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NATURE AND IMPACT OF THE GREEN REVOLUTION IN BANGLADESH

Mahabub Hossain

July 1988

INTERNATIONAL FOOD POLICY RESEARCH INSTITUTE

In collaboration with the BANGLADESH INSTITUTE OF DEVELOPMENT STUDIES

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CONTENTS

TABLES

ILLUSTRATIONS

FOREWORD

The International Food Policy Research Institute has always emphasized the role of modern technology in increasing the food supply of low-income countries. The growth in productivity that results from technology diffusion generates linkage effects that can lead to all-around economic development. IFPRI is profoundly concerned about the policies needed to encourage and increase the effectiveness of technology adoption and to maximize agricultural growth linkage effects in achieving major social objectives such as alleviation of poverty. It is clear that for poor, land-scarce countries like Bangladesh, food supplies necessary to meet even minimum expected growth rates of population and per capita income during the next few decades cannot be realized without development of higher-yielding cereal varieties and their accelerated spread to farmers' fields. Failure to increase food supplies at a matching rate will increase food prices and accentuate poverty, since the poor spend a large proportion of their income on food.

This report by Mahabub Hossain, a staff member of the Bangladesh Institute of Development Studies (BIDS), Dhaka, is an outcome of IFPRI's continuing research efforts on the above issue. The report assesses the pace of diffusion of the seed-fertilizer-water technology in Bangladesh and the impact of this technology on the growth of production. It examines input use, productivity, and profitability of modern varieties of rice compared with traditional varieties. It evaluates the impact of technological progress on income distribution and alleviation of poverty by looking at the pattern of technology adoption among different groups of farmers and at the generation of employment for the landless in agriculture and in rural nonfarm activities through linkage effects of agricultural growth. The report concludes that in Bangladesh the new technology has opened up great opportunities to increase food production and farm income and that it has a fairly neutral income-distribution effect. The incidence of poverty is found to be substantially lower in technologically developed villages than in underdeveloped ones.

A major finding of this study is that the poor gain from the new technology through the operation of the labor market. As agricultural incomes and labor productivity increase, farm households substitute leisure for labor and supply less labor in the market. This redistributes agricultural employment from higher- to lower-income groups. Such redistribution, together with an increase in the demand for labor owing to the higher labor intensity of the modern rice varieties, puts an upward pressure on the wage rate and increases wage earnings from the same amount of labor. Some income adjustments may also take place between technologically developed and underdeveloped villages through operation of rural-rural migration of agricultural workers.

This study is one of a series of collaborative research efforts between IFPRI and BIDS since 1981. The fieldwork was carried out by BIDS in connection with a joint IFPRI/BIDS evaluation of the food-for-work program in Bangladesh, the final report of which was submitted in 1985. IFPRI is pleased to have provided support to the author in Washington, D.C., for analyzing the data and writing the present report. The study was partially funded by the Ford Foundation office in Dhaka, Bangladesh. IFPRI is grateful to the foundation for its encouragement and support of this work.

John W. Mellor

Washington, D.C.
July 1988

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1

SUMMARY

A major constraint to increasing food production in Bangladesh is the limited supply of land. There is little scope for expanding cultivable land beyond the 22 million acres from which the country now feeds more than 100 million people. The cultivated land area has remained unchanged since independence in 1971, although the population has increased by about 50 percent since then. The growth of cereal production since the early 1970s has barely managed to keep food imports at 10 percent of domestic demand despite a respectable progress in the diffusion of new agricultural technology, modern seed varieties of rice and wheat, and chemical fertilizers.

Technological progress is the key to maintaining the national food-population balance—and the scope for further diffusion of the new technology is vast. Only about a third of the rice and wheat area has been covered with modern-variety seeds, and the consumption of chemical fertilizers has reached 18 nutrient kilograms per acre. But because of the results of early studies on the "green revolution" in India, there is widespread apprehension in Bangladesh that diffusion of the new technology may contribute to worsening income inequality and deepening absolute poverty.

There have been few systematic and representative studies on Bangladesh that examined the effects of technological change at the farm and economy levels. In 1979-82 a survey was made of 2,400 sample farms in 117 villages throughout the country; a second large survey of 16 villages was completed in 1981-82. This study analyzes these two sets of survey data to assess the effects of modern rice technology on productivity and equity.

The yield of paddy is estimated at 1.34 metric tons per acre for modern varieties, compared with 0.65 ton for local varieties, and the estimated profit is Tk 2,300 and Tk 1,050, respectively. In Bangladesh, where land is so scarce and the size of landholdings so small, high profit per acre is important, but cost per ton of output is a more conclusive measure of profitability. The cost per ton of paddy output was Tk 3,700 for local varieties and Tk 3,000 for the new varieties, clearly demonstrating that the value of increased output exceeded the increased costs of growing the modern varieties. At 1984/85 prices the net return to family labor was Tk 87 per day for modern varieties and Tk 75 for local varieties, compared with the agricultural wage rate of Tk 24 per day.

Small farmers and tenants adopted the new technology as readily as did medium and large ones. Farmers operating less than 2.5 acres of land allocated 52 percent of their rice land to modern varieties, compared with 45 percent for those with 2.5-5.0 acres and 42 percent for those with 5.0 acres of land or more. The yield per acre was also higher on smaller farms. But profits and family income were lower on smaller farms because they paid about 25 percent higher water charges and about 10 percent higher wage rates than the large farms. The profits were substantially less on rented land, since the tenant has to pay 50 percent of the gross produce as rent and bear all costs of inputs. But the profits per acre on tenant farms were higher for the modern varieties than for local varieties. Diffusion of the new technology thus increases income for all groups of farmers, but also increases the inequality in the distribution of agricultural income among farm households.

To get an overall indication of the effect of new technology on income distribution, the survey villages were divided into two equal groups according to the degree to which the new technology was used. In the technologically developed villages, 54 percent of the land was irrigated and farmers allocated 61 percent to modern rice varieties, compared with 8 and 5 percent, respectively, for the underdeveloped villages. The difference in fertilizer use was eight times between the two groups of villages. In the developed villages, total household income was 29 percent higher and per capita income 22 percent higher than in the underdeveloped villages. However, the comparative patterns of income distribution for all rural households (including the landless) show a neutral effect for the new technology. The Gini concentration ratio of household income was the same (0.39) in the two groups of villages, but the concentration ratio measured along the per capita income scale was slightly higher in the developed villages (0.36) than in the underdeveloped ones (0.34). The comparison of income for the two groups of villages in the per capita income scale shows that the relative position of the bottom 40 percent of the households remained unchanged, while the top 20 percent gained relatively at the expense of the middle 40 percent. The proportion of population living below the poverty line was 32 percent in the developed villages and 47 percent in the underdeveloped villages.

The positive effect of the new technology on alleviation of poverty resulted from substantial increases in the income of the functionally landless households (which have less than 0.5 acre of land and are the bottom one-third of households in the landholding scale) through higher employment and wages. The annual income for this group of households was about Tk 14,300 in the developed villages compared with Tk 9,700 in the underdeveloped villages—the difference in income for the landless between the two groups of villages was almost equal to that for the large landowners (with 5.0 acres of land or more). The farmers used 45 percent additional labor in growing modern varieties. Irrigation, by increasing cropping by about one-third, also increased the demand for labor. But as income increases, higher-income households substitute leisure for labor and supply less labor in the market. The increased labor demand is met by more employment for the functionally landless in developed villages and for lower-income households in underdeveloped villages. Total employment was 4 percent higher in the developed villages; for the functionally landless group it was 26 percent higher. The new technology also puts a significant upward pressure on the wage rate, which is another factor behind increases in the income of the poor. The wage rate for agricultural labor was about 25 percent higher in the developed villages than in the underdeveloped ones.

The growth of income from the new technology expands the market for nonfarm goods and services. In the underdeveloped villages, households spent about 60 percent of the marginal budget on the output of the crop and forestry sectors, which are land-based; in the developed villages, the share was 47 percent. The marginal budget share of rural services, which are mostly labor-based, and in which the poor are more involved, was about 18 percent in developed villages and 7.5 percent in underdeveloped villages. The expenditure pattern thus appears to be another mechanism through which some benefits of the new technology trickle down to lower-income groups.

The increased income, however, does not promote capital accumulation in agriculture or in nonfarm activities. The rate of directly productive investment is estimated at 7.3 percent of total expenditure in the developed villages, compared with 11.7 percent in the underdeveloped villages. The high-income group spends proportionately more for improvement of housing and for transfers, such as purchases of land. Households in developed villages acquired about 32 percent of the land through the market, compared with 25 percent for underdeveloped villages. The impact of the new technology on the land market may cause further concentration of landholding and greater inequality in the distribution of agricultural income.

Thus there is a case for siphoning off from the upper income groups some of the surplus accumulated through technological diffusion. This may be achieved through higher agricultural taxation and the cost recovery of public investment in agriculture. It may be advisable to withdraw subsidies on sales of irrigation equipment to individuals, since such sales mostly benefit the large and medium landowners. A reallocation of public investment from major irrigation projects to small-scale projects with pumps and tubewells—to the extent it is technically feasible—may also save resources, because the cost recovery from large-scale projects has proved to be extremely difficult. The government will need additional resources from domestic sources for irrigation investment and for strengthening agricultural research, extension, and credit institutions to promote further diffusion of the new technology. The present low levels of cereal prices in international markets and political pressures from cereal-surplus developed countries suggest that it may be increasingly difficult for the government to mobilize foreign aid for this purpose.

2

INTRODUCTION

There are few countries in the Third World where technological progress is of higher importance in maintaining the food-population balance than in Bangladesh. The country now supports a population of more than 100 million people with a density of 700 per square kilometer. The growth rate of population, which has started declining only recently, is still about 2.3 percent a year. Since per capita income is extremely low, nearly two-thirds of the income is spent on food. The income elasticity of demand for food (mostly rice) is variously estimated at 0.53-0.73.[1] Thus, if the country is to maintain a modest per capita income growth of about 2 percent a year, which has been the case since it gained independence from Pakistan in 1971, food production has to grow at over 3.4 percent a year to avoid a further increase in cereal imports, which are currently about 10 percent of domestic demand.

But agriculture does not have the resources to meet that challenge. Practically all cultivable land is in use, and the pressure of increasing population reduced the average size of a farm holding from 3.53 acres in 1960 to 2.25 acres in 1983/84.[2] The increase in intensity of land use through raising additional crops during a year (cropping intensity), which was the major source of growth of crop production until the late 1960s, has slowed down considerably in recent years. Nearly 85 percent of the cropped land is devoted to production of cereals, indicating that there is little scope for diversion of land from nonfood to food crops. Since Bangladesh was densely populated decades earlier (200 persons per square kilometer in 1901), the possibility of increasing production through additional use of labor in individual crop varieties may also have been exhausted long ago.

Thus, rapid technological progress is the key to maintaining the food-population balance in the country. This was recognized by the government in the early 1960s. At that time farmers rarely used modern agricultural inputs such as chemical fertilizers and irrigation. Fertilizer application was limited to tea gardens and government experimental farms, and irrigation was practiced on about 7 percent of the land, using labor-intensive indigenous methods. The major constraints to application of modern agricultural inputs were the flooding of land during the rainy season and the lack of irrigation facilities during the dry season. Recognizing that farmers would not come forward to make indivisible investments in modern irrigation equipment because of the small farm size and the scattered and fragmented nature of holdings, the government set up the Bangladesh Water Development Board (BWDB), with responsibility for developing the water resources of the country through multipurpose flood control, drainage, and irrigation projects. At the same time, the Bangladesh Agricultural Development Corporation (BADC) was established to procure modern irrigation equipment,

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[1] For various estimates of the income and expenditure elasticity of the demand for food for Bangladesh, see Wahiduddin Mahmud, "Foodgrain Demand Elasticities of Rural Households in Bangladesh: An Analysis of Pooled Cross-Section Data," *The Bangladesh Development Studies* 7 (No. 1, 1979): 59-70; Bangladesh, Bureau of Statistics, *Report of the Bangladesh Household Expenditure Survey, 1981-82* (Dhaka: Ministry of Planning, 1986), pp. 34-39; and Raisuddin Ahmed, *Agricultural Price Policies under Complex Socioeconomic and Natural Constraints,* Research Report 27 (Washington, D.C.: International Food Policy Research Institute, 1981), pp. 52-56.

[2] Bangladesh, Bureau of Statistics, *The Bangladesh Census of Agriculture and Livestock: 1983-84,* vol. 1 (Dhaka: Ministry of Planning, 1986), pp.32-33.

chemical fertilizers, and improved seeds and distribute them among farmers at highly subsidized prices.

Thanks to the efforts of these institutions, Bangladesh has experienced some progress in the use of modern agricultural inputs over the last 25 years. The modern varieties (MVs) of rice seeds developed in international research stations were made available to farmers for dry season (boro) crops in 1968 and wet season (aman) crops in 1970, but their diffusion really picked up after the mid-1970s. By 1984/85 the area irrigated by modern methods had increased to about one-fifth of cultivated land. Irrigation, along with flood control and improved drainage, facilitated the spread of modern-input-responsive MVs, which now cover about one-fourth of cropped land and one-third of sown area under cereal crops. The expansion of irrigation and the shift of cropped land from traditional varieties to MVs have been the major factors behind the rapid growth in fertilizer consumption, which rose from insignificance in the early 1960s to about 18 kilograms of nutrients per acre of cropped land in 1984/85 despite the gradual withdrawal of a subsidy on this input since the mid-1970s.[3] The above figures also indicate that the potential for further increase in production through diffusion of modern technology is still vast. It largely depends on the capacity of the government to accelerate investment in irrigation, flood control, and drainage, which determines the expansion of the other two elements of modern technology—MV seeds and chemical fertilizers.

In Bangladesh, however, modern technology is widely believed to be contributing to worsening income inequality and deepening absolute poverty.[4] This view is prevalent among development thinkers and practitioners in the country as well as within the donor community that finances most of the investment in water resource development. The growth in crop production in the postindependence period has been faster than it was during the previous two decades (1950-71),[5] but studies based on household expenditure surveys show that absolute poverty afflicts two-thirds to four-fifths of the rural population and that it worsened alarmingly during the 1970s.[6] Other indirect evidences of the deteriorating economic condition of the rural poor in the 1970s are downward trends in the real wages of agricultural laborers and in the intake of energy and protein. The results of the national nutrition surveys show that the per capita daily energy intake declined by about 9 percent between 1962-64 and 1975/76, and another 7 percent by 1981/82.[7]

In view of the above observations, concerns are expressed about the role of modern technology in improving the condition of the poor. The hypothesis is that the effect of production growth from application of modern technology is felt much more on the increase in land and labor productivity, which is appropriated mainly by the higher-

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[3] For details of developments in the field of fertilizer consumption, see Bruce Stone, ed., *Fertilizer Pricing Policy in Bangladesh* (Washington, D.C.: International Food Policy Research Institute/Bangladesh Institute of Development Studies, 1987).

[4] See, for example, Mosharraf Hossain, A. Rashid, and Selim Jahan, *Rural Poverty in Bangladesh: A Report to the Like-minded Group* (Dhaka: Dhaka University Press, 1986); Willem van Schendel, *Peasant Mobility: The Odds of Peasant Life in Bangladesh* (Assen, the Netherlands: Van Gorcum, 1981).

[5] Mahabub Hossain, "Agricultural Development in Bangladesh: A Historical Perspective," *The Bangladesh Development Studies* 12 (December 1984): 29-57.

[6] Azizur R. Khan, "Poverty and Inequality in Rural Bangladesh," in *Poverty and Landlessness in Rural Asia,* ed. Keith Griffin and Azizur R. Khan (Geneva: International Labour Organisation, 1977); Quazi K. Ahmad and Mahabub Hossain, "An Evaluation of Selected Policies and Programs for Alleviation of Rural Poverty in Bangladesh," in *Strategies for Alleviating Poverty in Rural Asia,* ed. Rizwanul Islam (Bangkok: International Labour Organisation, Asian Employment Programme, 1985), pp. 67-98.

[7] Nazmul Hasan and Kamaluddin Ahmad, "Studies on Food and Nutrient Intake by Rural Population of Bangladesh," *Ecology of Food and Nutrition* 15 (No. 12, 1984): 143-158.

income groups, than on the generation of new employment or on the increase in wage rate from which the poor may gain. This impression is obtained from early studies on the "green revolution" in India. These studies argued that, although the new agricultural technology is scale neutral, small farmers cannot participate in its diffusion as much as large ones because the new crop varieties require a large amount of investment in purchased inputs that the poor cannot afford, and small farmers have little access to financial institutions from which working capital can be borrowed on reasonable terms. Also, by making agricultural enterprises more profitable for larger farmers, the new technology forces tenants off the land as tenancy evictions follow, and the new inflated surplus of the rich is used to buy out the marginal and small landholders, forcing them into landlessness. The net result, it is argued, is a rapid increase in the inequality of income and asset distribution and a worsening of rural poverty.[8]

A contrasting view, which has only recently been appreciated, is that the new technology may benefit the poor in the long run by (1) reducing the cost of production and thereby lowering the prices of food, and (2) generating more employment in nonfarm sectors by keeping real wages low and stimulating demand for nonfarm goods and services.[9] Since most of the income of the poor originates from labor, and their marginal propensity to consume food is very high, these indirect effects of technological progress are considered highly favorable. According to this view, if poverty increases it is because of technological progress too late and slow for its favorable effects to outweigh the unfavorable effects of high population growth,[10] and delays in adopting new technology will result in even more accentuation of poverty.

The above hypotheses regarding the nature and impact of the new agricultural technology have not yet been rigorously tested for Bangladesh. A large number of village studies have been undertaken to look into the effects of farm size and tenancy on productivity, and these studies provide information on adoption of MVs and use of fertilizer for different groups of farms.[11] But the studies are not based on a rigorous and systematic treatment of sufficiently large and disaggregated data, so the results are speculative and conjectural in nature and do not show any consistent pattern. The few rigorous attempts that have been made are based on data collected from one or two villages during the early 1970s when the technology had not progressed very far. The effect of the technology on employment and its indirect effects on nonfarm activity and on income distribution among rural households are also poorly documented. An in-depth investigation into the characteristics of the new technology and its effects on productivity and income distribution is overdue. This is the objective of this study.

Two large household surveys conducted in recent years provide disaggregated information that forms the basis of this study. The first of these was conducted by the

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[8] For a detailed articulation of this view, see Keith Griffin, *The Political Economy of Agrarian Change: An Essay on the Green Revolution* (Cambridge: Harvard University Press, 1974); and Andrew Pears, *Seeds of Plenty, Seeds of Want: Social and Economic Implications of the Green Revolution* (Oxford: Clarendon Press, 1980). For a detailed empirical study reporting the early results of the new agricultural technology in India, see B. H. Farmer, ed., *Green Revolution? Technology and Change in Rice-Growing Areas of Tamil Nadu and Sri Lanka* (London: Macmillan, 1977).

[9] For this view, see John W. Mellor, "Determinants of Rural Poverty: The Dynamics of Production, Technology, and Price," in *Agricultural Change and Rural Poverty*, ed. John W. Mellor and Gunvant M. Desai (Baltimore and London: Johns Hopkins University Press, 1985, pp. 21-40); and John W. Mellor, "Food Price Policy and Income Distribution in Low-Income Countries," *Economic Development and Cultural Change* 27 (October 1978): 1-26.

[10] This is supported by M. L. Dantwala, "Technology, Growth, and Equity in Agriculture," in Mellor and Desai, *Agricultural Change and Rural Poverty*, pp. 110-123.

[11] A survey of the results of these studies can be obtained from Robert W. Herdt and L. Garcia, "Adoption of Modern Rice Technology: The Impact of Size and Tenure in Bangladesh," International Rice Research Institute, Manila, 1982 (mimeographed).

International Fertilizer Development Center (IFDC) in collaboration with the Bangladesh Agricultural Research Council to study the distributional consequences of fertilizer use. This is the most comprehensive farm survey conducted so far in the country. The survey work started with the 1979 aman season crops and continued for 10 consecutive seasons up to the 1982 aman season crops. A multistage, random sampling method was used in the survey, which ultimately covered 2,400 sample farms and about 10,000 sample plots in 117 villages from 20 upazilas scattered throughout 16 of the 21 Bangladesh (old) districts. Detailed input-output data were collected at the plot level for all crops, disaggregated by the type of technology used. The unpublished plot- or farm-level data were not available, but detailed disaggregated information was presented at the crop and technology levels in the published reports of the survey,[12] which has been used here for analyzing the nature of modern varieties of rice vis-à-vis traditional ones.

The second survey was conducted by the International Food Policy Research Institute in collaboration with the Bangladesh Institute of Development Studies to evaluate the development effects of the infrastructure created under the food-for-work program in the country.[13] The survey was conducted in 16 selected villages scattered through the four administrative divisions of the country and represents the principal ecological zones. A census of all households in the selected villages was carried out to serve as the sample frame for the study. The households were classified into eight groups based on the size of the landholding (four groups) and the occupation of the head of household (agriculture or nonagriculture). A proportionate random sample was then drawn from each stratum so as to have 40 households in each village. The total sample size thus consists of 640 households and about 5,200 plots operated by them. A few sample households could not be included in the analysis because of missing observations and doubtful information. The author was involved in the design and implementation of the survey.

The fieldwork was conducted from September 1981 to January 1983, administering five sets of structural questionnaires to collect information on the pattern of land use at the plot level in calendar year 1981, costs and returns for various crops grown at the farm level during 1982, and employment, income, investment, and consumption at the household level for 1982. The disaggregated household and plot data have been analyzed here to investigate the effects of the modern technology on productivity, employment, and income.

The villages studied represent a wide range of development of modern rice technology (see Table 1). In five villages, less than 5 percent of the cropped area was covered by modern varieties of rice, while in four others more than 70 percent of the area was covered by MVs. The variation is mainly the result of access to irrigation facilities, which have been developed primarily by the government during the last two decades and mostly through foreign assistance. Such facilities were almost nonexistent in four of the villages, two of them located in the coastal district of Khulna, where salinity of the water makes irrigation development difficult. In three other districts, some of the area was irrigated by indigenous methods (swing baskets and wooden lifters called *dhones*). At the other end, there were irrigation facilities for more than 50 percent of the cultivated land in five villages, three of them located in Comilla, where irrigation

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[12] International Fertilizer Development Center, *Agricultural Production, Fertilizer Use, and Equity Considerations: Results and Analysis of Farm Survey Data, 1979/80* and *1981/82* (Muscle Shoals, Ala.: IFDC, 1982, 1984).

