient in survey villages, 1987

Income source	Gini coefficient $G(x_k)$	Share in total income S_k	Rank correlation ratio $R(y, x_k)$	Contribution to overall Gini coefficient [a]	Percentage contribution to overall Gini
Anandban (irrigated)					
Total income	0.495	1.00	1.00	0.495 [b]	100
Rice income	0.574	0.40	0.88	0.205	41
Land income	0.757	0.21	0.89	0.148	
Labor income	0.572	0.09	−0.05	−0.003	
Capital income	0.734	0.10	0.82	0.060	
Nonrice farm income	0.575	0.41	0.88	0.207	42
Nonfarm income	0.764	0.19	0.57	0.083	17
Ramapur (rainfed)					
Total income	0.432	1.00	1.00	0.432 [b]	100
Rice income	0.536	0.52	0.84	0.235	54
Land income	0.655	0.29	0.85	0.164	
Labor income	0.515	0.11	−0.07	−0.004	
Capital income	0.697	0.12	0.84	0.075	
Nonrice farm income	0.446	0.26	0.75	0.087	20
Nonrice income	0.770	0.22	0.65	0.110	25

[a] Productivity of $G(x_k)$, S_k, and $R(y, x_k)$.
[b] Overall Gini coefficient.

$r(x_k)$) the covariance between income from kth source and the rank of household with respect to that income. R is larger, the larger the correlation between y and x_k; R could be negative, if x_k and y are negatively correlated.

In this formulation, the contribution of each income component to total income inequality depends not only on the Gini coefficient of component income but also on the share of component income in total income and the rank correlation ratio (Table 9). The conventional factor share analysis can be linked with this analysis because income shares are closely related to technology bias in production and factor prices, which affect factor shares. However, the separate effects of MV adoption and production environments cannot be identified in this analysis. Despite this limitation, the estimation of Gini coefficients by factor income components based on actual and counterfactual incomes (i.e., incomes without MVs) give some useful insights into the effect of MV adoption on returns to land and on income distribution.

Counterfactual incomes without MV are derived using the results of household income determination functions (Table 10); we subtract from actual incomes of households the contribution of MV and derive counterfactual incomes. In our income determination functions, the coefficient of FS × FRF more closely reflects the 'pure' contribution of MVs per ha, as this variable represents the effect of MVs in rainfed environment. On the other hand, the coefficient of FS × IRG reflects the combined effects of irrigation and MVs which grossly overestimates the contribution of MVs to component incomes. We discarded the significant coefficient of FS × FRF in nonrice income regression, because it is likely to reflect the effect of irrigation on nonrice production but not modern rice varieties as explained before. Thus, we used product of farm size and the significant coefficients of FS × FRF in land and labor income regressions to estimate the contribution of MV adoption to income of all farmers who adopted MVs.

Table 9 shows the Gini coefficients income shares, rank correlation ratios, and contributions of various income components to the overall Gini coefficient based on actual data. The contribution of nonrice farm income to the overall income inequality was much higher in Anandban (42%) than in Ramapur (20%) for three reasons. Both its share in total income and the Gini coefficient for this income source were higher in Anandban than in Ramapur. In addition, this income source was highly correlated with total income in Anandban. The latter observation implies that it is primarily households at the upper end of income distribution that received nonrice farm income in Anandban. The share of non-farm income in the total income inequality was higher in Ramapur (25%) than in Anandban (17%). This may be explained by the relatively higher share of this income source and the higher rank correlation ratio in Ramapur.

The contribution of rice income to total income inequality was higher in Ramapur (54%) than in Anandban (41%) despite the fact that both rice income Gini and rank correlation ratio were higher in Anandban than in Ramapur. The major reason for this was a substantially higher income share of rice income in total income in Ramapur which reflects the limited availability of profitable alternative crops because of lack of irrigation in the dry season. Among different components of rice income, the most important source of income inequality is land income for both villages, contributing between 30% and 37% of total income inequality and between 69% and 72% of rice income inequality. In contrast, the contribution of capital income was roughly half that of land income. It is more interesting to observe that the labor income negatively contributed to income inequality in both villages, primarily because of a negative rank correlation ratio of labor income with total income. These results suggest that given the skewed distribution of ownership and/or access to land, the most impor-

TABLE 10

Total income Gini coefficients and contributions by income components: Comparison of actual case with counterfactual case of no modern variety adoption

Villages	Total income	Contribution by				
		Rice production			Nonrice farm income	Nonfarm income
		Land	Labor	Capital		
Actual (with MVs)						
Anandban (irrigated)	0.495	0.148	−0.003	0.060	0.207	0.083
Ramapur (rainfed)	0.432	0.164	−0.004	0.075	0.087	0.110
All	0.480	0.148	0.001	0.066	0.174	0.093
Counterfactual (without MVs)						
Anandban (irrigated)	0.478	0.071	0.039	0.056	0.220	0.091
Ramapur (rainfed)	0.418	0.067	0.062	0.068	0.095	0.126
All	0.469	0.067	0.049	0.059	0.189	0.104

tant income source contributing to income inequality is land income whereas labor income is an income equalizing factor.

The estimation results of actual and counterfactual total income Gini coefficients and the absolute contributions of different income components (i.e., the product of income share, rank correlation ratio and component Gini ratio) to total income inequality are shown in Table 10. The results of counterfactual analysis show that Gini coefficients for total income in the counterfactual case, (0.478 for Anandban and 0.418 for Ramapur), are lower than in the actual case (0.495 for Anandban and 0.432 for Ramapur) primarily because the contribution of land income to the overall income inequality is considerably higher in the actual case with MV adoption. However, the increase in total income inequality with MV adoption due to increase in inequality of land income distribution was largely offset by decreases in the contribution of both labor income and nonrice income. The negative effect of labor income to the overall income inequality with MV adoption can be explained by decreased labor earnings of farm households from rice production, as it facilitated the substitution of hired for family labor. The decreased contribution of nonrice income to the overall income inequality with MV adoption is primarily a consequence of the lower relative importance of this income source in total income.

CONCLUDING REMARKS

This paper attempted to identify the distributional consequences of differential adoption of modern rice varieties based on an intensive survey of favorable and unfavorable villages in Nepal's Tarai. We found that MV adoption significantly increased returns to land but decreased family labor earnings of farm households from rice production, as it facilitated the substitution of hired for family labor. Consequently, the differential MV adoption did not significantly worsen household income distribution. Since the positive effect of MVs on wages through their direct and indirect effects on labor demand is not considered, this analysis possibly overestimates the inequitable effect of the differential adoption of MVs. If we could incorporate such effect in our analysis, the inequitable effect of MV adoption would have been even smaller.

A major policy implication of this analysis is that more resources should be allocated to development and dissemination of high-yielding rice technology as it improves production efficiency without significantly worsening household income distribution. In fact, the adoption of MVs and irrigation have a positive effect on the income of landless laborers who are the poorest members of the poor rural population.

This study also underscores the importance of education in determining income of landless households. This would imply that in order to alleviate the poverty of the landless larger investments in their human capital are required. Such investments, too, will improve both the efficiency and the equity of the Nepalese economy.

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