[13] Bangladesh Institute of Development Studies/International Food Policy Research Institute, *Development Impact of the Food-for-Work Program in Bangladesh,* a report submitted to the World Food Programme (Washington, D.C.: International Food Policy Research Institute, 1985).

Table 1—Basic characteristics of villages under study, 1982

Village	District	Average Size of Land-holding	Average Household Size	Share of Land Irrigated	Share of Cropped Land Under Modern Varieties of Rice	Fertilizer Consumption per Acre of Cropped Land[a]	Share of Crop Area Under Tenancy
		(acres)	(persons)	(percent)	(percent)	(kilograms)	(percent)
Developed area		2.26	6.52	53.8	61.4	82.2	16.0
Chasapara	Comilla	2.14	6.80	86.9	99.5	126.4	16.4
Illashpur	Comilla	1.67	6.78	56.3	73.2	133.6	21.1
Khunta	Comilla	1.80	6.23	83.3	83.2	130.4	15.8
Harishpur	Jessore	3.72	6.88	52.9	81.0	94.3	27.1
Rawtora	Pabna	0.98	6.89	58.0	46.9	65.1	2.5
Rajarampur	Dhaka	2.61	5.40	32.9	33.9	22.2	17.1
Charkhamar	Dhaka	2.50	6.40	42.4	25.7	30.3	4.7
Bandabeel	Kushtia	2.65	6.79	36.3	24.7	32.4	13.5
Underdeveloped area		2.26	6.35	8.0	5.2	10.8	15.9
Govindapur	Dhaka	2.36	5.43	20.4	13.8	14.1	7.8
Sayedpur	Dhaka	2.03	6.30	8.8	3.2	6.9	12.9
Patgari	Pabna	1.77	6.68	12.6	10.4	13.1	5.0
Roakuli	Kushtia	3.41	6.63	3.8	4.0	18.1	3.6
Gobrapara	Jessore	3.62	7.53	3.9	0.0	7.9	19.5
Khejurdanga	Khulna	1.61	5.62	13.8	17.2	30.1	14.8
Birhat	Khulna	1.84	6.25	0.0	0.0	1.0	36.2
Taliamara	Khulna	1.45	5.05	0.0	0.0	1.3	45.7

Source: Based on data from Bangladesh Institute of Development Studies/International Food Policy Research Institute field survey.

[a] The figures for fertilizer are in weights of materials (urea, phosphate, and potash), not in nutrients, which are difficult to measure accurately in the absence of information on the use of these different types of fertilizer. An approximate nutrient content may be obtained by multiplying the figures by 0.46.

facilities were developed early (in the 1960s) by the Comilla cooperative movement. The consumption of chemical fertilizer ranges from almost insignificant in the villages in Khulna to about 130 kilograms per cropped acre in the villages in Comilla and is highly related to the proportion of area under MVs.

One method used in this paper to assess the impact of technology is to compare mean values of the variables in the technologically developed and underdeveloped villages. Since only about one-fifth of the area in Bangladesh had irrigation facilities at the time of the survey, a 20 percent irrigated area was used as the cutoff figure for classifying the villages into two groups. This also divides the sample into two equal size groups, with eight villages and 317 households in each group. In the developed villages more than 60 percent of the cropped land was sown with MVs of rice, compared with only 5 percent in the underdeveloped villages. The developed villages used 82 kilograms of fertilizer per acre of cropped land compared with 11 kilograms for the underdeveloped ones (Table 1).

The pattern of land distribution for the sample households is shown in Table 2. About 30 percent of the households own up to 0.5 acre, which is considered in Bangladesh as functionally landless. This category is estimated by the recent agricultural census of Bangladesh (1983-84) at 46 percent.[14] At the other end, about 10 percent of the households own 5.0 acres or more; these are large farmers by the Bangladesh standard. Their proportion for the country as a whole is estimated at 8.5 percent. The

[14] Bangladesh, *Census of Agriculture and Livestock*, p. 81.

Table 2—Distribution pattern of landownership in sample, 1982

Landownership Group	Number of Samples	Share of Households	Share of Land Owned	Share of Population	Average Amount of Land Owned
(acres)		(percent)	(percent)	(percent)	(acres)
Developed area	317	100.0	100.0	100.0	2.26
Less than 0.5	97	30.6	2.0	25.6	0.17
0.5–2.5	103	32.5	16.6	29.6	1.16
2.5–5.0	80	25.2	36.1	28.6	3.24
5.0–7.5	20	6.3	16.7	8.2	5.90
7.5 or more	17	5.4	28.6	8.0	12.07
Underdeveloped area	317	100.0	100.0	100.0	2.26
Less than 0.5	94	29.7	2.0	23.1	0.15
0.5–2.5	111	35.0	17.4	33.8	1.13
2.5–5.0	81	25.6	38.1	29.1	3.37
5.0–7.5	17	5.4	14.8	6.6	6.24
7.5 or more	14	4.4	27.7	7.4	14.17
Total sample	634	100.0	100.0	100.0	2.26
Less than 0.5	191	30.1	2.0	24.4	0.15
0.5–2.5	214	33.8	17.0	31.7	1.14
2.5–5.0	161	25.4	37.1	28.8	3.31
5.0–7.5	37	5.8	15.7	7.4	6.10
7.5 or more	31	4.9	28.1	7.8	13.02

Source: Based on data from Bangladesh Institute of Development Studies/International Food Policy Research Institute field survey.
Note: Parts may not add to totals because of rounding.

average size of landownership for the sample is 2.26 acres, compared with 2.0 acres for Bangladesh. Thus the degree of landlessness is lower and the amount of land owned is higher for the sample than for Bangladesh. The pattern of land distribution is, however, very similar in the technologically developed and underdeveloped villages. The two groups have the same average size of landownership and the same proportion of landless households. The proportion of large farmers and their share of total land is, however, slightly higher in the developed villages. The proportion of area cultivated by tenants varies widely across villages, but the averages for the two groups of villages are similar (Table 1).

As a background to the detailed microlevel analysis that follows, Chapter 3 gives an overview of the technological progress in Bangladesh and its impact on agricultural growth and on trends in relative prices, using national data for 1950-85. The characteristics of modern varieties of rice vis-à-vis traditional ones, in terms of the use of various inputs and the implications for cost of production and profits, are described in Chapter 4, using detailed input-output information provided by the IFDC survey. The impact of technology on the productivity of land and labor and on the efficiency of resource use is analyzed in Chapter 5 through estimation of production functions and profit functions. Chapter 6 is a study of the effect of farm size and tenure on adoption of the new technology in order to assess the consequences of technological progress on the distribution of income among various groups of farmers.

To complete the assessment of equity implications of the technological diffusion, the employment effects are traced in Chapter 7 by an analysis of the supply of and demand for labor for different groups of households in the technologically developed and underdeveloped villages. Estimates of labor supply functions with disaggregated household information and of the effect of technological change on the agricultural wage rate are also given in this chapter. The issue of the indirect effects of the new technology on generation of employment and income for the poor through expansion of the market for nonfarm goods and services is taken up in Chapter 8, and the investment behavior of different landholding groups and the effects of growth of income on the land market are analyzed. The effects of technology on the level and distribution of income and on alleviation of rural poverty are summarized in Chapter 9. Finally, the implications of the major findings of the study for policies to promote rural development are discussed in Chapter 10.

3

TECHNOLOGICAL PROGRESS AND GROWTH OF CROP PRODUCTION—A MACRO PICTURE

Resource Base and the Need for Technological Progress

Continuous high growth of population has made Bangladesh an extremely land-scarce country, and land can no longer be counted as an important source of growth of agricultural production. The total area of the country is 35 million acres, of which about 60 percent is cultivated and most of the remainder is under forests, rivers, and homesteads (see Table 3). There has been little increase in cultivated land since the early 1950s (see Figure 1), and by the end of the 1960s, a type of equilibrium had been reached in the land use pattern that has since changed very little. During 1980-85, the wasteland that could be reclaimed for cultivation was only 1.9 percent of total land.

The effective supply of land could, however, be raised by growing additional crops on the same land during the year. This is indeed one of the means by which production has been increased from this limited resource base. In the early 1950s, only one-fourth of the total land was cropped more than once during the year. The intensity of cropping increased very rapidly in the 1960s—from about 130 percent in 1960/61 to 148 percent by 1969/70. The cropping intensity continued to increase after independence in 1971, but the rate of increase has slowed down (Figure 1 and Table 4). Further increase would depend on expansion of irrigation facilities, which allow the growing of additional crops on seasonally fallow land during the dry winter season (boro).

The majority of the people continue to depend on land for their livelihood because of limited expansion of nonagricultural sectors. Such expansion is inhibited partly by the small size of internal markets for nonagricultural goods and services and is perpetuated by low levels of income. The value added that is generated by manufacturing

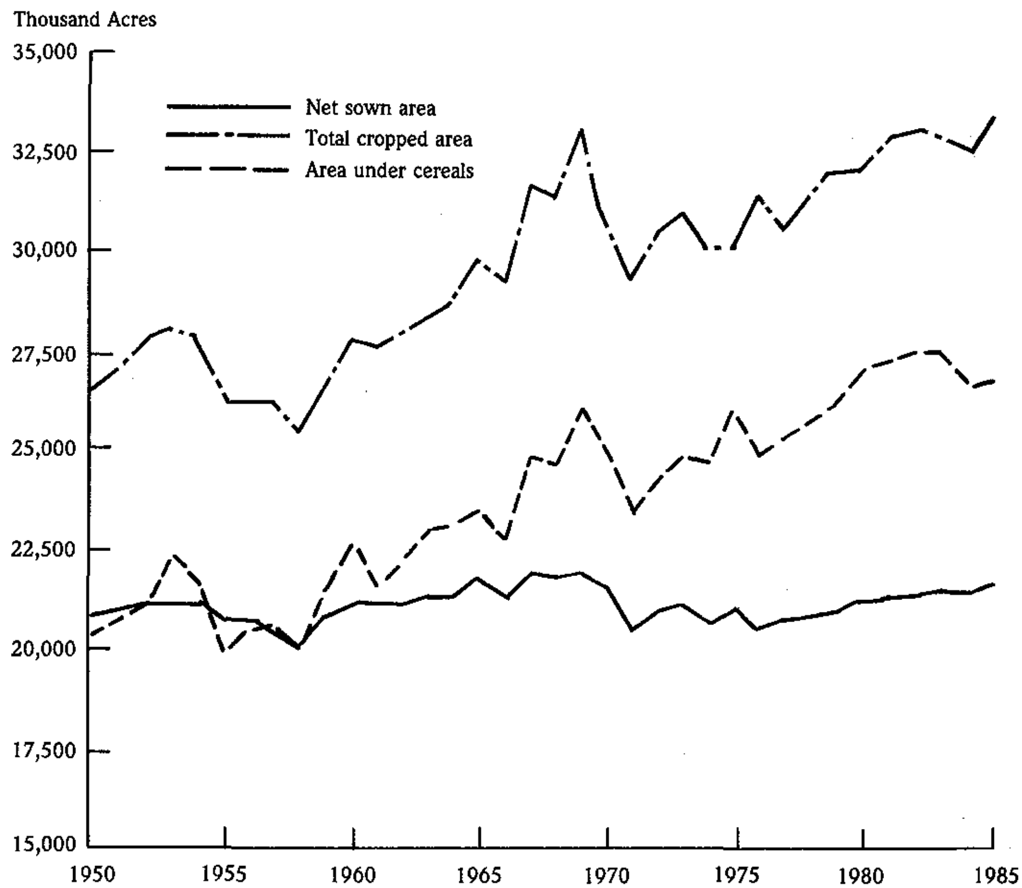
Table 3—Changes in pattern of land use, 1950-85

Land Use	1950-53 Area	1950-53 Share of Total	1967-70 Area	1967-70 Share of Total	1980-85 Area	1980-85 Share of Total
	(million acres)	(percent)	(million acres)	(percent)	(million acres)	(percent)
Cultivated land	20.7	58.7	21.7	61.5	21.3	60.0
Current fallow	1.6	4.4	0.8	2.1	1.3	3.6
Cultivable waste	2.1	5.8	0.9	2.5	0.7	1.9
Forest	5.5	15.7	5.5	15.7	5.3	15.0
Not available for cultivation (rivers, canals, homesteads, etc.)	5.4	15.3	6.4	18.2	6.9	19.2
Total land	35.3	100.0	35.3	100.0	35.4	100.0

Sources: Based on data from Pakistan, Central Statistical Office, *25 Years of Pakistan in Statistics* (Karachi: Government Press, 1972); and Bangladesh, Bureau of Statistics, *Statistical Pocket Book of Bangladesh, 1986* (Dhaka: Ministry of Planning, 1987).

Note: Parts may not add to totals because of rounding.

Figure 1—Trends in cultivated area and cropped area, 1950-85



is only about 10 percent of the gross domestic product, and the share of construction, trade, and transport services is another 20 percent. The 1983/84 labor force survey has recorded that only 8 percent of the civilian labor force is employed in manufacturing, 17 percent in construction, trade, and transport services, and 12 percent in other services.[15] Agriculture still provides employment to about 60 percent of the labor force.

Owing to the population pressure and lack of nonagricultural employment, the land is cultivated in very small holdings. Also, holdings are fragmented into many scattered plots because of Islamic laws of property inheritance. The 1977 agricultural census found that two-fifths of the farms had more than 10 fragments.[16] The small farm, defined as under 2.5 acres, is the dominant production unit. With traditional technology, such a farm is incapable of producing a subsistence income, so most small farmers also work as agricultural wage laborers and engage in various nonfarm activities during

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[15] Bangladesh, Bureau of Statistics, *Final Report: Labour Force Survey, 1983-84* (Dhaka: Ministry of Planning, 1986).

[16] Bangladesh, Bureau of Statistics, *Report on the Agricultural Census of Bangladesh, 1977* (Dhaka: Ministry of Planning, 1981).

Table 4—Changes in intensity of land use, 1950-85

Intensity of Use	1950-53 Area	1950-53 Share of Total Cultivated Land	1967-70 Area	1967-70 Share of Total Cultivated Land	1980-85 Area	1980-85 Share of Total Cultivated Land
	(million acres)	(percent)	(million acres)	(percent)	(million acres)	(percent)
Single-cropped	14.6	70.5	12.6	58.1	11.4	53.5
Double-cropped } Triple-cropped }	6.1	29.5				
Double-cropped			7.9	36.4	8.2	38.5
Triple-cropped			1.2	5.5	1.6	7.5
Total cropped area	26.8	129.5	32.0	147.4	32.7	153.5

Sources: Based on data from Pakistan, Central Statistical Office, *25 Years of Pakistan in Statistics* (Karachi: Government Press, 1972); and Bangladesh, Bureau of Statistics, *Statistical Pocket Book of Bangladesh, 1986* (Dhaka: Ministry of Planning, 1987).

Note: Parts may not add to totals because of rounding.

slack agricultural seasons to augment the income from farming. The proportion of small farmers increased from about a half in 1960 to over two-thirds by 1983/84, and they now cultivate about a third of total land (see Table 5). During the same period, the proportion of large farmers declined from 11 to 5 percent and the area operated by them fell from two-fifths to one-fourth of total land. The above landholding characteristics imply that there are few farmers who can generate enough surplus for reinvestment in agriculture, particularly in indivisible assets such as irrigation equipment.

While land is extremely scarce, Bangladesh is known to have abundant water resources, for which planned use in agricultural production was almost nonexistent even by the early 1960s. Three major rivers, the Ganges, the Brahmaputra, and the Meghna, and their numerous tributaries flow through Bangladesh and discharge huge volumes of water. Heavy rainfall and the geological structure produce excellent supplies of groundwater, which is available up to a depth of about 12 meters in most regions and at less than 6 meters in large parts of the country, and hence can be developed at relatively low cost. The recently completed National Water Plan estimates that nearly 40 percent of the cultivated land can be irrigated by development of surface water

Table 5—Changes in distribution pattern of landholdings, 1960-83/84

Farm Size	Share of Holdings 1960	Share of Holdings 1983/84	Share of Area Operated 1960	Share of Area Operated 1983/84	Average Size of Farm 1960	Average Size of Farm 1983/84
(acres)	(percent)		(percent)		(acres)	
Less than 1.0	24.3	40.4	3.2	7.8	0.47	0.44
1.0–2.5	27.3	29.9	13.0	21.2	1.68	1.60
2.5–5.0	26.3	18.0	26.4	27.5	3.55	3.45
5.0–7.5	11.4	6.8	19.3	17.6	6.00	5.91
7.5 or more	10.7	4.9	38.1	25.9	12.60	11.85
All farms	100.0	100.0	100.0	100.0	3.54	2.26

Sources: Based on data from Pakistan, Agricultural Census Organization, *1960 Census of Agriculture* (Karachi: Government Press, 1962), vol. 2, *East Pakistan;* and Bangladesh, Bureau of Statistics, *The Bangladesh Census of Agriculture and Livestock: 1983-84,* vol. 1 (Dhaka: Ministry of Planning, 1986).

through water conservation measures and withdrawing of streamflows from rivers.[17] The groundwater resource potential is estimated, on the basis of 75 percent usable recharge, at 17,140 million cubic meters, which can irrigate about 9.4 million acres, or about 45 percent of the cultivated land. Currently only about 20 percent of total land is irrigated. Obviously, there is a vast potential for further development of water resources in the country.

The new varieties of rice and wheat, developed by the international agricultural research stations and introduced to farmers in Bangladesh in the late 1960s, opened up the possibility of increasing the food supply on the limited land through development of water resources. The new varieties produce a substantially higher amount per unit of land compared with the traditional varieties, but they need careful water management and large amounts of chemical fertilizer, without which they fare no better than traditional varieties. Thus, production could be increased by shifting land from traditional to modern varieties (popularly known as "seed-fertilizer" technology), provided the land has access to flood control, drainage, and irrigation facilities. At the same time, expansion of irrigation facilities would increase the effective supply of land during the dry winter season when a large proportion of land is kept fallow because of inadequate moisture in the soil. The diffusion of new technology supported by the development of water resources is thus the key to maintaining the food-population balance in the country.

Diffusion of Modern Technology

The New Seeds

Experiments in the management of rice seed improvement have been conducted at the Dhaka Research Station since 1911, but a set of MVs was imported in the late 1960s to support the accelerated food production program sponsored by the Ford Foundation.[18] During the 1970s, large quantities of MV seeds were imported from the International Rice Research Institute (IRRI) in the Philippines and from India.

In 1970 the Bangladesh Rice Research Institute (BRRI) was set up to develop varieties better suited to local growing conditions. By 1983, BRRI had introduced 16 short-duration modern varieties. The newer varieties have yield rates similar to the earlier ones, but are superior in disease resistance and grain quality. Rice is grown in three distinct seasons: aus (April to August), aman (August to December), and boro (January to May). The new varieties have been introduced in all three seasons. In addition, a number of improved wheat varieties have been imported from the Centro Internacional de Mejoramiento de Maiz y Trigo (CIMMYT) in Mexico and from India and have been propagated on the seed multiplication farms of the Bangladesh Agricultural Development Corporation (BADC) for distribution among farmers. The most popular wheat variety is Sonalika, which was bred in India with materials from CIMMYT and its predecessors based on Mexican material.[19]

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[17] Bangladesh, Master Plan Organization, *National Water Plan Project: Draft Final Report,* vols. 1 and 2 (Dhaka: Ministry of Irrigation and Flood Control, 1985).

[18] Dana G. Dalrymple, *Development and Spread of High Yielding Rice Varieties in Developing Countries* (Washington, D.C.: U.S. Agency for International Development, 1986), p. 39.

[19] Carl E. Prey and Jock R. Anderson, *Bangladesh and the CGIAR Centers: A Study of Their Collaboration in Agricultural Research,* Study Paper 8 (Washington, D.C.: World Bank, 1985), p. 43.

The official statistics on the expansion of area under modern seed varieties of rice and wheat are given in Table 6. The figures show that use of the new seeds was negligible up to the end of the 1960s, but picked up rapidly in the 1970-74 period, which was followed by stagnation during 1974-78. The expansion, however, resumed during 1978/79 and continued through 1984/85 at a rate of about 600,000 acres a year, which doubled the area covered by the new seeds within seven years.

The apparent stagnation in the MV area in the mid-1970s may be statistical rather than real. The Ministry of Agriculture set up task forces in 1974 and 1975 to evaluate the progress of MV aman and wheat programs, and their field investigations revealed substantial overreporting of MV aman acreage and minor underreporting of MV wheat acreage.[20] Recognizing that the early information on MV expansion was overreported, the Bangladesh Bureau of Statistics made substantial downward adjustments in the area under aman and boro MVs for 1974/75-1976/77.[21] In view of this adjustment it could be argued that the diffusion of new seed varieties has proceeded steadily since their introduction in the late 1960s.

By 1985 nearly one-third of the cereal area had been covered by the new seeds. Nearly two-thirds of the MV area is cropped during the overlapping boro and aus

Table 6—Expansion of area under modern-variety (MV) seeds, 1967-86

	Rice MVs				Rice and Wheat MVs	
Year	Boro Season	Aus Season	Aman Season	Wheat MVs	Total Area	Share of Total Rice and Wheat Area
		(1,000 acres)		(1,000 acres)	(1,000 acres)	(percent)
1967/68	156	...	...	...	156	0.6
1968/69	361	17	...	...	378	1.5
1969/70	580	43	29	...	652	2.5
1970/71	857	79	200	...	1,136	4.6
1971/72	793	121	625	...	1,539	6.7
1972/73	1,087	163	1,378	52	2,680	11.1
1973/74	1,455	329	2,043	72	3,899	15.8
1974/75	1,630	699	1,240	82	3,651	14.9
1975/76	1,588	872	1,376	217	4,053	15.7
1976/77	1,338	902	1,046	288	3,574	14.2
1977/78	1,586	981	1,233	388	4,188	16.6
1978/79	1,650	1,055	1,694	583	4,892	19.4
1979/80	1,788	994	2,154	1,015	5,953	22.7
1980/81	1,845	1,200	2,376	1,412	6,833	25.4
1981/82	2,218	1,166	2,361	1,277	7,022	25.8
1982/83	2,670	1,175	2,653	1,231	7,729	28.2
1983/84	2,635	1,235	2,628	1,475	7,973	28.3
1984/85	3,040	1,151	2,669	1,622	8,482	31.5
1985/86	2,998	1,191	2,906	1,291	8,386	31.0

Sources: Based on data from Bangladesh, Bureau of Statistics, *Yearbook of Agricultural Statistics,* various issues (Dhaka: Ministry of Planning, various years); and Bangladesh, Bureau of Statistics, *Monthly Statistical Bulletin of Bangladesh,* various issues.

[20] Bangladesh Agricultural Development Corporation, *HYV Task Force Reports, 1974/75* (Dhaka: BADC, 1977).

[21] See Mahabub Hossain, "Foodgrain Production in Bangladesh: Performance, Potential and Constraints," *The Bangladesh Development Studies* 8 (Nos. 1 and 2, 1980): 39-70.

seasons, when the crops are grown with irrigation. About 97 percent of the area under wheat has been covered by MVs, which have expanded largely at the expense of minor dry season crops such as oilseeds and pulses. The MV wheat area, however, constitutes only 15 percent of the MV cereal area. For rice, the coverage is about 78 percent for the boro season, 16 percent for the aus season, and 20 percent for the aman season. A major constraint to expansion of the MV area during the aman season is that more than two-thirds of the area remains under deep water throughout the season and is not suitable for growing the dwarf MVs.

Development of Irrigation Facilities

Before modern irrigation was introduced in Bangladesh, cultivators used to irrigate boro paddy by lifting surface water through such traditional devices as swing baskets and *dhones.* The 1960 agricultural census estimated that in 1959/60 nearly 7 percent of the cultivated land received irrigation by these traditional methods, mostly concentrated in the depressed basins of Sylhet, Mymensingh, and Rajshahi districts, where surface water was available at a height of 1-2 meters below the field during the driest months of the year.[22] The subsequent development of modern irrigation has partly replaced these traditional sources of irrigation, and the area under traditional irrigation reportedly declined from about 1.5 million acres in 1970/71 to 0.9 million acres by 1984/85.[23]

The initiative for development of modern irrigation facilities had been taken by the government, since farmers were unwilling or unable to make large, lump-sum investments in irrigation equipment. The major constraint has been the small average size of farms and the fragmented holdings. During 1976-84 the government expenditure for development activities in the agricultural sector was Tk 7,720 million a year, of which Tk 3,200 million (42 percent) was spent for irrigation and flood control.[24] The projects were financed mainly with foreign aid.

The government's earliest approach to expansion of irrigation facilities was through construction of large-scale multipurpose irrigation, flood control, and drainage projects carried out by the Bangladesh Water Development Board (BWDB). A number of major projects built during the 1960s and 1970s have been largely successful in protecting coastal and river belt areas from saline-water intrusion and floods, but they played only a minor role in the irrigation development of the country. The area irrigated by such projects constitutes only about one-tenth of the total area irrigated in Bangladesh. The provision of irrigation through the BWDB projects has been costly, since both the capital and current costs are borne almost entirely by the government.[25]

Most irrigation development in Bangladesh has taken place through use of small-scale equipment such as low-lift pumps, deep tubewells, and shallow tubewells. Up to the mid-1970s, expansion followed upon subsidized rental to farmers' cooperatives of low-lift pumps with a capacity of 1-2 cubic feet per second (see Table 7). The number of pumps under operation rose quickly from about 3,000 in 1965/66 to about 35,000 by 1973/74, but expansion since then has been slow. In 1978/79 the government

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[22] Pakistan, Agricultural Census Organization, *1960 Pakistan Census of Agriculture,* vol. 1, *East Pakistan* (Karachi: Ministry of Food and Agriculture, 1962).

[23] Bangladesh, Bureau of Statistics, *Yearbook of Agricultural Statistics* (Dhaka: Ministry of Planning, 1982); and Bangladesh, Bureau of Statistics, *Monthly Statistical Bulletin of Bangladesh,* March 1986.

[24] At the 1984/85 official rate of exchange, US$1.00 = Tk 30.

[25] See Siddiqur R. Osmani and M. Abul Quasem, "Pricing and Subsidy Policies for Bangladesh Agriculture," Bangladesh Institute of Development Studies, Dhaka, 1985 (mimeographed), pp. 134-137.

Table 7—Development of modern irrigation facilities, 1960-85

Year	Units of Irrigation Equipment Under Operation: Low-lift Pumps	Deep Tubewells	Shallow Tubewells	Area Irrigated by Modern Methods[a]: Acres	Share of Cultivated Land	Total Area Irrigated: Acres	Share of Cultivated Land
		(thousands)		(thousands)	(percent)	(thousands)	(percent)
1960/61	1.4	...	...	62	0.3	1,433	7.0[b]
1965/66	3.4	...	...	200	0.9	n.a.	n.a.
1969/70	17.9	1.0	...	830	3.8	2,613	12.0
1973/74	35.3	1.5	1.0	1,501	7.2	3,201	15.3
1974/75	35.5	2.7	2.4	1,564	7.5	3,562	17.0
1975/76	36.4	3.8	4.0	1,606	7.6	3,458	16.5
1976/77	28.2	4.5	5.4	1,341	6.6	3,004	14.7
1977/78	36.7	7.5	12.3	1,951	9.4	3,223	15.8
1978/79	35.9	9.3	17.0	2,295	11.0	3,903	18.9
1979/80	37.4	9.8	22.4	2,638	12.6	4,226	20.3
1980/81	36.1	10.1	38.4	3,033	14.3	4,520	21.4
1981/82	38.2	11.5	66.5	3,626	17.1	5,076	23.9
1982/83	42.2	13.8	104.1	4,036	19.0	5,345	25.1
1983/84	43.7	15.5	109.7	4,313	20.2	5,432	25.4
1984/85	49.8	16.7	137.0	4,579	21.5	5,483	25.7

Sources: Based on data from Bangladesh Agricultural Development Corporation, *Annual Report*, various issues (Dhaka: Government Press, various years); Bangladesh, Ministry of Finance, *Bangladesh Economic Survey*, various issues (Dhaka: Government Press, various years); Bangladesh Agricultural Development Corporation, "Sale of Shallow Tubewells in the Northwest and South-eastern Districts of Bangladesh," BADC, Dhaka, 1984 (mimeographed); and Pakistan, Agricultural Census Organization, *1960 Census of Agriculture* (Karachi: Government Press, 1962), vol. 2, *East Pakistan*.

Note: n.a. means not available.

[a] Figures for shallow tubewells include those fielded by the Bangladesh Krishi Bank, as estimated in Bangladesh Agricultural Development Corporation, "Sale of Shallow Tubewells." The area irrigated as reported in this table exceeds the figure provided by the Bangladesh Bureau of Statistics because of this discrepancy, as the latter did not include the area irrigated by these shallow tubewells.

[b] For 1959/60, as estimated in Pakistan's 1960 agricultural census.

started selling pumps to individual farmers and cooperatives. The subsidy remains at about 30 percent of the procurement cost.[26]

The promotion of groundwater development started late, beginning in 1967/68, and moved at a slow pace through 1977/78. Initially, deep tubewells were rented to bona fide farmers' cooperatives, which formed groups of water-users with contiguous plots totaling at least 50 acres. The groups would bear the operation cost and pay a highly subsidized pump rental to BADC. Beginning in 1978/79, the government started selling deep tubewells to groups and private individuals at a subsidy of about 70-80 percent. The number of deep tubewells increased gradually from 800 in 1970/71 to about 4,500 by 1976/77 and then more rapidly to about 16,700 by 1984/85.

The spurt of expansion of irrigation, however, began in the mid-1970s with the promotion of small-capacity (less than 0.5 cubic foot per second) shallow tubewells. From the beginning, these were sold to farmers almost at cost, but most of the purchases were financed by loans from the Bangladesh Krishi Bank (agricultural development bank), a large proportion of which were not repaid. The sales of shallow tubewells

[26] Osmani and Quasem, "Pricing and Subsidy Policies," pp. 291-296.

increased rapidly during 1979-83 but have slackened since then. The tubewells now account for over half of the total irrigated area in the country.

The reasons behind the slowdown of the sales of minor irrigation equipment have not yet been investigated thoroughly. It is conjectured that the tightening of disciplines regarding recovery of institutional loans and reduction in farmers' cash income due to low prices of jute may be the major factors. Further expansion may also be constrained because relatively large farms that can afford private investment in irrigation equipment have already been covered, and the government will have to tackle the more difficult problem of organizing the small and medium farms into cooperatives. The 1983-84 agricultural census found that only 89,000 rural households owned more than 15 acres of land (the command area of a shallow tubewell), and according to a World Bank estimate, there are already more than 170,000 shallow tubewells in the country.[27]

Official statistics on the area irrigated by different methods are known to be of dubious quality. The figures provided by different agencies in charge of irrigation development are not consistent with the figures published by the Bangladesh Bureau of Statistics, which probably underestimates the area irrigated by shallow tubewells sold through the private sector by the Bangladesh Krishi Bank. It is also reported in a number of field surveys that some of the equipment sold to farmers may be used for nonagricultural purposes.[28] The margin of error, however, may not be very large, as the 1983-84 agricultural census estimates the irrigated area at 1.62 million acres, against the official estimate of the area irrigated by modern methods at 1.75 million acres for that year.

The time series data on irrigated land, compiled from the figures released by BADC, BWDB, and the Ministry of Finance, are represented in Table 7. Modern irrigation, though almost negligible through the late 1960s, has developed rapidly since 1977/78. Still, only about one-fourth of the cultivated area is irrigated and about one-fifth is irrigated by modern methods. The potential for further development of irrigation is thus considerable.

Economic analysis of various modes of irrigation conducted by the National Water Plan on the basis of (1) the observed cropping pattern and input-output coefficients, and (2) shadow prices of inputs and output, gives a rate of return on investment of 35 percent for large flood control, drainage, and irrigation projects and more than 90 percent for minor irrigation equipment.[29] The incentive for farmers to invest in small-scale irrigation equipment has also been examined by the National Water Plan, using a cash-flow analysis, at the existing terms of loans from the financial institutions. The analysis shows that individual farmers have enough incentives to invest in shallow tubewells and low-lift pumps, but for deep tubewells private investment is not financially feasible at existing terms. However, investment through cooperatives provides ample financial incentives.

In spite of high profitability, the government achieved only 25 percent of the planned targets for irrigation expansion during the First Five-Year Plan (1973-78), and 71 percent during the Second Five-Year Plan (1980-85). The major constraints to expansion of irrigation seem to be (1) poor financial capacity owing to the low income

[27] Bangladesh, *Census of Agriculture and Livestock.*

[28] See, for example, M. Abdul Hamid, *Low-Lift Pumps under IDA Credit in South-East Bangladesh: A Socio-Economic Study,* Rural Development Studies, Series 12 (Rajshahi: Rajshahi University, Department of Economics, 1984).

[29] Bangladesh, *National Water Plan Project.*

of the farmers, low tax-GNP ratio, and inability of the government to recoup the investment cost from the beneficiary; (2) low implementation capacity of public institutions, which often leads to time and cost overruns in project implementation; (3) differential pricing of water by BADC and BWDB and of different equipment by BADC, all of which may dampen private initiatives for investment; (4) high unit costs on account of variable inputs due to low-capacity utilization of equipment; (5) lack of proper zoning of areas suitable for different equipment, which may result in improper siting that leads to low-capacity utilization; and (6) organizational problems in forming cooperatives of water users.

Fertilizer Consumption

Although chemical fertilizers were introduced into Bangladesh in the 1950s, their application was mostly limited to tea gardens and government experimental farms until the early 1960s. With the objective of popularizing this new input to farmers, BADC, a parastatal organization established for procurement and distribution of modern agricultural inputs to farmers, started selling fertilizers to farmers at highly subsidized prices. It is estimated that in 1968/69 the average rate of subsidy was about 58 percent for urea and phosphate, and 67 percent for potash.[30] With rapidly increasing sales, the subsidy rates began to put a heavy burden on the government budget in the early 1970s. This burden, together with an increase in the procurement cost of fertilizers, led the government to reduce subsidies. By 1983/84 the budgetary subsidy was reduced to about 25 percent of the cost, and the economic subsidy valued at border prices was about 23 percent in that year.[31] At present, there is little subsidy on fertilizer. During 1972-84 fertilizer prices increased by 20 percent a year, compared with a 10 percent increase in the prices of crop output. Another policy change introduced since 1978 is the handing over of fertilizer distribution at the local level from BADC to private traders. Under the new system, traders can buy fertilizer from BADC sales centers at the government-fixed prices and sell it to farmers at a market-determined price. BADC still keeps control over procurement of fertilizers and distribution to primary sales points and, for that purpose, also plans supply to maintain adequate stocks.

The trend in consumption of fertilizers can be reviewed in Table 8. In 1960/61 consumption was almost negligible at less than 1 kilogram of nutrient per acre of sown area. By the end of the 1960s, consumption had increased to over 4 kilograms per acre and it tripled within the next decade to about 13 kilograms in 1979/80. After a brief period of stagnation during 1979-83, consumption picked up again from 1983 to 1985. Sales in 1984/85 reached 1.26 million metric tons[32] of fertilizers valued at about 5.3 percent of the value added in crop production. During 1970-85, the trend rate for growth of consumption was about 10 percent a year.

Time series data for fertilizer application on crops are not available for Bangladesh. Trends of use in different seasons could, however, be constructed from BADC sales figures, which are available by months. Fertilizer is applied on the main aman paddy crop from July to October, when no other fertilizer-using crops are widely cultivated. November to March is the fertilizer application season for various rabi crops such as

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[30] F. Kahnert et al., *Agriculture and Related Industries in Pakistan* (Paris: OECD Development Center, 1970).

[31] Raisuddin Ahmed, "Structure, Dynamics, and Related Policy Issues of Fertilizer Subsidy in Bangladesh," in Bangladesh Institute of Development Studies/International Food Policy Research Institute, *Fertilizer Pricing and Foodgrain Production Strategy in Bangladesh, Technical Annex* (Washington, D.C.: IFPRI, 1985).

[32] All tons referred to in this report are metric tons.

Table 8—Trends in consumption of chemical fertilizers, by season, 1960/61-1984/85

Year	Total Fertilizer Sales: Aman Season	Boro Season	Aus Season	All Seasons	Sales per Unit of Cropped Land: All Seasons	Boro Season
	(1,000 metric tons)				(kilograms of nutrients/acre)	
1960/61	20	13	16	49	0.9	2.6
1965/66	45	28	35	108	1.7	5.3
1970/71	109	130	70	309	4.6	15.2
1973/74	109	200	81	390	5.9	22.1
1975/76	139	234	92	465	7.0	24.1
1976/77	154	227	140	521	8.0	24.9
1977/78	207	325	195	727	10.9	33.0
1978/79	256	358	140	754	11.1	35.7
1979/80	252	424	179	855	12.5	37.6
1980/81	265	429	195	889	12.8	35.2
1981/82	291	392	160	843	12.1	30.9
1982/83	245	507	216	968	13.7	38.0
1983/84	267	629	233	1,129	16.1	47.3
1984/85	364	669	228	1,261	18.1	44.8

Sources: Based on data from Bangladesh Agricultural Development Corporation, *Annual Report*, various issues (Dhaka: Government Press, various years); and Bangladesh, Bureau of Statistics, *Monthly Statistical Bulletin of Bangladesh*, various issues.

potato, wheat, mustard, and sugarcane, and also for boro paddy, which is grown under irrigated conditions. Aus paddy and jute are treated with fertilizer from April to June. The constructed time series data on season-specific consumption of fertilizer, reported in Table 8, show that the major focus of growth of fertilizer consumption has been on the boro and rabi crops cultivated during the winter season. Most of the area under MVs is also cultivated during this season. These crops now account for about one-fourth of the sown area, but sales during the 1984/85 season accounted for over half of the total fertilizer sales in the country. The present application rate of fertilizer on boro season crops is about 3.5 times higher than that for all crops taken together (Table 8). It is estimated elsewhere[33] that the share of MV crops in total fertilizer consumption increased from about 25 percent in 1969/70 to over 61 percent in 1983/84. Of the total increase in consumption during 1977-84, 81 percent was associated with the increased use of MVs and 51 percent with increased use on irrigated land. Thus MV seeds and irrigation have played an increasingly important role in the growth of fertilizer consumption in Bangladesh.

Complementarity of the Modern Technology Package

The time series data reviewed above show a high degree of complementarity between irrigation, fertilizer use, and diffusion of MV seed (Figures 2 and 3).[34] But

[33] Mahabub Hossain, "Fertilizer Consumption, Pricing and Foodgrain Production in Bangladesh," in BIDS/IFPRI, *Fertilizer Pricing*, pp. 149-150.

[34] This section draws heavily from Mahabub Hossain, "Irrigation and Agricultural Performance in Bangladesh: Some Further Results," *The Bangladesh Development Studies* 14 (No. 4, 1986): 39-56. The main conclusions are also supported by James K. Boyce, "Water Control and Agricultural Performance in Bangladesh," *The Bangladesh Development Studies* 14 (No. 4, 1986): 1-35.

Figure 2—Expansion in modern irrigation and modern-variety seeds, 1960-84

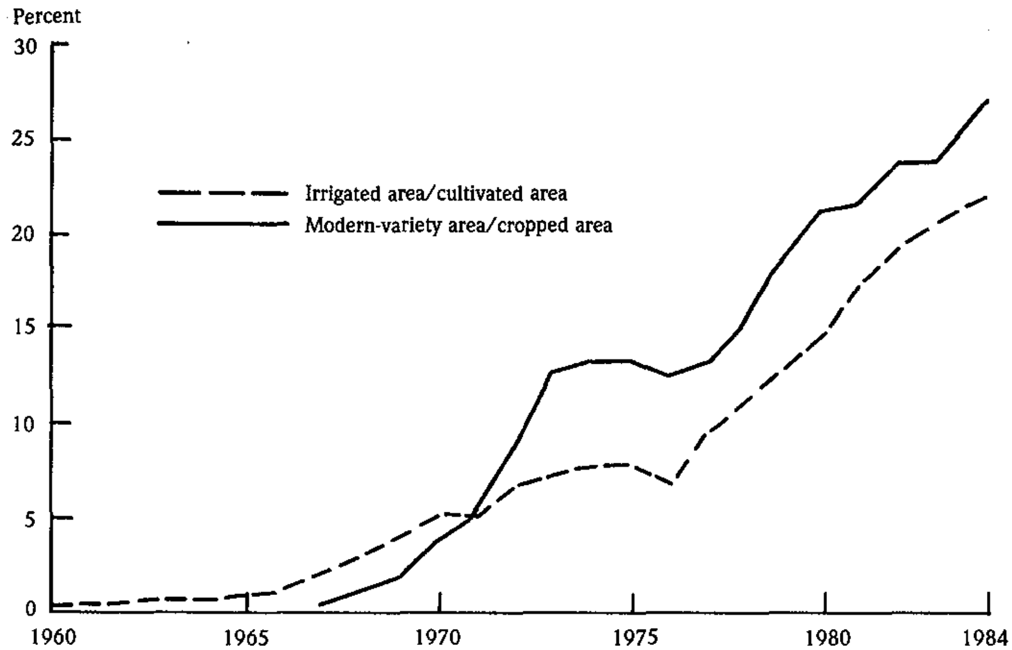
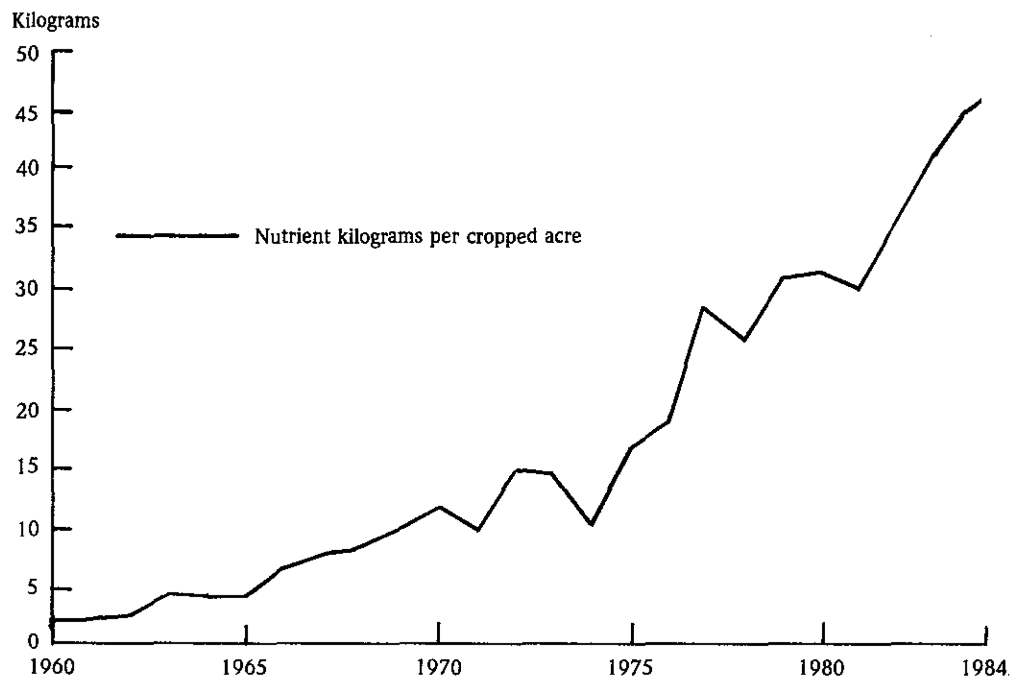


Figure 3—Trend in fertilizer use, 1960-84



irrigation could be the leading input in the sense that adoption of MVs and application of fertilizers follow development of irrigation facilities. The following analysis based on regional cross-section data for 1983/84, the latest normal year for which data are available, shows the nature of this complementarity and the leading role of irrigation.

A large variation in the diffusion of the new technology is found among the regions of Bangladesh. By 1984/85 the proportion of land irrigated by modern methods had increased to over one-third in the districts of Bogra, Kushtia, and Chittagong, while it was still less than 15 percent in the coastal districts of Patuakhali, Barisal, Khulna, and Noakhali. Similarly, the proportion of cereal area cultivated with MV seeds varied from 75 percent in Chittagong to less than 20 percent in Patuakhali, Barisal, Khulna, and Sylhet. Fertilizer consumption per acre of cultivated land varied from over 40 kilograms in the districts of Chittagong, Bogra, and Kushtia to less than 10 kilograms in the districts of Patuakhali, Barisal, Khulna, Faridpur, and Sylhet.

The relationship between the intensity of fertilizer consumption and the percentage of net sown area irrigated is shown by regression equations in Table 9, estimated by the ordinary least square (OLS) method on the district-level cross-section data. To reduce specification errors, important structural factors that differ across districts, such as annual rainfall, land elevation, and average farm size, have been used as additional

Table 9—Association of fertilizer consumption and adoption of modern varieties (MVs) with irrigation, 1983/84

Dependent Variables	Regression Coefficient of Independent Variables					$\bar{R}^2$	'F' Statistics
	Constant Term	Share of Cultivated Area Irrigated: Total	Share of Cultivated Area Irrigated: Modern Methods	Rainfall Deviation from Normal[a]	Share of Medium-High Land		
		(percent)			(percent)		
Fertilizer consumption (kilograms per acre)	8.27 (0.43)	5.81 (5.31)	. . .	−0.22 (−0.29)	−0.54 (−1.57)	0.60	10.5
	7.74 (0.54)	. . .	6.07 (7.71)	−0.30 (−1.18)	0.11 (0.20)	0.77	21.7
	5.77 (0.83)	. . .	5.87 (8.11)	. . .	. . .	0.79	65.8
Percent of cultivated area under dry-season MVs (boro rice and wheat)	5.82 (1.79)	0.86 (5.92)	. . .	−0.07 (−1.52)	−0.03 (−0.26)	0.67	14.1
	5.88 (1.31)	. . .	0.89 (8.83)	−0.03 (−1.02)	−0.04 (−0.61)	0.82	30.5
	2.44 (1.12)	. . .	0.89 (9.65)	. . .	. . .	0.83	93.2
Percent of cultivated area under wet-season MVs (aus plus aman)	22.71 (−1.69)	. . .	0.49 (1.92)	0.16[a] (3.16)	−0.09 (−0.47)	0.41	5.4
	22.71 (−2.27)	. . .	0.53 (2.28)	0.15[a] (3.23)	. . .	0.44	8.4

Notes: Estimates are from district-level data. The sample size is 20 Bangladesh (old) districts. Figures in parentheses are estimated t-values.

[a] The variable is measured by the amount of annual rainfall in the district.

explanatory variables. The farm size variable was found to be statistically insignificant in all estimating equations and hence it was dropped. Since both too much and too little rainfall can affect fertilizer use, the absolute deviation of rainfall in the district from normal rainfall in Bangladesh has been used. The land elevation variable has been measured by the percentage of area under medium-high land in the district, as recorded in the 1977 agricultural census.[35] Two alternative irrigation variables have been used—total area irrigated and area irrigated by modern methods. Although most of the data are now available for 1984/85, the reference year for this analysis is 1983/84, which was chosen because the 1984/85 aus and aman crops were affected by a number of abnormal floods during July-September 1984, while 1983/84 was a relatively normal year.

The estimated equations show that the structural factors (rainfall and land elevation) do not influence fertilizer consumption or adoption of MVs during the dry season. Both these variables are, however, strongly correlated with the level of irrigation. A better statistical fit is obtained with modern irrigation than with traditional irrigation. This is expected because traditional irrigation is practiced mostly in the depressed basins of the country and is the outcome of the natural endowment of land and water rather than of a conscious investment decision by the farmer or the state. The low-lying areas remain unsuitable for growing any crop during the monsoon season and are used for growing local boro during the dry season when the water level is reduced, but deep flooding still does not allow adoption of MVs or economic use of fertilizer.

The estimated equations that contain only the statistically significant variables show that irrigation alone explains about 79 percent of the regional variation in fertilizer consumption and about 83 percent of the variation in diffusion of MVs during the dry season. The elasticity of fertilizer consumption in relation to irrigation is estimated from the equation at 0.90 at the mean level of use of these inputs, and the elasticity of MV adoption during the dry season is estimated at 0.89.

The area covered by MVs during the wet season is, however, more strongly associated with rainfall than with irrigation. Only about 44 percent of interdistrict variation in the coverage of MVs during the wet season is explained by these two variables. It appears that some other important determinants have not been incorporated in the analysis. One such variable may be the duration of the monsoon, since an early monsoon would facilitate adoption of aus MVs, and districts receiving adequate rainfall during the late monsoon period (September-October) may have a relative advantage in growing rain-fed aman MVs. The depth of flooding may be another variable.

The relatively weak relationship between irrigation and expansion of wet season MVs may be due to the initial spreading of MVs in districts that have favorable rainfall endowments and to the low-lift pump irrigation initially spread to low-lying areas where adequate surface water is available in the dry season, but deep flooding of such land during the wet season does not permit raising dwarf MVs. With increased extraction of groundwater resources by tubewells, irrigation facilities are now being extended to medium-high and high land areas, which could be used for providing supplementary irrigation required for raising MV aus and aman crops.

Development and use of modern irrigation facilities require prior capital investment and institutional arrangements for the coordination of actions among many cultivators. The adoption of MV seeds and application of chemical fertilizers are, however, current

[35] Bangladesh, *Report on the Agricultural Census, 1977.*

production decisions undertaken by individual cultivators. These special attributes of irrigation and the high degree of complementarity among the seed-water-fertilizer inputs in the new technology package suggest that development of irrigation poses the key constraint to diffusion of modern technology in Bangladesh. (This is discussed further in Chapter 6.)

Impact on Growth

What has been the impact of technological progress on the growth of crop production? This section analyzes the official time series data on sown area and production of different crops for 1950-85 to see whether production growth has accelerated since the introduction of the new agricultural technology.

A large number of crops are grown in Bangladesh, but three crops—rice, wheat, and jute—account for nearly 90 percent of the total sown area. This analysis considers rice and wheat (cereal group), and jute, sugarcane, tobacco, pulses, oilseeds, potato, and chili (noncereal group). These crops accounted for about 94 percent of the sown area during 1980-85, so the exclusion of other crops should not seriously affect the results. The 1981/82 crop-level harvest prices have been used as weights for valuation of production at constant prices. In Bangladesh, prices fluctuate widely from year to year, particularly for minor crops, whose production is highly responsive to changes in relative prices.[36] The 1981/82 price level was chosen because, for most of the crops, it was very close to the trend for 1976-84.

The yield rates have been estimated by dividing the gross value of production by the sown area. To assess the impact of the new technology on growth, the time series has been divided into two parts, 1950-71 and 1971-85, and the growth performance of the two periods has been compared (see Figure 4). The crop year 1971/72 has been taken as the dividing line because, as noted earlier, little progress was made with the new technology through the late 1960s and, also, Bangladesh became independent of Pakistan in 1971 and a close scrutiny of the official series indicates that a downward adjustment has been made since 1971/72 in the crop-yield figures.

To see whether the growth rate has accelerated since 1971/72 with the diffusion of the new agricultural technology, the following trend equation has been fitted on the data for the entire period (1950-85):

$$\text{Ln}Y = a_0 + a_1D + b_0T + b_1DT + u,$$

where Ln is the natural logarithm of the variable, Y is the variable for which the rate of growth is estimated, D is the dummy variable, taking value one for 1971-85 and zero otherwise, and T is time. The rate of growth for 1950-71 is given by b_0 and that for 1971-85 is given by $(b_0 + b_1)$. The value of b_1 is expected to be positive if there has been an acceleration of growth during 1971-85. The coefficient of the dummy variable, a_1, will indicate whether any adjustment has been made in the time series since 1971.

[36] John T. Cummings, "The Supply Response of Bangalee Rice and Cash Crop Cultivators," *The Bangladesh Development Studies* 2 (October 1974): 235-251; and Sultan H. Rahman, "Supply Response in Bangladesh Agriculture," *The Bangladesh Development Studies* 14 (No. 4, 1986): 57-100.

Figure 4—Trends in yield of cereal and noncereal crops, 1950-85

The growth rates derived from the estimated equations (see Appendix, Table 72) are presented in Table 10. The growth of production has accelerated from about 2.5 percent a year during 1950-71 to about 2.9 percent during 1971-85. This has taken place in spite of a deceleration in the growth of cropped land in the later period. The impact of technological progress should be felt on the growth of land productivity. It is estimated that the growth of yield rates has accelerated from 1.4 to about 2.0 percent a year for all crops. The acceleration coefficient is found to be statistically significant at about 5 percent probability level.

For investigation of the issue at hand, cereals are more important than noncereals, since technological progress has taken place mainly in the production of rice and wheat. The production of cereals has grown at faster rates than production of noncereal crops, and the difference in performance is particularly noticeable in the postmodern-technology period. The growth of production for cereal crops has accelerated from about 2.6 percent a year during 1950-71 to about 3.4 percent during 1971-85. The acceleration in production is mainly on account of the growth in crop yields, that is, land productivity, which has increased from 1.5 to 2.2 percent a year. The acceleration in the growth of productivity in the postmodern-technology period is almost twice as much for cereals

Table 10—Growth in crop production before and after introduction of modern technology

Crops/Period	Trend Rate of Growth		
	Cropped Land	Yield per Unit of Land	Production
		(percent/year)	
Cereal			
1950-71	1.10	1.52	2.62
1971-85	1.16	2.20	3.36
Noncereal			
1950-71	1.26	0.89	2.15
1971-85	−0.73	1.26	0.53
All			
1950-71	1.12	1.40	2.52
1971-85	0.90	2.02	2.92

Source: Derived from equations in Table 72, based on estimates from official statistics from Bureau of Statistics, Bangladesh.

as for noncereal crops. The acceleration coefficient for cereal yield is found to be statistically significant at 10 percent probability level.

The technological progress in cereal crops, however, has had adverse effects on the production of noncereal crops, many of which cannot compete with MVs of rice and wheat. The most seriously affected crops are jute, pulses, and oilseeds, whose cultivated area has declined consistently since the late 1960s. Jute competes for land with aus rice, but owing to a long-term decline in the price of jute relative to the price of rice, large fluctuation in its prices, and technological advances made in rice, some of the traditional jute land has been shifted to MV aus and boro crops. The expansion of cropped land under boro rice and wheat has been partly at the expense of pulses and oilseeds. It will be noted from Table 10 that cereal crops have maintained their growth in cropped land at about 1.1 percent a year, largely at the expense of noncereal crops, whose cultivated area declined absolutely at a rate of about 0.7 percent a year during 1971-85.

Level and Fluctuation of Food Prices

Technological progress implies a downward shift in the cost function (Chapter 4), and depending on the nature of demand, some of the benefits may be shifted to consumers in the form of lower prices. It is argued in the literature that one of the important ways through which technological progress indirectly benefits the poor is the lowering of real food prices.[37] So a relevant empirical question at this point is what has happened to the prices of cereals compared with those of noncereal crops since the introduction of modern technology.

[37] See Mellor, "Food Price Policy and Income Distribution"; and Yujiro Hayami and Robert W. Herdt, "Market Price Effects of Technological Change on Income Distribution in Semi-Subsistence Agriculture," *American Journal of Agricultural Economics* 59 (May 1977): 245-256. For Bangladesh the issue has recently been studied by Mohammad Alauddin and Clem Tisdell, "Market Analysis, Technical Change, and Income Distribution in Semi-Subsistence Agriculture: The Case of Bangladesh," *Agricultural Economics* 1 (No. 1, 1986): 1-18.

Table 11 presents estimates of the rate of increase in the retail prices of major commodities in the consumption basket for 1950-71 and 1971-85. Since prices fluctuate considerably from year to year, the rates of growth have been estimated by fitting semilogarithmic trend lines to the time series data. The rate of inflation, as measured by the trend rate of growth in the consumer price index, was only about 3 percent a year during the 1950s and 1960s but increased to about 11 percent after independence. So in comparing price changes for the two periods, the relative increase in prices, rather than the absolute increase, should be examined.

During the two decades before the introduction of the new technology, rice prices increased at a much faster rate (80 percent higher) than the general rate of inflation in Bangladesh. In fact, among the major commodities in the consumption basket, the price of rice increased at the fastest rate. This position, however, was completely reversed in the postmodern-technology period, when the prices of rice increased at the same rate as the general rate of inflation in the country.[38] Some of the commodities, such as pulses, beef, and fish, which experienced slower rates of increase in prices than did rice during the earlier period, had price increases at 10 to 50 percent higher rates than rice during the later period. Only for oil, gur (raw sugar), and potato did prices continue to increase at a slower rate. The lower prices for oil and gur may have been maintained by the government by importing substitute commodities, soybean oil,

Table 11—Changes in food and nonfood consumer prices before and after introduction of modern technology

Commodity	1950-71 Rate of Increase	1950-71 Standard Error of Estimate	1950-71 Instability Index	1971-85 Rate of Increase	1971-85 Standard Error of Estimate	1971-85 Instability Index
	(percent/year)		(percent)	(percent/year)		(percent)
Food						
Rice	5.42	0.47	12.9	10.98	0.76	9.0
Pulses	3.89	0.47	12.8	12.16	1.47	14.5
Potato	1.05	0.47	12.2	5.56	1.40	15.8
Gur (raw sugar)	3.51	0.59	17.0	8.99	1.24	14.1
Fish	2.32	0.58	15.8	16.56	1.93	13.6
Beef	3.86	0.27	7.6	16.17	2.51	16.9
Oil	3.43	0.55	15.5	8.89	0.82	9.6
Nonfood						
Firewood	4.98	0.49	14.0	10.98	0.68	9.0
Textiles	1.52	0.58	13.8	9.21	0.66	5.7
Consumer price index	2.95	0.20	5.5	10.99	0.59	6.8

Source: Estimated by fitting semilogarithmic trend lines on time series.
Notes: The retail prices are reported for major urban centers in Dhaka, Chittagong, Khulna, Rajshahi, Sylhet, and Rangpur. The figures in the table are based on the series for Dhaka. The consumer prices are for laborers in the industrial city of Narayangong. The year 1974/75, when famine conditions prevailed in the country, was excluded in estimating trends for the later period.

[38] Since rice is a major commodity in the consumption basket, it may be argued that the movement in the cost-of-living index is mainly determined by the rice prices. According to a 1983-84 survey, rice accounted for 32 percent of the national consumption expenditure, so the rice price index and the CPI may not necessarily increase at the same rate. See Bangladesh, Bureau of Statistics, "Report of the Bangladesh Household Expenditure Survey, 1983-84," Ministry of Planning, Dhaka, 1987 (mimeographed).

and sugar and by distributing them to urban consumers through the rationing system, and also by controlling the price of sugar produced in government-owned mills. Potato is the only noncereal food for which the long-run growth in production has been faster than for cereals. The growth rate is estimated at 8.2 percent for 1950-84 and 3.5 percent for 1971-85.

A general problem with agricultural prices in Bangladesh is that they are very unstable. The new crop varieties are less dependent on weather than the traditional ones, as the land on which they are grown generally has access to irrigation facilities. So with a large proportion of cereal production coming from the new varieties, the weather-induced fluctuations in production and prices are expected to be reduced.[39] Table 11 also presents a measure of the instability of consumer prices for the periods before and after introduction of the new technology. Following Cuddy and Della Valle,[40] the instability index is derived as follows:

$$I = CV/(1 - \bar{R}^2),$$

where I is the index (percent), CV is the coefficient of variation (standard deviation as a percentage of arithmetic mean), and $\bar{R}^2$ is the adjusted coefficient of determination of the semilog trend function. It will be noted from the estimates that although the rate of inflation has increased by over three times in the postmodern-technology period, the instability index has not changed much. In general the prices are more unstable for noncereal food crops than for cereals. This has been the experience particularly in the postmodern-technology period, when prices of important food crops such as potato and pulses have been more unstable than they were during the earlier period. For rice, in which the technological progress has taken place, the degree of instability has been reduced; the index went down from about 13 percent for 1950-71 to 9 percent for 1972-85.

The slowing of the increase in real prices of rice, and its greater stability in the postmodern-technology period, may not be entirely due to technological progress. Changes in the government's monetary and fiscal policy can influence these variables. More important, the government has followed a price-intervention policy for rice, declaring support prices and participating in markets through procurement after harvests, and distributing cereals directly to consumers through various channels. The effect of technological progress can only be worked out after dissociating the effect of these other factors, which in itself is an important topic of research and has not been pursued in this study.

Conclusions

In Bangladesh, agricultural growth is constrained by limited availability of land. The amount of cultivated land has not increased since the early 1950s. At present the

[39] In India, instability in cereal production increased greatly in the post-new technology period. Hazell, however, shows that about 82 percent of the increased variation can be attributed to increases in the covariances of production between crops grown in the same state and in different states—a development that cannot be blamed on improved technologies. Only 6 percent of the variances of total cereal production was attributed to variances of individual crop yields measured at the state level. See Peter B. R. Hazell, *Instability in Indian Foodgrain Production*, Research Report 30 (Washington, D.C.: International Food Policy Research Institute, 1982).

[40] J. D. A. Cuddy and P. A. Della Valle, "Measuring the Instability of Time Series Data," *Oxford Bulletin of Economics and Statistics* 40 (February 1978): 79-85.

wasteland that can be reclaimed for cultivation is only about 2 percent of total land. But Bangladesh has vast water resources that can be developed for adoption of modern rice technology to increase foodgrain production. In fact, the country has maintained the food-population balance since its independence in 1971 mainly through technological progress. About one-fifth of cultivated land has been brought under modern irrigation, mostly through public investment. This, together with improved flood control and drainage, has made possible an expansion of MVs to about one-third of the sown area under cereals and an increase in fertilizer consumption from 4.5 to 18.2 kilograms of nutrients per acre during 1971-85. The growth of cereal production has accelerated from 2.6 percent a year during 1950-71 to 3.4 percent during 1971-85, mostly due to acceleration in the growth of crop yields. The productivity growth may have been one of the factors that has helped to keep rice prices low. The retail price of rice, which increased at a rate about 80 percent faster than the cost-of-living index during 1950-71, has moved at par with the general rate of inflation during 1971-85. There is still vast potential for further diffusion of the new technology, whose rate of exploitation may depend on the government's undertaking appropriate policies.

4

NATURE OF ALTERNATIVE RICE TECHNOLOGIES

The term "technology" is generally used to mean the application of knowledge to produce output through optimum use of combined inputs. The new technology would thus mean a change in the combination of inputs and in their amounts and methods of application. It is important to understand the nature of these changes, because in underdeveloped agriculture, where endowments and real costs of resources vary across farms, the suitability and acceptance of the new technology depend on these changes.[41]

This chapter documents in detail the characteristics of the alternative crop technologies currently in use in Bangladesh and their implications for cost of production, capital requirements, profitability of cultivation, and returns to family resources. The information is drawn mainly from the farm household survey conducted by the International Fertilizer Development Center (IFDC) from aman 1979 through boro 1982 seasons[42] and is supplemented by the information collected by the Bangladesh Institute of Development Studies/International Food Policy Research Institute (BIDS/IFPRI) survey.[43] The IFDC survey is the largest household survey ever conducted in Bangladesh, covering 2,400 randomly selected households from 16 out of 21 Bangladesh (old) districts. The input-output information on crops was collected for about 10,000 sample plots belonging to the selected households. Since the farmers do not keep any records of their operations, the input-use information collected at the plot level tends to be more reliable than those collected at the farm level. The findings of this study are expected to be representative for the country as a whole, and the degree of accuracy is as much as can be obtained by asking questions of the farmers.

As noted earlier, technological progress in Bangladesh is mainly confined to production of rice and wheat. Wheat was an unimportant crop even up to the mid-1970s, but a rapid increase in wheat area since 1975/76 has turned it into the third major crop after rice and jute. Wheat now occupies about 5 percent of total cropped land, most of it under MVs. The scope for further expansion is limited, however, because the soil and the duration of the winter season in Bangladesh are not very suitable for production of wheat. Rice occupies nearly four-fifths of the sown area in the country and is grown in three seasons. The monsoon rice, aman, harvested from November to January, accounts for about 46 percent of cropped land and 58 percent of rice land. About one-fourth of aman land is broadcast-seeded (deep-water variety), sown in March when the land is dry and harvested in November and December when the water recedes. On this type of land the depth of flooding prevents raising any other crop during the monsoon season. On the remaining aman land (medium-low and medium-high elevations) the crop is transplanted, and the MVs have spread to about one-fourth of the area. The early monsoon rice, aus, harvested in July and August, consists mostly of broadcast varieties sown in March-April on either very low or very high land. In some areas transplanted rain-fed aus varieties are also grown.[44] This crop traditionally

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[41] Pears, *Seeds of Plenty.*

[42] International Fertilizer Development Center, *Agricultural Production, Fertilizer Use, and Equity Considerations.*

[43] BIDS/IFPRI, *Development Impact.*

[44] See Noel P. Magor, *Potential in Rainfed Transplanted Rice Production in North-East Bangladesh* (Dhaka: Bangladesh Rice Research Institute, 1984), p. 32.

competes with jute and now accounts for about one-fourth of the total sown area in the country. MVs have spread to about one-sixth of the aus land and have tended to remain at that amount since the late 1970s. Aus MVs are mostly transplanted, but in some areas broadcast MVs are also grown. The remaining one-sixth of rice land is under boro, which is grown under irrigation, transplanted during December-February, and harvested in April-June. The major impact of the new technology has been on this boro rice crop. The cropped area increased from 1.56 million acres in the late 1960s to about 3.89 million acres by 1984/85, facilitated by expansion of modern irrigation. Nearly four-fifths of the area under this crop is now under MVs. The traditional boro is grown on extremely low-lying land that is unsuitable for growing any crop during the monsoon season because of severe flooding. Boro MVs are grown on relatively high land. Since boro and aus seasons overlap, boro MVs compete with aus and jute, whose cropped area has declined steadily in recent years, and there is further possibility of substituting boro MVs for aus crops. The exclusive focus on alternative rice technologies in this chapter is dictated by the importance of rice and the great potential for expansion of the area under MVs.

Amount and Fluctuation of Crop Yield

Bangladesh has little scope for increasing the supply of land (Chapter 2). Even an individual farmer who has the means to accumulate more land finds it difficult to do so, because in the absence of adequate nonagricultural job opportunities, rural people tend to cling to their holdings and the market for land tends to be thin. So, for both the nation and the individual farmer, the only scope for increasing production is through increased cropping intensity or increased crop yield. A new crop variety that has intrinsic capacity to produce more per unit of land would thus be widely accepted. It would provide the means to increase production from the limited land base through reallocation of land from traditional to new varieties.

Table 12 presents the findings of the two surveys on yield rates (output per unit of land) for the alternative crop varieties and compares them with the official statistics for the entire country. Since yields vary considerably from year to year, the figures are presented as averages for a number of years, which should give a relatively normal picture. The IFDC survey estimated the yield for three years, from 1979/80 to 1981/82, and the BIDS/IFPRI survey for two years, 1981 and 1982. The survey estimates are very close to the official statistics, which support the representativeness of the surveys. The MVs produce more output per unit of land than do the traditional varieties in all three seasons: about one and a half times higher during the aus season, three-fourths higher during the boro season, and one-half higher during the aman season. On average, the yield of the new varieties is about 100-120 percent higher than the yield of traditional ones. Diffusion of the new technology thus contributes to a substantial increase in rice production from the limited land.

A large majority of farmers in Bangladesh operate around or below the subsistence level, so they may respond not only to the average yield but also to the fluctuations in yield, thus making investment in agricultural inputs a risky venture. Being risk-averse, a farmer may be willing to sacrifice a substantial amount of expected income—as indicated by higher mean value of output in the MVs—in exchange for a low probability of falling below the subsistence level. The new crop varieties are less dependent on weather than are traditional ones, since the land has access to irrigation facilities, and during the monsoon season they are generally grown on higher land, which is less

Table 12—Estimates of crop yield for traditional and modern varieties of rice

Season/Variety	Weight[a]	IFDC Survey: Annual Average, 1980-82	BIDS/IFPRI Survey: Annual Average, 1981 and 1982	Government Statistics: Annual Average, 1982-85
			(tons of paddy/acre)	
Aus (early monsoon)				
Traditional	0.180	0.53	0.48	0.50
Modern	0.037	1.28	1.31	1.32
Aman (monsoon)				
Traditional, broadcast	0.103	0.62	0.69	0.61
Traditional, transplanted	0.265	0.77	0.70	0.75
Modern, transplanted	0.089	1.11	1.16	1.17
Boro (dry winter)				
Traditional	0.026	0.79	1.01	0.93
Modern	0.094	1.51	1.51	1.66
All seasons[b]				
Traditional	0.574	0.67	0.65	0.65
Modern	0.220	1.31	1.33	1.41
			(percent)	
Difference in modern over traditional	. . .	96	105	117

Sources: International Fertilizer Development Center survey and Bangladesh Institute of Development Studies/International Food Policy Research Institute field survey. Government statistics are based on data from Bangladesh, Bureau of Statistics, *Monthly Statistical Bulletin of Bangladesh*, various issues.
[a] The area under the variety as a proportion of the total cropped area during 1985 for the country as a whole.
[b] Weighted averages.

susceptible to floods. So the weather-induced fluctuation in production is expected to be low for the new varieties. However, they may be more susceptible to pest attacks, and the risk of crop damage on that account is expected to be higher. Also, for rain-fed MVs (for example, aman MVs) water stress may reduce the yield more than in the case of a local variety.[45]

The estimates of variation in crop yields could not be obtained, as primary information from the IFDC survey was inaccessible. The estimates obtained from the plot (1981) and farm (1982) data collected by the BIDS/IFPRI survey are presented in Table 13. The estimates of variation are expected to be lower at the farm level than at the plot level, as the fluctuation is reduced by summing over the data for a number of plots that the farm operates. In 1981, for which the estimates are obtained from the plot data, the standard deviation of yield as a percent of the arithmetic mean is found to vary between 32 and 78 percent.[46] But the magnitude of variation is, in general, lower for the MVs. For MV boro and aman it is about 48 percent, and for aus, 32 percent, compared with 69 percent for traditional aman and 78 for traditional aus. For 1982 also, the magnitude of variation is lower in MVs for the aus and aman seasons and is

[45] Magor found that a substantial reduction in rainfall in 1981 over 1980 reduced the yield of modern aman varieties by 30 percent, while the reduction in yield of local varieties was 25 percent. See Magor, *Rainfed Transplanted Rice Production*, p. 32.

[46] Cropping system research in an upazila in Sylhet District found that for the aman crop, 62 percent of the yield variation in 1981 was attributable to transplanting date and water stress. The yield loss per water-stress day was estimated at 75 kilograms per hectare for MVs, compared with 48 kilograms per hectare for a local variety. See Magor, *Rainfed Transplanted Rice Production*, p. 2.

Table 13—Variation in yield for traditional and modern varieties of rice, 1981 and 1982

Season/Variety	1981 Plot Data: Number of Plots	Mean Yield	Standard Deviation	Coefficient of Variation	1982 Farm Data: Number of Farms	Mean Yield	Standard Deviation	Coefficient of Variation
		(metric tons/acre)		(percent)		(metric tons/acre)		(percent)
Aus								
Traditional, broadcast	584	0.53	0.41	78	152	0.45	0.22	48
Modern, transplanted	281	1.26	0.40	32	86	1.38	0.26	19
Aman								
Traditional, broadcast	379	0.73	0.40	55	144	0.65	0.29	45
Traditional, transplanted	789	0.69	0.48	69	179	0.73	0.50	69
Modern, transplanted	634	1.05	0.51	49	159	1.26	0.77	61
Boro								
Traditional, transplanted	231	1.09	0.69	63	94	0.93	0.33	35
Modern, transplanted	765	1.38	0.66	48	204	1.62	0.65	40

Source: Based on data from Bangladesh Institute of Development Studies/International Food Policy Research Institute field survey.

similar for the boro season. The boro crop was severely affected by hailstorms in April 1982 in two of the villages where MV boro is a major crop.

For 1982, information was also collected from farmers about the extent of crop damage from natural factors. During that year the aus crops were affected by drought in the villages in Kushtia and Jessore, the aman crops were affected by a flash flood in two villages in Comilla, and the boro crops were affected by hailstorms in two villages in Dhaka and one village in Comilla. Each farmer was asked to report the percentage by which the actual yield was lower than the expected yield, given the application of inputs. The response is subjective, but comparison of the figures for traditional and modern varieties would indicate the direction of change. The findings also show a high degree of crop damage, but it is lower for MVs than for traditional varieties of aus and aman (Table 14). For the boro season, however, the damage is reported to be lower for traditional varieties.

Table 14—Farmers' perception of extent of crop damage, 1982

Season	Traditional Variety: Arithmetic Mean	Traditional Variety: Standard Error	Modern Variety: Arithmetic Mean	Modern Variety: Standard Error
	(percent of expected yield)			
Aus	45	2.2	32	2.6
Aman	38	2.0	33	2.1
Boro	21	2.6	28	2.0

Source: Based on data from Bangladesh Institute of Development Studies/International Food Policy Research Institute field survey.

Use of Inputs

Family and Hired Labor

The estimates of labor input used per acre of land in operation under different technologies, as obtained from the IFDC survey, are presented in Table 15. The survey collected this information at the plot level for all seasons from aman 1979 to boro 1982. The figures in the table are averages for the three years' estimates. The following features emerge from the table.

Farmers use more labor per unit of land in MVs than in traditional varieties in all three seasons. The increase is about 41 percent for the aus season, 38 percent for the aman season, and 6 percent for the boro season. For all three seasons together, labor use per acre is about 47 percent higher under the MVs.[47] The diffusion of the new technology will thus create more employment from the limited land base through reallocation of land from traditional to modern varieties.

The new varieties, however, economize on labor needed to produce a given amount of output. The amount of labor used to produce a ton of paddy was about 57 eight-hour days for the new varieties, compared with 85 days for the traditional crops. Thus unit cost of production on account of labor was considerably less.

Only a small part of the increase in employment under the new varieties is due to harvesting and threshing of the additional yield. The employment increase is mainly

Table 15—Labor input in rice cultivation for traditional and modern varieties, 1980-82 averages

Season/Variety	Land Preparation	Sowing and Transplanting	Weeding and Other Intercultural Operations	Harvesting and Threshing	All Operations
		(8-hour days/acre of cropped land)			
Aus					
Traditional	14	2	19	21	56
Modern	15	13	23	28	79
Aman					
Traditional, broadcast	11	1	15	25	52
Traditional, transplanted	13	13	7	20	53
Modern, transplanted	15	15	17	26	73
Boro					
Traditional	13	17	25	28	83
Modern	16	17	26	29	88
All seasons					
Traditional	13	7	13	22	55
Modern	15	16	22	28	81
Increase in modern over traditional	2	9	9	6	26

Sources: Compiled from International Fertilizer Development Center, *Agricultural Production, Fertilizer Use, and Equity Considerations: Results and Analysis of Farm Survey Data, 1979/80* (Muscle Shoals, Ala.: IFDC, 1982); and International Fertilizer Development Center, *Agricultural Production, Fertilizer Use, and Equity Considerations: Results and Analysis of Farm Survey Data, 1981/82* (Muscle Shoals, Ala.: IFDC, 1984).

[47] Ahmed estimated from a survey of 459 farms in three villages during 1975/76 that, compared with traditional varieties, the labor input per unit of land in the cultivation of modern varieties was 28 percent higher during the aman season and 50 percent higher during the boro season. See Iftikhar Ahmed, "Technological Change and Labor Utilization in Rice Cultivation: Bangladesh," *The Bangladesh Development Studies* 6 (No. 3, 1977): 359-366.

due to the shift from direct seeding to transplanting of seedlings. For all new varieties, seedlings are grown on a separate seed bed and then transplanted to the main fields. On the other hand, inadequate rain and moisture in the soil during the premonsoon season does not permit transplanting of seedlings for the aus crop, so the seeds are broadcast on the main field, which does not require much labor. For traditional aman varieties the seedlings are transplanted, but mostly in a random manner, while new varieties are mostly transplanted in lines, thus requiring more labor than does random transplanting. The intensive intercultural operations such as weeding, irrigation, and fertilizer use also generate more demand for labor in the cultivation of MVs. The use of labor in land preparation is only marginally higher. Table 15 shows that MVs used 26 additional days of labor per acre, of which 35 percent was generated during sowing and transplanting, 35 percent during weeding and other intercultural operations, 23 percent during harvesting and threshing, and only 7 percent during land preparation.

Transplanting and harvesting are busy agricultural operations for which most farm households hire labor, although they may have surplus labor in the family during other times of the year. By raising labor requirements during these operations, MVs would also increase the demand for hired labor. The IFDC survey did not collect information on the use of hired labor. The estimates obtained from the BIDS/IFPRI survey are presented in Table 16. Nearly two-fifths of the total labor used in rice cultivation came from hired workers, and the proportion was almost the same under the traditional and modern varieties. The new technology thus appears to be neutral in the use of these two types of labor. During the boro and aus seasons, however, MVs use proportionately more hired labor than family labor. The agricultural operations for these two seasons take place from January to June, a traditionally slack period of agricultural activity. Diffusion of the new technology during these seasons would thus reduce the seasonality of underemployment, particularly for the landless who provide hired labor. It will be noted from Table 16 that the additional employment per unit of land generated by

Table 16—Use of hired labor under traditional and modern varieties of rice, 1982

Season/Variety	Hired Labor	Family Labor	Hired Labor as Share of Total Labor
	(8-hour days/acre)		(percent)
Aus			
Traditional	16	40	29
Modern	33	47	41
Aman			
Traditional, broadcast	20	32	38
Traditional, transplanted	22	32	41
Modern, transplanted	30	43	41
Boro			
Traditional	20	62	24
Modern	30	58	34
All seasons			
Traditional	20	36	36
Modern	30	50	38
		(percent)	
Difference in modern over traditional	50	39	6

Source: Based on data from Bangladesh Institute of Development Studies/International Food Policy Research Institute field survey.

MVs is proportionately more (50 percent) for hired labor than for family labor (39 percent). Thus, poor households who supply hired labor also benefit from technological progress. (See also Chapter 7.)

Animal and Mechanical Power

Bullocks and cows are widely used in Bangladesh to perform heavy agricultural operations such as plowing and leveling land, transporting harvests from the field to the yard of the homestead, and threshing the crop. The animals are used in pairs. The extent of animal power used in the cultivation of different varieties of rice, as estimated by the IFDC survey, is shown in Table 17. The figures are averages for 1979/80-1981/82. For land preparation, use of animal power is higher for transplanted varieties than for broadcast ones, but for harvesting and threshing no systematic pattern is observed. The average use under traditional crop varieties is about 128 hours per acre for a pair of animals. On the basis of an eight-hour working day, employment for a pair of animals comes to about 16 days per acre of land, which is less than one-third of the use of human labor (56 days).

The modern rice varieties generate more demand for animal power due to the practice of transplanting seedlings and the need to transport additional harvest. The extent of increase is found at 15 percent, about a third of the additional demand for human labor. The animal power used per ton of output is 105 pair-hours for MVs, compared with 196 hours for traditional varieties.

In Bangladesh, the market for animal labor is very thin, partly because of the highly seasonal pattern in demand for animal services. The BIDS/IFPRI survey collected information on cultivation expenses for hired animals during the 1982 crop seasons. Only

Table 17—Use of animal and mechanical power for traditional and modern varieties, 1979/80-1981/82 averages

Season/Variety	Animal Power			Mechanical Power			
	Land Preparation	Harvesting and Threshing	Total	Land Preparation	Irrigation	Threshing	Total
	(hours/pair/acre)			(hours/acre)			
Aus							
Traditional	114	24	138	0	0	6	6
Modern	123	26	149	0	7	9	16
Aman							
Traditional, broadcast	89	36	125	0	0	8	8
Traditional, transplanted	106	14	120	0	0	9	9
Modern, transplanted	115	24	139	0	1	9	10
Boro							
Traditional	102	36	138	0	13	4	17
Modern	125	29	154	0	30	9	39
All seasons							
Traditional	105	22	127	0	1	7	8
Modern	121	26	147	0	15	9	24
	(percent)						
Difference in modern over traditional	15	18	15	...	large	29	200

Sources: Compiled from International Fertilizer Development Center, *Agricultural Production, Fertilizer Use, and Equity Considerations: Results and Analysis of Farm Survey Data, 1979/80* (Muscle Shoals, Ala.: IFDC, 1982); and International Fertilizer Development Center, *Agricultural Production, Fertilizer Use, and Equity Considerations: Results and Analysis of Farm Survey Data, 1981/82* (Muscle Shoals, Ala.: IFDC, 1984).

one-fourth of the farmers reported use of hired animals. The average use was equivalent to about 11 pair-days for those hiring animals, and only 3 days for all farms. The practice of animal hiring was more prevalent among very small farmers, presumably because they cannot afford to invest in a pair of animals and bear the maintenance cost. Some large landowners, whose main occupation was nonagriculture, also hired animal power. Owing to the thinness of the market, most of the households that are engaged full time in farming have to keep at least a pair of draft animals, which remains substantially underutilized. Thus the animals are fixed costs, and the cost per unit of output on this account can be reduced by increasing the rate of utilization. The diffusion of modern technology allows more intensive use of animals, since an additional crop is grown on the same piece of land each year.

In many parts of South Asia, diffusion of the new technology followed substitution of machines for animal and human labor. This change is often mentioned as an important factor behind the negative distribution effect of the new technology, although the effect of mechanization on labor use remains controversial.[48] In Bangladesh, mechanization of agricultural operations, except for irrigation, is rarely visible. In some parts of the country a few farmers use small mechanical threshers (mostly in the Comilla, Noakhali, and Chittagong belt), and power tillers (mainly in the Dhaka region for potato cultivation). The 1977 agricultural census noted that among 6.3 million farm holdings, only 35,000 used tractors and 12,000 used power tillers at some time.[49] Only 0.66 percent of farmers reported mechanical cultivation, and the area cultivated was only 0.38 percent.

Information on the use of mechanical power in alternative rice technologies, as estimated by the IFDC survey, is reported in Table 17. Mechanical power is used only for irrigation and threshing. For traditional varieties, mechanical power was used for only eight hours per acre—about 3 percent of the use of animal power. Under MVs, the use is about three times more, but most of the increase is due to power used for irrigation. For threshing, the use is only about one-fifth higher. For land preparation, mechanization has yet to be introduced, even for the cultivation of MVs.

Chemical Fertilizer and Manure

The use of chemical fertilizers is now widespread. The BIDS/IFPRI survey found that nearly 87 percent of farmers used fertilizers, and in irrigated villages almost all farmers used them. Only in 4 out of 16 villages studied was the diffusion limited to less than two-thirds of the farmers. Three of the villages are located in the coastal district of Khulna, which has saline soil, and most of the land is single-cropped with local transplanted aman. The other village is located on the Brahmaputra active flood plain, where most of the land is sown with deep-water broadcast aman.

Many of the fertilizer-using farmers, however, did not apply fertilizer on all plots. The application depends on the type of crop, and whether the plot has previously been treated with fertilizer. The farmers argue that once they apply fertilizer on a plot (for example, to grow the highly fertilizer-responsive MVs), they will have to continue using fertilizer on the same plot even for growing a local variety with low fertilizer response—otherwise the yield will be less than normal. The IFDC survey found that during 1981/82 nearly 45 percent of the land was not treated with fertilizer.

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[48] For a recent survey of the literature on the labor-displacing effects of agricultural mechanization, see Michael Lipton, *Modern Varieties, International Agricultural Research, and the Poor,* CGIAR Study Paper 2 (Washington, D.C.: World Bank, 1985), pp. 64-70.

[49] Bangladesh, Bureau of Statistics, *The Statistical Yearbook of Bangladesh, 1984-85* (Dhaka: Ministry of Planning, 1985), p. 332.

The findings of the two surveys on the extent of fertilizer use under alternative rice technologies are presented in Table 18. The figures indicate a clear dualism in fertilizer application. Less than one-fifth of the land under deep-water aman and traditional boro is treated with fertilizer. These crops are grown on deep-flooded land where local varieties are less fertilizer-responsive and fertilizer use is less effective. Even on flood-free land, only about 50 percent of the plots are treated with fertilizer if they are sown with local varieties, but more than 90 percent are treated if they are sown with MVs. Fertilizer use on aus and boro season MVs is about six times higher than on the substitute traditional variety, and on aman season MVs the use is about three times higher. On transplanted MVs, use of fertilizers has reached a high level—over 113 kilograms of materials per acre of land. The higher yield of MVs is thus achieved by substantially higher use of chemical fertilizer per unit of land.

To increase soil fertility, Bangladesh farmers also use manures, so a pertinent question is whether intensive fertilizer application on MVs has led to the substitution of chemical fertilizers for manures. The BIDS/IFPRI survey found that nearly two-thirds of the farmers applied farmyard manure, while the IFDC survey found that nearly one-third of the plots were treated with manure. The application of manure was more common in traditional varieties. The findings of the two surveys, however, do not agree on the magnitude of application of manure (Table 18). The IFDC survey showed that use of manure was about 30 percent lower for MVs, while the BIDS/IFPRI survey indicated that farmers used almost twice as much on MVs as on traditional varieties.

Table 18—Use of chemical fertilizers and manure for traditional and modern varieties, 1980-82 averages

Season/Variety	Share of Plots Treated (IFDC Survey)		Use per Acre (IFDC Survey)		Use per Acre (BIDS/IFPRI Survey)	
	Fertilizer	Manure	Fertilizer[a]	Manure	Fertilizer[a]	Manure
	(percent)		(kilograms)	(metric tons)	(kilograms)	(metric tons)
Aus						
Traditional, broadcast	45	61	19	1.81	19	1.60
Modern, broadcast[b]	74	66	41	1.93	[c]	[c]
Modern, transplanted	98	29	114	0.61	96	0.89
Aman						
Traditional, broadcast	18	15	7	0.15	5	0.59
Traditional, transplanted	54	24	22	0.25	18	0.10
Modern, transplanted	84	9	68	0.17	84	0.23
Boro						
Traditional, transplanted	12	3	9	0.06	1	0.00
Modern, transplanted	96	34	117	0.62	130	2.22
All seasons						
Traditional	43	33	18	0.71	15	0.65
Modern	91	25	94	0.49	106	1.42

Sources: Compiled from International Fertilizer Development Center, *Agricultural Production, Fertilizer Use, and Equity Considerations: Results and Analysis of Farm Survey Data, 1979/80* (Muscle Shoals, Ala.: IFDC, 1982); International Fertilizer Development Center, *Agricultural Production, Fertilizer Use, and Equity Considerations: Results and Analysis of Farm Survey Data, 1981/82* (Muscle Shoals, Ala.: IFDC, 1984); and data from Bangladesh Institute of Development Studies/International Food Policy Research Institute field survey.

[a] The figures for fertilizer are in weights of different kinds of materials (urea, phosphate, and potash). The nutrient content may be obtained by multiplying the figures by 0.46.

[b] According to the International Fertilizer Development Center survey, about one-fourth of the MV aus area was broadcast-seeded. Information on this is not available for the country as a whole.

[c] In the Bangladesh Institute of Development Studies/International Food Policy Research Institute survey area, modern broadcast aus variety was not grown.

Irrigation and Pesticides

According to the IFDC survey, irrigation was rarely practiced in the cultivation of local aus and aman, but about 65 percent of the plots under traditional boro and 89 percent of the plots under modern boro were irrigated (see Table 19). During the aman season, MVs are grown basically under rain-fed conditions. The intensity of irrigation, as measured by the average number of times of irrigation, is also highest in the cultivation of MVs of boro.

The market for irrigation is imperfect, and the cost of irrigation per unit of land varies widely, depending on the source of irrigation and on the type of ownership of irrigation equipment. Irrigation was provided free of cost to farmers in 2 of the 16 villages in the BIDS/IFPRI survey, as they happened to be under the Ganges-Kobtak project area of the Bangladesh Water Development Board. Two of the villages used low-lift pumps, rented to farmers' cooperatives by the Bangladesh Agricultural Development Corporation. In these villages the water charge paid by farmers varied from Tk 230 to Tk 320 per acre. In three villages where irrigation has been practiced since the late 1960s under the auspices of Comilla-type cooperatives, a combination of low-lift pumps, shallow tubewells, and deep tubewells has been used, and the water charge came to about Tk 650 per acre. In another three villages, irrigation was recently introduced by private shallow tubewell owners, who sold water to owners of adjoining plots at a charge varying from Tk 1,400 to Tk 1,800 per acre. Thus the water charge observed at the farm level in no way measures the irrigation input. The average water charge in the cultivation of boro MVs comes to about Tk 690 per acre for the sample as a whole—about one-eighth of the gross value of output.

Pesticides are rarely used on local varieties, but some use in MVs was noted (Table 19). The increase in cost on this account is only marginal. The highest level of use is on MVs grown during the aus and boro seasons. For these crops the cost on account of pesticides was reported at Tk 90 per acre—only 1.5 percent of the gross value of output.

Table 19—Use of irrigation and pesticides under traditional and modern varieties of rice, 1980-82 averages

Season/Variety	Share of Plots Irrigated	Mean Number of Times Irrigated	Share of Plots Treated with Pesticides	Average Use of Pesticides
	(percent)	(average for plots)	(percent)	(kilograms/ acre)
Aus				
Traditional, broadcast	0	0.0	3	. . .
Modern, broadcast	3	. . .	9	0.12
Modern, transplanted	61	5.4	19	0.25
Aman				
Traditional, broadcast	0	0.0	0	0.00
Traditional, transplanted	5	0.1	. . .	. . .
Modern, transplanted	14	0.8	17	0.12
Boro				
Traditional	65	4.4	3	. . .
Modern	89	7.4	50	0.79

Sources: Compiled from International Fertilizer Development Center, *Agricultural Production, Fertilizer Use, and Equity Considerations: Results and Analysis of Farm Survey Data, 1979/80* (Muscle Shoals, Ala.: IFDC, 1982); and International Fertilizer Development Center, *Agricultural Production, Fertilizer Use, and Equity Considerations: Results and Analysis of Farm Survey Data, 1981/82* (Muscle Shoals, Ala.: IFDC, 1984).

Seeds

The amount of seed used per unit of land depends on whether the seed is broadcast or a separate seedbed is prepared to grow seedlings that are then transplanted to the main field. According to the Bangladesh Bureau of Statistics, the normal seed requirement for broadcast varieties is 32-37 kilograms per acre, while for transplanted varieties it is about 8-10 kilograms.[50] The value of seedlings is, however, higher than the cost of seeds used, because of the additional cost of land and labor used in seedbed preparation. For traditional varieties, seeds are generally kept from the harvest, but for MVs a significant proportion of the seed may be purchased from markets or government centers (particularly if the seed is new in the area), hence the cost may be higher.

The cost per unit of land was lower for transplanted varieties than for broadcast ones (see Table 20).

Among transplanted crops, the seed cost per unit of land is found to be higher for MVs by about 16 percent for the aman season and nearly 55 percent for the boro season. For all seasons together, the seed cost per acre is almost the same, but because of higher yield, the cost per unit of output for MVs is only about half of that for traditional varieties (Table 20).

Unit Costs and Profitability of Cultivation

This section estimates the effect of the changes in input-output relationships described above on the costs and profitability of rice cultivation. First, estimates are derived by applying national-level prices on the average input-coefficients for 1980-82 (IFDC survey), except for seed, for which the information is only available for 1982. In order to dissociate the effect of climatic factors, the average crop yield for the last three years (1982-85), as reported in official statistics, is used for estimating the gross returns. Then, BIDS/IFPRI survey data are used to estimate profits for different groups of farms at the farm-specific prices of inputs and output.

Table 20—Cost of seeds for traditional and modern varieties of rice, 1982

Season/Variety	Cost per Acre	Cost as Share of Output
	(Tk)	(percent)
Aus		
Traditional	183	9.8
Modern	130	2.6
Aman		
Traditional, broadcast	175	6.5
Traditional, transplanted	135	4.9
Modern, transplanted	158	3.5
Boro		
Traditional	107	2.7
Modern	165	2.8
All seasons		
Traditional	156	6.3
Modern	156	3.0

Source: Based on data from Bangladesh Institute of Development Studies/International Food Policy Research Institute field survey.

[50] Ibid.

National information on farm prices of inputs is not available, except for wage rates. The IFDC survey estimated that for urea, which accounts for over 70 percent of chemical fertilizers consumed in the country, the farm prices were higher than the officially fixed prices in the range of 2.8-10.7 percent for the eight crop seasons for which information was collected. In calculating fertilizer costs, it is assumed that farmers pay about 10 percent more than the official prices set by the government, the variable for which time series information is available. As mentioned earlier, the unit cost of irrigation varies across locations, depending on the source of water. To standardize the cost, the weighted average water charges paid by irrigators to private owners of shallow tubewells (as found in a recent survey by Quasem)[51] are used as the standard to estimate the irrigation cost for other crops by applying the IFDC survey information on the mean number of times a crop is irrigated. For other time periods, the irrigation cost has been adjusted by the price index of diesel. The farm price of manure is available from the IFDC survey for 1980. Similarly, the cost of seed is available only for 1982 (Table 20). For other time periods, the manure and seed costs are derived by adjusting them by the price index of rice. It is reported in a 1980 survey of six villages in Comilla and Noakhali that the hiring charge for a pair of animals, along with the worker who operates them, is about 2.5 times higher than the wage rate paid to hired workers.[52] On this basis, the cost of a pair of animals is assumed at 1.5 times the wage rate, since the hired worker is included in the input of human labor. The family labor input is imputed by the wage rate of the hired labor.

The cost of mechanical power could not be included due to nonavailability of information on rental charges for machines. In any case, nearly two-thirds of the mechanical power input is on account of irrigation, the costs of which are included in irrigation charges. The unaccounted input is only about eight hours per acre (in threshing), the cost of which would be very low as a proportion of the value of output.

Land is an important fixed asset, but the opportunity cost of the investment in land has not been included in the cost of production. The justification is that land, unlike other fixed assets, does not depreciate in value, particularly in countries where land is scarce. According to the Bangladesh Bureau of Statistics, during 1973-84 the price index of single-cropped, unirrigated land (the type of land not affected by productivity-raising investment) increased at an annual rate of about 17.6 percent, compared with the 11 percent rate of inflation during this period and the 14 percent rate of interest currently paid by commercial banks on fixed deposits. Thus a person investing in land can get a higher return than the interest on money deposited in banks, even if the land is kept fallow. In this sense, use of the land for cultivation does not involve any real cost to its owners. For tenants, however, the rent paid to the landowner is a real cost and has to be included in estimating their profits.

Another cost element that has not been included in the estimates is the rate of interest paid on working capital borrowed from outside. In Bangladesh, farmers borrow for agricultural purposes from various institutional sources, which generally charge 16 percent interest annually. Borrowings from informal sources for extremely short periods are widespread. These informal loans bear high rates of interest (10 percent a month is common) and so may not be used for financing production expenses. Also, information on credit is available at the household level and is difficult to apportion to various

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[51] Md. Abul Quasem, *Impact of the New System of Distribution of Fertilizer and Irrigation Machines in Bangladesh—Survey Findings,* Research Report 62 (Dhaka: Bangladesh Institute of Development Studies, 1987), p. 30.

[52] Bangladesh Unnayan Parishad, *A Socio-Economic Evaluation of the Chandpur II Irrigation Project,* a report prepared for the World Bank (Dhaka: Bangladesh Unnayan Parishad, 1982), app. A, pp. 6-25.

crops. The BIDS/IFPRI survey found that the sample farmers borrowed an average of Tk 150 per acre of cropped land from institutional sources during 1982. This amount constituted only one-fourth of total borrowing. The cost has not been included because of the problem of apportioning it to various crops.

The choice of an appropriate price for output is a problem. Here the growers' price of paddy as reported by the Bangladesh Bureau of Statistics is used. The government also declares, in advance of the harvest, a procurement price for paddy at which the farmers can sell their produce at government-operated purchasing centers. While it is estimated that nearly 40 percent of the rice is marketed, the average procurement of the government in 1980-85 was only about 2 percent of domestic production. Use of the growers' price thus appears more appropriate. Another problem is the quality differences for different varieties of rice. The grain of the rice MVs produced during the aus and boro seasons is coarse and fetches the lowest price in the market. Among traditional varieties, aus and boro are coarse, while aman grains are generally of superior quality and fetch the highest prices. Information provided by the Department of Agricultural Marketing shows that the average price of fine-quality aman rice during 1980-84 was about 22 percent higher than the price of MV rice.[53] For the present calculation, the reported average growers' prices for traditional varieties of aus and boro and MVs of aman have been applied, and prices have been assumed to be 10 percent higher for traditional aman and 10 percent lower for MVs of aus and boro.

Estimates of costs and returns have been made at prices for 1984/85, the most recent year for which price information was available. However, the relative input-output prices underwent considerable change during 1975-85, partly because of the government policy of gradual withdrawal of subsidies from modern inputs such as fertilizers and irrigation, which are used more in the cultivation of MVs. Some of the profitability gains of the new technology may have been eroded by such price changes. In order to see the effect of price changes on profitability, costs and profits have also been estimated at 1975/76 prices.

The estimates of costs and profits at 1984/85 prices are presented in Table 21. The "cash cost" includes the cost of seed, fertilizer, manure, irrigation, pesticides, and hired labor, while the "total cost" also includes the imputed value of family and animal labor. Small farmers and tenants who have surplus family labor and low opportunity cost of employing it elsewhere may give more weight to cash costs in making production decisions than to total cost, which is a more relevant variable for the large farmers who have high opportunity cost of family labor. The cash cost per unit of land also shows the working capital requirement, and the small farmer may be in a more disadvantaged position to supply it than the large farmer, who would have a higher amount of surplus (production over family consumption) and better access to financial institutions. In the cultivation of traditional varieties, the cash cost of production per unit of land is almost the same in the aus and aman seasons, but about three-fourths higher in the boro season because of the requirement for irrigation. Per unit of output, however, the cost is lowest for the aman season crops. In transplanted aman, the cost is about one-fourth lower than for aus (highland) or boro (lowland) varieties.

In the cultivation of MVs, the cash cost per unit of land is about 1.7 times higher than for the traditional varieties—1.9 times for the aus season, 1.1 times for the boro season, and nearly three-fourths for the aman season. The MVs have higher yields, but

[53] Bangladesh, "Wholesale Prices of Agricultural and Animal Products in Bangladesh, 1972-85," Department of Agricultural Marketing, Dhaka, 1986 (mimeographed).

Table 21—Costs of production and profits under traditional and modern varieties, at 1984/85 national-level prices

Season/Variety	Cash Costs: Per Acre	Cash Costs: Per Metric Ton	Total Costs: Per Acre	Total Costs: Per Metric Ton	Estimated Profit: Per Acre	Estimated Profit: As Share of Costs
			(Tk)			(percent)
Aus						
Traditional	736	1,466	2,524	5,027	−35	−1
Modern	2,121	1,612	4,149	3,153	1,723	42
Aman						
Traditional, broadcast	737	1,205	2,261	3,699	1,071	47
Traditional, transplanted	811	1,089	2,299	3,086	1,764	77
Modern, transplanted	1,406	1,198	3,242	2,761	2,578	80
Boro						
Traditional	1,354	1,454	3,666	3,937	950	26
Modern	2,808	1,696	5,136	3,102	2,253	44
All seasons						
Traditional	799	1,226	2,425	3,720	1,038	43
Modern	2,122	1,510	4,200	2,990	2,296	55
			(percent)			
Difference in modern over traditional	166	23	73	−20	121	12

Source: Estimated from International Fertilizer Development Center survey data.

per unit of output the cash cost is also higher for their cultivation. For all three seasons, the weighted average difference is about 23 percent. The absolute cash cost on account of purchased inputs is Tk 1,513 per ton of paddy for MVs and Tk 1,226 for traditional varieties.

A different conclusion is reached if total cost of production is considered. The cost per unit of land is higher by about three-fourths for the cultivation of MVs than for traditional varieties, but the cost per unit of output is lower by about one-fifth. The absolute cost per ton of paddy is Tk 3,720 (US$124) for traditional varieties and Tk 3,000 (US$100) for MVs. Compared with traditional aus (the main substitute crop), which has the highest unit cost of production (US$168 per ton), the cost of cultivation of MVs is lower by about 40 percent.

Since land is scarce, the farmer is interested in maximizing the net return per unit of land. At the assumed average prices the profit (gross return minus total cost) is negative for cultivation of the traditional aus variety[54] and is substantially lower for all other traditional varieties compared with MVs. For all seasons, the difference in net return per unit of land is Tk 1,250 per acre—about 1.2 times higher for cultivation of MVs than for traditional varieties. Subsistence farmers may be interested in maximizing the net return to the family (gross returns minus cost of purchased inputs). The new technology gives a better return in this respect also. The return to family inputs is estimated at Tk 4,370 per acre for MVs, compared with Tk 2,670 for traditional varieties—an increase of about 64 percent. The family income per day of labor is estimated at Tk 87 for MVs, compared with Tk 75 for local varieties. The wage rate of agricultural labor prevailing in 1984/85 for the country as a whole was Tk 24.

[54] The traditional aus is a very low yield crop, and in areas in which it is a major crop, the wage rate is also found to be very low. For the BIDS/IFPRI sample, the wage rate paid for cultivation of local aus is estimated at Tk 12.92 per day, compared with Tk 23.88 in the cultivation of modern-variety boro. If the cost of labor is evaluated at the crop-specific wage rate, the net profit in the cultivation of local aus would also be positive.

Households that consider farming as an investment alternative base their decisions on the rate of return on capital. The estimates of total cost show that the new technology gives scope for investing more capital on a fixed amount of land. The rate of profit, measured as a percentage of total cost, is also found to be higher for MVs, particularly during the aus and boro seasons. For all three seasons, the rate of profit is estimated at 55 percent for the new varieties compared with 43 percent for the traditional ones.

Whether the farmers would consider the rate of profit adequate to maintain a reasonable standard of living is a separate issue. Comparison of the rate of profit in farming with that in nonagricultural activities is not justified, because accumulation of capital in farming is constrained by the amount of land owned, while in nonagriculture profits can be reinvested for further accumulation. Only about 5 percent of households in Bangladesh operate farms larger than 7.5 acres. If a 7.5-acre farm grew one traditional and one modern variety during a year, it would have a profit of about Tk 24,700, which for a six-member household gives a per capita income of Tk 4,110. For 1984/85 the per capita income for the nation was estimated at Tk 3,990, and the poverty-level income at Tk 3,096.[55] Thus, even at this high rate of profit, farming alone does not guarantee an acceptable standard of living for a large-farm family.

The effect of the changes in agricultural prices during 1975-85 on cost and profitability in rice cultivation is shown in Table 22. Owing to the gradual withdrawal of

Table 22—Effect of price changes on costs of production and profits, 1975/76-1984/85

Season/Variety	Costs of Production			Profits		
	1975/76	1984/85[a]	Change	1975/76	1984/85[a]	Change
	(Tk/acre)		(percent)	(Tk/acre)		(percent)
Aus						
Traditional	928	1,104	19	41	−15	large negative
Modern	1,402	1,814	29	883	753	−15
Aman						
Traditional, broadcast	831	989	19	465	468	1
Traditional, transplanted	838	1,005	20	743	771	−4
Modern, transplanted	1,144	1,418	24	1,121	1,128	1
Boro						
Traditional	1,256	1,603	28	540	415	−23
Modern	1,669	2,246	35	1,207	985	−18
All seasons[b]						
Traditional	890	1,060	19	437	454	4
Modern	1,423	1,836	29	1,097	1,004	−8
Total	965	1,275	32	530	606	14

Source: Estimates are based on crop-level input-output data obtained from the International Fertilizer Development Center survey and on prices of inputs and output in Bangladesh, Bureau of Statistics, *The Statistical Yearbook of Bangladesh,* various issues (Dhaka: Ministry of Planning, various years).

[a] Estimated at 1984/85 prices of inputs and output and then converted at 1975/76 constant prices by using the consumer price index for 1975/76 and 1984/85.

[b] Weighted averages, using the share of crop variety of the total cropped area under rice in Bangladesh for the referenced year.

[55] The Bangladesh Bureau of Statistics has recently made estimates of the poverty line income for 1981/82 from the returns of the national household expenditure survey. This figure is based on this estimate, adjusted for changes in the cost-of-living index. For details see Chapter 8 of this study.

subsidies, input prices have increased faster than output prices. The cost of cultivation in real terms increased by about one-third during that period, and the rate of increase was faster for MVs, since they are more fertilizer- and water-intensive. The rate of profit over the investment in working capital declined from about 55 percent in 1975/76 to 48 percent by 1984/85; the rate of decline has been faster for MVs—from about 77 percent to 55 percent during the same period. The profit per unit of the scarce factor, land, has also declined, particularly for aus and boro season crops. But the absolute profit in cultivating MVs remains much higher than that for traditional varieties. In spite of declining profits in individual crop varieties, farmers have increased the profits per unit of land for all crops taken together, through reallocation of land from low- to high-profit crops. The share of MVs in the total sown area under rice doubled from about 14 percent in 1975/76 to 28 percent by 1984/85. The productivity growth as a result of this reallocation of land has ensured farmers about 14 percent higher profits in spite of the adverse movement in relative input-output prices.

The government controls the supply of fertilizer and irrigation, and the operation involves a considerable amount of subsidy. Since these inputs are consumed more in the cultivation of MVs than traditional varieties, a pertinent question is what would happen to the difference in costs and profits if the subsidies were fully withdrawn. As mentioned earlier, through a number of consecutive price increases the fertilizer subsidies had been withdrawn by 1985. The fertilizer price used in the calculation (US$167 per ton) is close to the world price. The cost of irrigation would, however, increase if subsidies were withdrawn. The Master Plan organization estimated that for 1984 the annualized capital cost plus the operation and maintenance for irrigation would come to Tk 1,720 per acre for deep tubewells and Tk 1,530 for large-scale irrigation projects (at economic prices).[56] In the cost calculation a water rate of Tk 1,250 per acre was assumed. Thus, if the subsidies are withdrawn, the irrigation charge to farmers may increase by about 37 percent.[57] At this price the total cost of production would be Tk 3,168 per ton of paddy for MVs, compared with Tk 3,738 for traditional varieties—still about 15 percent lower. The net profit would be Tk 2,050 per acre for MVs, compared with Tk 1,025 for traditional varieties.

The estimates of costs and profits at farm-specific prices, input use, and yield rates obtained from the BIDS/IFPRI survey are shown in Table 23. To estimate total costs, family labor was imputed at the wage rate paid by the household to hired labor. For households that did not hire labor, the average wage rate for the village was used to impute cost. Costs on account of animal labor supplied by the family could not be included, as the survey did not collect information on this variable. Seeds, both household-supplied and purchased, were included in cash costs. The estimates show substantially higher costs of production for cultivation of MVs than for local varieties, but the superiority of MVs is clearly demonstrated in profits and family income per unit of land. Cultivation of MVs yielded Tk 1,570 additional profits per acre of land and Tk 1,835 additional return to family labor and animals. The net income per day of family labor is estimated at Tk 53 for local varieties and Tk 74 for MVs, while hired labor was paid an average wage of Tk 19.5.

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[56] Cited in Hossain, "Fertilizer Consumption," p. 224.

[57] The actual subsidy on irrigation may in fact be higher than this proportion. A large part of the irrigation subsidy is consumed by owners of irrigation machines, who charge substantially higher prices to water users than the capital and operation costs. For 1982/83 the markup (water charge paid by irrigators over the cost) is estimated at 62 percent for deep tubewells, 34 percent for power pumps, and 10 percent for shallow tubewells. See Osmani and Quasem, "Pricing and Subsidy Policies," p. 166.

Table 23—Costs and profitability at farm-specific prices, production and input use, 1982

Season/Variety	Gross Value of Output	Cash Costs of Production	Total Costs of Production	Returns to Family Labor	Profits
			(Tk/acre)		
Aus					
Traditional	1,618	528	992	1,090	626
Modern	5,395	1,381	1,931	4,014	3,464
Aman					
Traditional, broadcast	2,596	569	1,023	2,027	1,573
Traditional, transplanted	2,737	742	1,118	1,995	1,619
Modern, transplanted	4,854	1,193	1,777	3,661	3,077
Boro					
Traditional	3,800	536	960	3,264	2,840
Modern	5,767	2,103	2,945	3,664	2,822
All seasons					
Traditional	2,511	626	1,050	1,885	1,461
Modern	5,330	1,610	2,299	3,720	3,031
All varieties	3,292	899	1,396	2,393	1,896

Source: Estimated from Bangladesh Institute of Development Studies/International Food Policy Research Institute field survey data.

Table 24 shows the estimates of profits for different farm sizes and tenurial groups. For MVs, profits are higher on larger farms, but for traditional varieties no systematic pattern is found. The tenants pay 50 percent of the gross produce as rent for the sharecropped land. After deduction of the rent the profit is very small on the sharecropped land, but is higher for MVs than for local varieties. The net return to tenants' family labor and draft animals was Tk 750 per acre for local varieties and Tk 1,140 for MVs, or about 52 percent higher. The net return per day of tenants' labor is estimated at Tk 21 for local varieties and Tk 23 for MVs—only marginally higher than the average rate of Tk 19.5 for the entire sample. Thus the rented land benefits tenant farmers mainly through reducing underutilization of family labor and animals.

Table 24—Profits and family income at farm-specific prices for different farm sizes and tenurial groups, 1982

Group of Farmers	Profits			Return to Family Labor and Animals		
	Traditional Varieties	Modern Varieties	Difference	Traditional Varieties	Modern Varieties	Difference
	(Tk/acre)		(percent)	(Tk/acre)		(percent)
Landownership group						
Small (less than 2.5 acres)	1,355	2,619	93	1,688	3,747	100
Medium (2.5 to 5.0 acres)	1,539	2,669	73	1,967	3,349	70
Large (5.0 or more acres)	1,448	3,685	155	1,787	4,152	132
Tenurial group						
Owner-cultivator	1,322	3,062	132	1,797	3,682	105
Owner-cum-tenants	1,154	2,049	78	1,578	2,829	79
Owned land	1,069	2,974	85	2,034	3,754	85
Rented land	323	360	12	748	1,140	52

Source: Based on data from Bangladesh Institute of Development Studies/International Food Policy Research Institute field survey.

Comparison of relative gains from adoption of MVs across different groups shows that owner-farmers gain more than tenants, and large farmers gain more than small and medium ones. But the gains of small farmers are also higher than those of medium ones. Thus the gains are not systematically positively related to the size of household landownership.

Conclusions

The rice MVs have opened up an opportunity to increase production substantially from a given amount of land. The yield of MVs on a farmer's field is twice that of the traditional varieties. The fluctuations in yield caused by natural factors are also lower for MVs, indicating that the new technology has reduced the risk of cultivation. Farmers use about 45 percent more labor per unit of land for the cultivation of MVs than for traditional varieties. But per unit of output, use of labor is about 35 percent lower, and use of draft power is about 45 percent lower for MVs. The new crops, however, use substantially more fertilizer, irrigation, and pesticides per unit of output. The cash costs of production per unit of land are about 1.7 times higher, and per ton of output are about one-fifth higher for MVs. The total cost of production per ton of paddy is estimated (at 1984/85 prices) at US$100 for MVs, compared with US$124 for traditional varieties. The profit per acre of land is estimated at Tk 2,300 for MVs, which is about 2.2 times that for traditional varieties (Tk 1,040). The rate of profit over the cost of production is 55 percent for MVs, compared with 43 percent for traditional varieties. The gradual withdrawal of subsidies from fertilizer and irrigation during 1975-85 has reduced the profitability gap, but farmers have increased their profits from cultivation of rice through reallocation of land from traditional to modern varieties, since the absolute profit for MVs is still higher. Even if subsidies were fully withdrawn, the profit per unit of land would still be about twice as much for cultivation of new varieties as for traditional ones, and the unit cost of output would be about 15 percent lower.

5

PRODUCTIVITY AND EFFICIENCY OF RESOURCE USE

The effects of the new technology on productivity of land and labor and on efficiency in their utilization are assessed in this chapter. Land is the most scarce input in Bangladesh. It could be argued that the development of irrigation, which is the most critical input in the modern technology package, could raise the effective supply of land by creating conditions for growth of an extra crop on fallow land during the dry winter season.[58] In order to see whether and to what extent this has happened in Bangladesh, the first section compares the pattern and the intensity of land use in the technologically developed and underdeveloped areas as well as on the irrigated and unirrigated land. This is followed by an analysis of the production function for estimating the factor shares and the marginal productivity of land and labor for traditional and modern technology. The final section applies a profit function model to study the relative economic efficiency of adopters of the new technology and farmers still growing only traditional crops.[59] The analyses in this and the following chapters are based on disaggregated farm and plot data collected by the BIDS/IFPRI survey.[60]

Intensity of Land Use and Cropping Patterns

The effect of technological change on the pattern and intensity of land use can be seen in Tables 25 and 26. The tables are based on information collected at the plot level on the use of the land during the three crop seasons in 1981 in the 16 villages covered by the BIDS/IFPRI survey. The survey enumerated 5,255 plots belonging to 639 sample households (8.2 plots per household). About 68 percent of the plots were owner operated; 13 percent were rented out to others, mostly under sharecropping arrangements; 6 percent were under orchards or bamboo bushes; 2 percent were under ponds; and the remaining 11 percent were under homesteads. Some of the landowners did not know about the use of the plots operated by tenants, so complete information could not be obtained for this type of land. It was also found that the practice of renting out land for only one season was prevalent; the plot rented out for cultivation during the boro season was taken back by some landowners for self-cultivation during the aman season. To avoid problems caused by these complications, the information presented here is based on the data obtained for the owner-operated plots only. The following main points can be noted from the information.

Irrigation has a significant effect on increasing the effective supply of land during the boro season. Only two-fifths of the unirrigated land is cropped during the boro

[58] Shigeru Ishikawa, *Economic Development in Asian Perspective* (Tokyo: Kinokuniya, 1967). For Bangladesh this hypothesis has been tested in James K. Boyce, "Water Control and Agricultural Performance in Bangladesh," *The Bangladesh Development Studies* 14 (No. 4, 1986): 1-35.

[59] Lawrence J. Lau and Pan A. Yotopoulos, "Profit, Supply and Factor Demand Functions," *American Journal of Agricultural Economics* 54 (No. 1, 1972): 11-18; and Lau and Yotopoulos, "A Test for Relative Efficiency and an Application to Indian Agriculture," *American Economic Review* 61 (No. 1, 1971): 94-109.

[60] BIDS/IFPRI, *Development Impact.*

Table 25—Pattern and intensity of use of irrigated and unirrigated land, 1981

Season/Crop	Irrigated Land: Sown Area	Irrigated Land: Share of Cultivated Land	Unirrigated Land: Sown Area	Unirrigated Land: Share of Cultivated Land
	(acres)	(percent)	(acres)	(percent)
Aus	70.84	21.0	198.20	30.4
Local aus	12.82	3.8	148.65	22.8
Modern-variety aus	54.41	16.1	4.25	0.6
Jute	3.60	1.1	45.30	7.0
Aman	227.80	67.6	412.10	63.2
Local broadcast aman	18.23	67.6	119.82	63.2
Local transplanted aman	83.76	24.9	237.27	36.4
Modern-variety aman	125.45	37.2	15.75	2.4
Sugarcane	0.35	0.1	39.25	6.0
Boro	257.50	75.4	251.15	38.6
Local boro	14.75	4.4	44.40	6.8
Modern-variety boro	196.65	58.3	13.55	2.1
Wheat	9.40	2.8	21.17	3.3
Pulses	10.03	3.0	117.00	18.0
Oilseeds	19.80	5.9	21.35	3.3
Vegetables	5.35	1.6	15.20	2.3
Spices	1.50	0.5	14.38	2.2
Other	...	...	4.10	0.6
Total cropped land	556.15	165.0	861.45	132.2
Total cultivated land	337.10	100.0	651.75	100.0

Source: Based on data from Bangladesh Institute of Development Studies/International Food Policy Research Institute field survey.
Note: Parts may not add to totals because of rounding.

season, but with irrigation the intensity of use increases to about three-fourths (Table 25). Part of the increase is at the expense of the overlapping aus season crops, which are grown on 30 percent of the unirrigated land, but on only 21 percent of the irrigated land. MV boro, for example, competes for land with local aus and jute. It is harvested at the beginning of May, when it is too late to broadcast aus and jute seeds on the same land. About 31 percent of the land remains fallow over these two seasons when the land is unirrigated, but the proportion is reduced to only 14 percent with access to irrigation facilities. Irrigation, however, does not change the pattern of land utilization during the aman season, when crops are grown basically under rain-fed conditions. Two-thirds of the cultivated land is cropped during the aman season; one-third remains fallow, presumably owing to excessive flooding. Provision of irrigation facilities does not appreciably change the proportion of aman season fallow land.

The adoption of MVs is facilitated mostly by irrigation. Only 6 percent of the unirrigated land was used to grow MVs during the three seasons. For irrigated land the proportion was about 112 percent, which also indicates that some of the land was used to grow two MV rice crops during the same year. Of the 86 percent of irrigated land cropped during the aus and boro seasons, 75 percent was used for growing MV rice. Only during the aman season was a large proportion of the irrigated land used to grow local paddy.

Irrigation has an adverse effect on diversification of crops. Except for rice and oilseeds, all crops are grown less often on irrigated land than on unirrigated land. Following the development of irrigation facilities, rice varieties replace not only the low-yielding pulses but also the major cash crops, jute and sugarcane. These three

Table 26—Pattern and intensity of land use in technologically developed and underdeveloped villages, 1981

Season/Crop	Developed Villages: Cropped Land	Developed Villages: Share of Cultivated Land	Underdeveloped Villages: Cropped Land	Underdeveloped Villages: Share of Cultivated Land	All Villages: Cropped Land	All Villages: Share of Total Cultivated Land
	(acres)	(percent)	(acres)	(percent)	(acres)	(percent)
Aus	100.78	21.4	168.23	32.5	269.01	27.2
Local aus	29.20	6.2	132.30	25.6	161.50	16.3
Modern-variety aus	51.67	11.0	6.96	1.3	58.63	5.9
Jute	19.91	4.2	28.97	5.6	48.88	5.0
Aman	312.80	66.4	327.05	63.1	639.85	64.7
Local broadcast aman	58.59	12.4	79.46	15.3	138.05	14.0
Local transplanted aman	110.34	23.4	210.72	40.7	321.06	32.5
Modern-variety aman	134.96	28.7	6.22	1.2	141.18	14.3
Sugarcane	8.92	1.9	30.65	5.9	39.57	4.0
Boro	293.44	62.3	215.40	41.6	508.84	51.5
Local boro	39.72	8.4	19.44	3.8	59.16	6.0
Modern-variety boro	184.26	39.1	25.91	5.0	210.17	21.3
Wheat	8.57	1.8	22.03	4.3	30.60	3.1
Pulses	16.62	3.5	110.43	21.3	127.05	12.8
Oilseeds	26.30	5.6	14.85	2.9	41.15	4.2
Vegetables	9.51	2.0	11.04	2.1	20.55	2.1
Spices	6.89	1.5	8.99	1.7	15.88	1.6
Other	1.58	0.3	2.72	0.5	4.30	0.4
Total sown area	707.02	150.1	710.68	137.2	1,417.70	143.4
Total cultivated area	470.95	100.0	517.91	100.0	988.86	100.0

Source: Based on data from Bangladesh Institute of Development Studies/International Food Policy Research Institute field survey.
Note: Parts may not add to totals because of rounding.

crops are grown on about 31 percent of the unirrigated land, but on only about 4 percent of the irrigated land. Owing to the large-scale replacement of noncereal crops by rice, the effect of irrigation on intensity of land use is much less pronounced than its effect on cereal cultivation. The sown area under cereals is about 87 percent of cultivated land for the unirrigated plots; with irrigation the proportion rises to about 153 percent—an increase of over 66 percent. The total cropping intensity is, however, estimated at 165 percent for the irrigated land, compared with 132 percent for unirrigated land—an increase of only 33 percent.

Table 26 compares the patterns of land use in sample villages that are classified into two equal-size groups according to the scale of diffusion of the new agricultural technology (see Chapter 2). MV rice is grown on almost 80 percent of the cultivated land in the developed villages, compared with only 8 percent of the land in underdeveloped villages. For the aus and boro seasons together, the proportion of cultivated land under MV rice in both groups of villages is similar to the proportion of area irrigated, indicating a singular relationship between irrigation and adoption of MV seeds. This supports the findings of strong complementarity between the two inputs reported in Chapter 3 on the basis of regression analysis of district cross-section data. Intensity of land use is estimated at about 150 percent for the technologically developed villages, compared with 137 percent for the underdeveloped villages. Thus a 40 percent increase in irrigation leads to a 13 percent increase in effective supply of land, indicating an elasticity of supply of land to irrigation of 0.33.

Productivity of Land and Labor

A technique frequently used to analyze productivity and efficiency of resource use is the Cobb-Douglas production function. The technical coefficients of production estimated from the function are used in various policy applications. The input coefficients of the function represent production elasticities of the inputs. The sum of the elasticities is used as an indicator of the degree of returns to scale in production. This section uses the farm-level cross-section data for 1982 to estimate production functions for the traditional and modern varieties of rice in order to study the effect of the new technology on productivity of land and labor.

The production function for each crop was fitted in the following form:

$$\text{Ln}Y_i = \text{Ln}\beta_0 + (\beta_1 + \beta_2)\text{Ln}A_i + \beta_2\text{Ln}(N/A)_i + \sum_{j=1}^{15}\lambda_{ij}V_{ij} + V_iD_i, \qquad (1)$$

where Y_i is the value added (Tk) for the ith farm in the cultivation of the crop, as measured by the gross value of output net of the costs on account of seeds, manure, fertilizer, pesticides, and irrigation. The cost of animal labor could not be included owing to nonavailability of data. Ln is the natural logarithm of the variable, A is the amount of land sown under the crop, and N is the total number of labor days (hired plus family labor) used during the production period (from land preparation to threshing). A number of crops were affected by droughts, floods, and hailstorms during the year, and the effect was not uniform across villages or across farms within a village (owing to variations in land elevation). Information was collected from every farmer about the amount of crop damage as a percentage of the harvest expected, given the extent of application of the inputs. This farm variable, D_i, has been used to dissociate the effect of natural calamities. Since the information comes from 16 widely scattered villages in different ecological zones, it is expected that the variation in climate, soil type, and intensity of land use permitted by these agroclimatic factors would contribute to some variation in output, irrespective of the amount of inputs used. Therefore 15 village dummy variables, V_j, have been used to dissociate the effect of the environmental factors. The coefficients β_1 and β_2 are the output elasticity of land and labor, respectively. The coefficient of $\text{Ln}A_i$ gives the sum of the elasticities, which, along with its standard error of estimate, can be used to test the hypothesis about the degree of returns to scale in the specific crop-production activity.

Equation (1) is a modified form of the general Cobb-Douglas production function,

$$\text{Ln}Q_i = \text{Ln}\beta_0 + \sum_{j=1}^{m}\beta_i\text{Ln}X_{ij}, \qquad (2)$$

where for the ith farm, Q is the gross output, and X_j is the amount of the m different inputs used in its production. This particular functional form assumes that the elasticity of substitution between any two inputs is equal to one. Value added is used instead of gross output and is related only to the primary inputs, land and labor, for the following reasons. Seed is an important material input, but it has a technologically fixed relationship with land, which violates the unit elasticity of substitution assumption. The variation in the amount of fertilizer used per unit of land in individual crop varieties is limited to a certain range. Changes in the use of fertilizer are realized more through choice of crop varieties. Animal power is an important input, but it is used along with human labor, which produces strong complementarity rather than substitutability assumed in the production function. Inputs like fertilizer and irrigation are also complements rather than substitutes. Fertilizer, manure, pesticides, and irrigation are not essential for production of local varieties: this is indicated by the small proportion of farmers applying these inputs (see Chapter 4). The log-linear production function is not appropriate if these inputs are used as explanatory variables. Thus deduction of the costs on account of the material inputs from the gross value of production appears more appropriate than using them as separate variables in the Cobb-Douglas production function framework.

Since farm-level cross-section data are used to estimate the function, one expects the amount of land and labor to be highly correlated across farms. This creates the well-known problem of multicollinearity in estimating the parameters of the function. To avoid this problem, the labor input has been measured per unit of land, which breaks the high degree of correlation between land and labor. This produces the modified form of the function as shown in equation (1), in which the coefficient of logarithm of the land variable becomes the sum of the elasticities of land and labor.

The estimates of the parameters of the function obtained from use of the OLS method are reported in Table 27. The following major conclusions can be drawn from the findings.

Crops are significantly affected by damage due to natural factors. The coefficient of damage is statistically significant for all crop varieties. This indicates the prevalence of a high degree of uncertainty in rice cultivation, so the farmer cannot be sure about the productivity of the inputs applied on the land. Thus the rate of application of the inputs may depend not only on the prices but also on the degree of risk aversion of the farmer. The regression coefficient of crop damage is, however, found to be lower for MVs than for traditional varieties in all three seasons.

Table 27—Estimates of Cobb-Douglas production functions for different varieties of rice, 1982

Season/ Variety	Constant	Elasticity[a] Land	Labor	Coefficient of Crop Damage	$\bar{R}^2$	'F' Statistic
Aus						
Local	5.640	0.511	0.555	−1.41	0.82	59.0
	(0.980)	(0.055)	(0.190)	(0.19)		
Modern	7.364	0.701	0.338	−0.86	0.89	98.6
	(0.852)	(0.062)	(0.190)	(0.31)		
Aman						
Local	6.110	0.570	0.490	−0.86	0.82	46.9
	(0.474)	(0.060)	(0.120)	(0.12)		
Modern	7.701	0.636	0.374	−0.54	0.83	66.9
	(0.417)	(0.053)	(0.100)	(0.18)		
Boro						
Local[b]	7.280	0.787	0.296	−1.13	0.96	720.0
	(0.298)	(0.028)	(0.080)	(0.14)		
Modern	7.196	0.613	0.371	−0.69	0.93	669.4
	(0.262)	(0.023)	(0.063)	(0.08)		

Notes: Figures in parentheses are standard errors of the estimated coefficients. The regression coefficients of village dummies have not been reported.

[a] The standard error of estimate is for the sum of the elasticity of land and labor.

[b] Local boro is grown in only one ecological zone. Hence the village dummies have not been used.

The sum of the output elasticity (factor share) of land and labor is less than one for MV boro and greater than one for other varieties. But except for local boro, the value is not statistically significantly different from unity. This indicates the existence of constant returns to scale in rice cultivation.

The elasticity of land is generally higher, and that of labor lower, for the cultivation of MVs than for traditional varieties. Only in the case of the boro season is elasticity of labor found to be higher for MVs than for local varieties. In the boro season, boro MVs compete for land with local aus (grown on high land) more than with local boro (grown on extremely low land). Compared with local aus, the elasticity of labor is lower for MV boro.

The estimates of marginal productivity of land and labor, at the mean level of application of the inputs, are reported in Table 28. In estimating the marginal productivity of land, the output elasticity of land is taken as the difference of the elasticity of labor from unity, since constant returns to scale prevails. The table also compares the value of the marginal productivity of land with the rent paid by sharecroppers to landowners, and the value of labor with the average farm-specific wage rate paid to hired casual laborers in the cultivation of crops during the survey year. The following major points can be noted from the table.

Compared with local aus, the marginal product of land is about 5.3 times higher in the cultivation of MV aus and 4.8 times higher in the cultivation of MV boro. In the aman season, the increase in the marginal product in MV cultivation is less, but compared with the local variety, it is still about 2.2 times higher. In the boro season, however, the increase in productivity from use of modern technology is only about one-twelfth, but compared with local aus, which is the main substitute crop, the productivity increase is about 4.8 times. Thus modern technology gives tremendous scope for increasing the net returns from the fixed endowment of land that the farmer has.

The effect of modern technology on increasing the productivity of labor is small. Compared with local varieties, the marginal product of labor is higher for MVs by about 51 percent for the aus season, 41 percent for the boro season, and only 5 percent for the aman season. The difference would not be statistically significant, as indicated by

Table 28—Estimates of average and marginal products of land and labor, crop level, 1982

Season/ Variety	Land: Average Productivity	Land: Marginal Productivity	Labor: Average Productivity	Labor: Marginal Productivity	Rent[a]	Wage Rate[b]
	(Tk/acre)		(Tk/day)		(Tk/ acre)	(Tk/ day)
Aus						
Local	1,302	579	23.25	12.90	841	12.92
Modern	4,613	3,054	57.66	19.49	2,596	17.64
Aman						
Local	2,371	1,209	43.91	21.52	1,418	20.09
Modern	4,342	2,718	60.30	22.55	2,390	21.75
Boro						
Local	3,627	2,553	44.23	13.09	2,022	20.00
Modern	4,386	2,759	49.84	18.49	2,897	23.88

Source: Estimated from Bangladesh Institute of Development Studies/International Food Policy Research Institute field survey data.

[a] The value of rent is based on actual production, share rental, and input shares received from landowners in the cultivation of rental land.

[b] These are average farm-specific wage rates paid to hired workers in the cultivation of the crop.

the high standard error of estimate of the elasticity of labor (Table 27). It may also be noted that most of the increase in the marginal product of labor is passed on to workers in the form of higher wages. The workers, however, gain more through additional employment under the new crops (Chapter 4).

Efficiency in the allocation of resources is determined by comparing the marginal product of the factor with its price. According to neoclassical theory, allocation of resources is at optimum when the marginal product of the resources is equal to their prices. In Bangladesh, under sharecropping—the most common tenancy arrangement—the tenant pays 50 percent of the gross produce as rent to the landowner. In the cultivation of MVs, the landowner sometimes shares half the cost of fertilizer and irrigation.[61] The survey found that less than 1 percent of the cost of material inputs was paid by the landowner. The value of rent reported in Table 28 is based on actual production of rented-in land, rent paid by the tenant, and the input cost shared by the landowners. For aus and aman varieties, the marginal product of land is lower than the rent for the local varieties, indicating that the tenants have to pass on a portion of the return on their labor in the form of rent in order to get the land. For MVs, the marginal product of land is higher than the rent—14 percent for the aman season and 18 percent for the aus season. Thus the tenants tend to gain with the diffusion of modern technology in these seasons. For the boro season MVs, however, the marginal product of land is lower than the rent.

Labor seems to be optimally allocated during the aus and aman seasons, as its marginal product is almost in line with the wage rate for the four crop varieties grown during these seasons. During the boro season, however, the marginal product is lower than the wage rate, indicating overutilization of this input. This is usually the slack season of agricultural activity. Nearly half of the land remains fallow during the boro season (Table 26). Only about one-fourth of the land is cultivated with rice. Pulses and oilseeds, which are low-labor-intensive, are the major crops grown during the season. It appears from the findings that farmers facing underemployment of family workers are willing to accept low returns for labor during this season.

Relative Economic Efficiency

In recent economic literature, a profit function model, derived by the application of duality relation between the cost and the production function, is used to measure and compare economic efficiency and price efficiency for groups of farms.[62] Although the model has been severely criticized,[63] its use for empirical studies remains popular. The model is appropriate for the present analysis, as farm households can be classified into two groups, adopters and nonadopters of the modern technology, and their relative economic efficiency compared.

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[61] M. Raquibuz Zaman, "Sharecropping and Economic Efficiency in Bangladesh," *The Bangladesh Economic Review* 1 (No. 2, 1973): 149-172. It is found from this survey that 39 out of 72 farmers who cultivated modern-variety boro on rented land received some input from the landowner, but the value of the landowner-supplied input was only 0.8 percent of the cost on account of seeds, fertilizer, irrigation, and pesticides. The incidence of cost-sharing was even less for other crops.

[62] Pan A. Yotopoulos and Lawrence J. Lau, "A Test for Relative Economic Efficiency," *The American Economic Review* 63 (No. 1, 1973): 214-223.

[63] See, for example, John Quiggin and Anh Bui-Lan, "The Use of Cross-Sectional Estimates of Profit Functions for Tests of Relative Efficiency: A Critical Review," *Australian Journal of Agricultural Economics* 28 (No. 1, 1984): 44-55; and Ramesh Chand and J. L. Kaul, "A Note on the Use of the Cobb-Douglas Profit Function," *American Journal of Agricultural Economics* 68 (No. 1, 1986): 162-164.

In the model, farms are assumed to have fixed endowments of land, L, and capital, K, which cannot be varied in the short run, but farms can choose variable inputs, labor, N, and fertilizer, F, whose prices are W and C, respectively.[64] The amount of variable inputs that the farm decides to use is determined by setting the marginal cost of the input i to $1/P_i$ times the marginal value product, where P is considered the opportunity cost of the input supplied from the farm family. Farms are called price efficient if all the P_i are equal to unity. One farm may be more technically efficient than another if it produces a larger quantity of output from the same quantities of measurable inputs. Technical efficiency may differ between two groups of farms by a multiplicative factor, δ. Differences in economic efficiency among groups of farms may be caused by differences in technical or price efficiency or both.

Under the assumption of Cobb-Douglas technology, the model yields a unit output price (UOP) profit function:[65]

$$\text{Ln}\pi = \text{LnA} + \delta\text{T} + \alpha_1\text{LnW} + \alpha_2\text{LnC} + \beta_1\text{LnL} + \beta_2\text{LnK}, \tag{3}$$

and input demand equations:

$$-\text{WN}/\pi = \alpha_{11}\text{T} + \alpha_{12}(1 - \text{T}) \quad \text{and} \tag{4}$$

$$-\text{CF}/\pi = \alpha_{21}\text{T} + \alpha_{22}(1 - \text{T}), \tag{5}$$

where π is the unit output price profit (gross revenue minus total variable cost), W and C are, respectively, labor and fertilizer prices normalized by the output price, and T is a dummy variable taking value 1 for MV adopter farms and 0 for nonadopters.

The hypothesis of equal relative economic efficiency implies that δ is equal to zero. The hypothesis of equal relative price efficiency implies that $\alpha_{11} = \alpha_{12}$ and $\alpha_{21} = \alpha_{22}$. The hypothesis of absolute price efficiency implies that for adopter farms, $\alpha_{11} = \alpha_1$ and $\alpha_{21} = \alpha_2$, and for non-adopter farms, $\alpha_{12} = \alpha_1$ and $\alpha_{22} = \alpha_2$.

The error terms are assumed to be additive with zero expectation and finite variance for each of the three equations. But the covariances of the error of either equation corresponding to different farms are assumed to be identically zero. Under this specification of errors, Zellner's seemingly unrelated regression equation (SURE) provides an asymptotically efficient method of estimation.[66] The efficiency of estimation can be increased by imposing known constraints on the coefficients in the equation.[67]

In estimating the model from the data, profits have been measured by deducting farm-specific costs of variable inputs—seed, fertilizer, manure, pesticides, irrigation, and labor—from the gross value of output. The cost of animal labor could not be counted because of nonavailability of data. It has been treated as a fixed input and included in farm capital. The cost of family labor has been imputed by the wage rate paid to hired workers. It was mentioned earlier that the market for irrigation was very imperfect,

[64] The profit function is estimated for the sample farm households for all crops taken together. Since over 90 percent of the farmers used fertilizer on one crop or another, fertilizer was included as a variable production input, since output elasticity of fertilizer is often used as an important parameter in policy analysis (such as estimating costs and benefits of fertilizer subsidy). Also, information on farm capital was available at the household level and not at the crop level, so this variable could be included in the profit but not in the crop-specific production function reported earlier.

[65] For details of the derivation, see Yotopoulos and Lau, "A Test for Relative Economic Efficiency," pp. 215-218.

[66] A. Zellner, "An Efficient Method for Estimating Seemingly Unrelated Regressions and Test for Aggregation Bias," *Journal of the American Statistical Association* 57 (No. 2, 1962): 348-368.

[67] Yotopoulos and Lau, "A Test for Relative Economic Efficiency," p. 219.

and the irrigation charge varied widely depending on the source of supply of water. Since the MV crops were irrigated (Chapter 4), the cost of irrigation was also imputed by multiplying the area under MVs by the average cost of irrigation per unit of land for the entire sample. The prices of variable inputs at the farm level could be computed only for labor and fertilizer, since information on both quantity and cost was available only for these two inputs. For this reason, only fertilizer and labor could be used as variable inputs on the right-hand side of the profit equation. A significant proportion of farmers (9.5 percent) did not hire labor or use chemical fertilizer, so prices could not be computed for them. These cases have been dropped because of the nonavailability of farm-specific prices. The profits, wage rate, and fertilizer price variables have been normalized by paddy prices. The capital input has been measured in flow terms by multiplying the replacement cost of the stock of agricultural implements and draft animals by the rate of interest charged on loans from commercial banks.

Because of widespread crop damage from natural calamities during the reference year of survey, and the use of the wage rate as the opportunity cost of family labor, the profits were negative for a large number of cases (99 out of 475 farms in the sample). Since the UOP profit function is log linear, these cases had to be excluded. Since lower profits may also be due to inefficiency of resource use, this might introduce sample selection bias in the results. It is found from the tests of the difference of arithmetic means that farms making negative profits are one-third smaller in size and use 48 percent less fertilizer, but are not significantly different in adoption of modern varieties and use of capital services when compared with farms making profits (Table 29).

A major criticism of the model is that the invariability of the prices in the cross-section data vitiates the usefulness of the methodology.[68] This is not found to be a serious problem for the data set used here. Since the sample was selected from a large number of villages scattered throughout the country, and a number of villages are located in

Table 29—Selected characteristics of profitable and unprofitable sample farms, 1982

Variable	Farms Showing Profit (N = 331)	Farms Showing Loss (N = 99)	Percent Difference[a]	Estimated t-Value	Level of Significance
	(acres)				
Average amount of land owned	3.10	1.97	−37	−2.95	0.003
	(percent)				
Cropped area under modern varieties	36	37	1	0.28	0.777
	(kilograms)				
Fertilizer use per acre of cropped land	78	41	−48	−4.02	0.000
	(Tk)				
Capital services per acre of cropped land	298	334	12	0.61	0.543

Source: Based on data from Bangladesh Institute of Development Studies/International Food Policy Research Institute field survey.
[a] Values for farms showing losses over those for farms showing profits.

[68] Quiggin and Bui-Lan, "Use of Cross-Sectional Estimates," pp. 44-45.

interior areas with underdeveloped infrastructural facilities, differences in prices across locations were quite significant, particularly for labor and fertilizer. The coefficient of variation of prices across villages was found at 24 percent for labor, 14 percent for fertilizer, and 7 percent for paddy.[69]

The results of the tests of various hypotheses regarding the absolute and relative price efficiency in the use of labor and fertilizer, and also of constant returns to scale in production, are presented in Table 30. The hypothesis that the price efficiency is the same for the adopter and nonadopter farms is accepted for labor but rejected for fertilizer. The χ^2 value for the equality of the parameters in the fertilizer demand equation for the two groups is highly statistically significant. Both groups are absolutely price inefficient in the use of labor and fertilizer. But when the hypothesis of equal relative efficiency in the use of labor is maintained, both groups appear to be absolutely price efficient in the use of fertilizer. The hypothesis of constant returns to scale is also accepted.

The estimates of the parameters of the profit function and the factor share equations are presented in Table 31. The technology dummy is found to be highly statistically significant and the value of the parameter is positive, indicating that the adopter farms are more economically efficient. Even under the assumption of equal price efficiency for labor and constant returns to scale, the technology dummy remains statistically significant, the value indicating that the adopter farms are also more economically efficient, compared with the nonadopter farms, by about 29 percent.

In estimating profits, the cost of family labor was imputed at the wage rate paid to hired workers. This may be a very restrictive assumption, as the opportunity cost of labor could vary across farms, depending on the availability of family labor. To see the bias created by this assumption another explanatory variable was incorporated in the

Table 30—Tests of hypothesis of relative and absolute price efficiency and constant returns to scale

Test	Parameter Restriction	χ^2 Value	Significance Level
Relative efficiency in use of labor	$\alpha_{11} = \alpha_{12}$	1.19	0.275
Relative efficiency in use of fertilizer	$\alpha_{21} = \alpha_{22}$	7.85	0.005
Absolute efficiency in use of labor	$\alpha_{11} = \alpha_1$ $\alpha_{11} = \alpha_{12}$	8.25	0.016
Absolute efficiency in use of fertilizer	$\alpha_{21} = \alpha_2$ $\alpha_{21} = \alpha_{22}$	7.86	0.020
Absolute efficiency in use of fertilizer for adopter farms maintaining equal relative efficiency in use of labor	$\alpha_{21} = \alpha_2$ $\alpha_{11} = \alpha_{12}$	1.19	0.549
Absolute efficiency in use of fertilizer for nonadopter farms maintaining equal relative efficiency in use of labor	$\alpha_{22} = \alpha_2$ $\alpha_{11} = \alpha_{12}$	1.31	0.518
Constant returns to scale	$\alpha_{11} = \alpha_{12}$ $\alpha_{21} = \alpha_2$ $\beta_1 + \beta_2 = 1$	5.09	0.166

[69] The price variations are almost of a similar range to those reported in a study of Philippine rice growers by J. Flinn, K. Kalirajan, and L. Castillo, "Supply Responsiveness of Rice Farmers in Laguna, Philippines," *Australian Journal of Agricultural Economics* 26 (No. 1, 1982): 39-48.

Table 31—Joint estimates of profit functions and input demand equations, 1982

Variable (Parameter Restriction)	Parameter	Unrestricted Equation	Restricted ($\alpha_{11} = \alpha_{12}$ $\alpha_{21} = \alpha_2$ $\beta_1 + \beta_2 = 1$)	Restricted ($\alpha_{11} = \alpha_{12}$ $\alpha_{22} = \alpha_2$ $\beta_1 + \beta_2 = 1$)
Profit function				
Constant	LnA	−0.368 (−0.97)	−0.824 (−2.76)	−0.807 (−2.71)
Technology dummy	δ	0.258 (2.50)	0.282 (2.92)	0.288 (2.98)
Log wage rate	α_1	−0.368 (−2.52)	−0.312 (−2.21)	−0.305 (−2.15)
Log fertilizer price	α_2	−0.179 (−0.52)	−0.158 (−6.31)	−0.058 (−1.93)
Log land	β_1	0.767 (11.95)	0.882 (33.14)	0.882 (33.14)
Log capital services	β_2	0.128 (4.73)	0.118 (4.44)	0.118 (4.44)
Labor demand				
Adopter dummy	α_{11}	−1.058 (−5.52)	−0.953 (−0.582)	−0.956 (−5.83)
Nonadopter dummy	α_{12}	−0.653 (−2.06)	−0.953 (−5.82)	−0.956 (−5.84)
Fertilizer demand				
Adopter dummy	α_{21}	−0.172 (−6.09)	−0.158 (−6.31)	−0.158 (−6.31)
Nonadopter dummy	α_{22}	−0.019 (−0.40)	−0.058 (−1.89)	−0.058 (−1.93)
χ^2 for restriction	...	...	5.08	5.32
Level of significance	...	...	0.166	0.150

Note: Figures in parentheses are asymptotic t-values, $\bar{R}^2 = 0.50$, and the sample size consists of 331 profit-making farms.

profit function, FLBR, which is measured by the proportion of labor supplied from the farm family. If the opportunity cost of labor depends on the availability of family labor, this variable should be a proxy of the price of family labor. If the variable is statistically significant, the hypothesis that the opportunity cost of family labor is equal to the wage rate can be rejected.

The unrestricted joint estimates of the profit function and the labor demand relations are as follows:

$$
\begin{aligned}
\mathrm{Ln}\pi = {} & \underset{(0.71)}{-0.274} + \underset{(3.26)}{0.343\,T} - \underset{(-5.33)}{0.698\,\mathrm{LnW}} - \underset{(-0.50)}{0.195\,\mathrm{LnC}} \\
& + \underset{(10.6)}{0.702\,\mathrm{LnL}} + \underset{(3.26)}{0.122\,\mathrm{LnK}} - \underset{(3.85)}{0.702\,\mathrm{FLBR}}; \qquad (6)
\end{aligned}
$$

$\bar{R}^2 = 0.52, \ N = 331;$

$$WN/\pi = -1.05\,T - 0.65\,(1-T), \text{ and} \quad (7)$$
$$\qquad\qquad (-5.52) \quad (-2.05)$$

$$WC/\pi = -0.171\,T - 0.019\,(1-T). \quad (8)$$
$$\qquad\qquad (-6.09) \quad (-0.40)$$

The figures within parentheses are asymptotic t-values.

The coefficient of FLBR is negative and highly statistically significant. Thus the estimated profits decline with increased use of family labor, indicating that the opportunity cost of family labor is lower than the wage rate. Inclusion of this variable increases the value of the coefficient of the price of labor (LnW) from −0.37 in the previous estimate (Table 31) to −0.70. Since family labor has been incorporated as a separate variable, W can now be interpreted as the price of hired labor. The hypothesis that the value of parameter (α_1) is equal to the parameters of the labor demand relation ($\alpha_{11} = \alpha_{12}$) was also tested. The tests produced a χ^2 value of 2.59 with a significance level of 0.17, which can be taken to mean that the farmers are absolutely price efficient in the use of hired labor.

Maintaining the hypothesis that the farmers are both absolutely and relatively price efficient in the use of hired labor and that constant returns to scale prevails, the following estimate of the profit function is produced:

$$\begin{aligned} Ln\pi \;=\; & -1.378 + 0.331\,T - 0.747\,LnW - 0.073\,LnC \\ & (-5.73) \quad (3.28) \quad (-7.38) \quad (-0.20) \\ + \; & 0.895\,LnL + 0.105\,LnK - 0.570\,FLBR. \qquad (9) \\ & (34.13) \quad (3.28) \quad (-3.24) \end{aligned}$$

The coefficient of FLBR suggests that a 10 percent increase in the proportion of family labor reduces profits by 5.7 percent. Even after incorporating the effect of the lower cost of family labor, the coefficient of the technology variable (δ) remains positive and highly statistically significant. The value of the coefficient indicates that the adopter farms get about 33 percent more output from a given level of input than the nonadopter farms.

The output elasticity of various inputs for the Cobb-Douglas production function can be derived indirectly from joint estimates of the parameters of profit function and input demand equations. The estimates are statistically more consistent than the ones derived from the direct estimates of the Cobb-Douglas production function, which assumes all inputs to be exogenously determined, while in practice the variable inputs may be simultaneously determined, depending on prices, which is the maintained assumption in the profit function model. Since α_1 and α_2 appear in both the profit function and the respective input demand equations, imposing the restriction that they are equal in both equations, the efficiency of the estimates is improved. The parameters can also be estimated by imposing the condition of constant returns to scale ($\beta_1 + \beta_2 = 1$). In the estimates derived from equation (7) (unrestricted), the elasticity of land is 0.37, compared with a 50 percent share rental paid by sharecroppers to landowners in Bangladesh. It renders a marginal return of Tk 2,000 per acre. The elasticity of fixed nonland capital assets is estimated at 0.06, showing the relative unimportance of this input, which yields a return of Tk 1.1 per unit of investment. The elasticity for hired labor is 0.37, which yields a marginal productivity of Tk 22.00 per day of labor against an average wage rate of Tk 19.50 paid by the sample farms. The elasticity of fertilizer is estimated at 0.10, which gives a marginal return of Tk 2.10 per unit of taka investment in this input.

The estimate from the unrestricted profit function thus shows considerable inefficiency in the allocation of fertilizer. As indicated earlier, the inefficiency is mainly due to farms that produce local varieties on which fertilizer is used in small amounts. The new crops are not only more technically efficient, they allow farmers to achieve higher levels of allocative efficiency by creating conditions to use more fertilizer per unit of land.

Conclusions

Diffusion of the modern technology increases the effective supply of land by reducing the proportion of fallow land during the dry season. The sown area under cereals is about 87 percent of the cultivated land for unirrigated plots—on irrigated plots it is 150 percent. The increase in the intensity of cereal cultivation is partly at the expense of other crops. Pulses, jute, and sugarcane are grown on about one-third of the unirrigated land, but only 4 percent of the irrigated land is allocated to these crops. With the provision of irrigation facilities, the cropping intensity of the land increases by one-third.

Technological diffusion would increase marginal returns from land many times and provide scope to the landowner to earn more from this scarce resource through the gradual reallocation of land from local to modern varieties. The increase is about five times for the aus and boro seasons and 2.2 times for the aman season. The marginal product of labor is almost the same for the alternative varieties in the aman season, but in the aus and boro seasons the productivity is higher by about 50 percent for the modern varieties. Labor tends to gain more from additional employment than from the increase in marginal product.

The adopters of the new technology are absolutely price efficient in the allocation of fertilizer compared with the nonadopters, but both groups are absolutely price inefficient in the use of labor. The inefficiency in the use of labor is mainly due to low opportunity cost of family labor. The marginal product of hired labor is found to be close to the wages paid. The adopter farms are more technologically efficient than the nonadopter farms by about 33 percent. Diffusion of the new technology would thus improve the efficiency of resource utilization in agriculture.

6

FARM SIZE, TENANCY, AND ADOPTION OF MODERN TECHNOLOGY

A crucial factor in determining equity implications of the new rice technology is the extent and intensity of its adoption among different groups of farmers. The literature is full of studies that analyze adoption behavior of farmers to test the hypothesis that gains from the introduction of the new agricultural technology have been unequally distributed.[70] Most of the evidence for the early period of the green revolution suggests that the incidence of adoption is positively related to farm size, which appears counterintuitive, given the evidence that the new technology is seemingly scale neutral. It is argued that the new technology may entail some fixed costs in the form of access to information and sources of supply of the new inputs, and arrangements for marketing, which tend to discourage adoption by small farmers.[71] The role of tenurial arrangements in the adoption decision is also a subject of considerable controversy. A number of recent studies, however, argue that even if small farmers and tenants initially lag behind in adopting the new technology, they eventually catch up and ultimately may use it more than the large owner-farmers.[72] But even if this is the case, the early adopters can accumulate more wealth and power, which they can use for further accumulation of land from the laggards, thereby establishing a process of unequal distribution of income with the diffusion of the new technology.

To assess the equity implications of the modern technology for Bangladesh, this chapter studies adoption behavior among different size and tenurial groups of farmers and tests pertinent major hypotheses put forward in the literature. Major issues raised in the literature are outlined in the following section. Next, a descriptive account of the intensity of adoption among different groups of farmers is given. The factors affecting adoption are then analyzed, using multivariate regression techniques. The final section investigates the differences in land productivity and prices faced by different groups of farmers, since these also have a bearing on the income distribution effect of the new technology among farmers.

The Issues

The relationship between farm size and adoption of the new technology cannot be determined a priori. Farm size is often a surrogate for a large number of factors[73] that

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[70] This is in fact an overresearched issue. There are also a large number of surveys of the literature. See, among others, Lipton, *Modern Varieties;* Michael Lipton, "Inter-farm, Inter-regional and Farm-nonfarm Income Distribution: The Impact of the New Cereal Varieties," *World Development* 6 (No. 3, 1978): 319-337; Gershon Feder, Richard E. Just, and David Zilberman, "Adoption of Agricultural Innovations in Developing Countries: A Survey," *Economic Development and Cultural Change* 33 (No. 2, 1985): 255-298; M. Prahladachar, "Income Distribution Effects of the Green Revolution in India: A Review of Empirical Evidence," *World Development* 11 (No. 11, 1983): 927-944; and Richard Perrin and Don Winkelmann, "Impediments to Technical Progress on Small Versus Large Farms," *American Journal of Agricultural Economics* 58 (December 1976): 888-894.

[71] Pears, *Seeds of Plenty,* p. 120.

[72] Vernon W. Ruttan, "The Green Revolution: Seven Generalizations," *International Development Review* 19 (No. 4, 1977): 16-23.

[73] R. Albert Berry and William R. Cline, *Agrarian Structure and Productivity in Developing Countries* (Baltimore: Johns Hopkins University Press, 1979).

may have an important bearing on the adoption decision. Since the importance of these factors varies across space and over time, variant relationships between farm size and the rate of adoption are observed in empirical investigations.

An important factor is the degree of risk aversion among farmers.[74] Apart from the objective risk of having uncertain returns on investment under conditions of weather variation and pest attacks, the new varieties entail in the initial years a subjective risk of having an uncertain yield with an unfamiliar technique, the full intricacies of which have not yet been mastered by the farmer. The more risk averse is the farmer, the less willing he will be to adopt, and even if he adopts, he will try to minimize the risk by devoting a smaller proportion of land to the new crops. The degree of risk aversion may depend on the farmer's income. If the farmer operates around the poverty level, he will want to ensure survival for self and family by avoiding the risk of falling below the subsistence level. Since farm size and income may be highly correlated, the small farmer may be more risk averse and less likely to adopt the new technology than is the large farmer. In the case of Bangladesh, a large majority of farmers operate near the subsistence level. But the new technology is now sufficiently known to the farmers and the objective risk is found to be lower for the new crops (Chapter 4), so the risk-aversion factor may not be important in explaining adoption behavior.

The need for working capital to cultivate a given amount of land is higher for the new crop varieties (Chapter 4). For farmers who need to invest in indivisible irrigation equipment like tubewells and power pumps, adoption of the new crops would also require a large initial fixed investment. So, unless the government bears the cost of irrigation development, access to capital in the form of accumulated savings or financial institutions may be an important determinant of the rate of adoption. In many low-income countries, small farmers have limited access to financial institutions. Thus the credit constraint may induce farmers to borrow from the high-cost noninstitutional sources. Working capital constraints may, however, be eased considerably after a few years if the small farmer can accumulate the incremental profits from cultivation of the new crops.

Access to information about sources of new inputs, knowledge about how they can be optimally used, and marketing of the additional output can also be an important factor in determining the differential rate of adoption.[75] The level of education of the farmer can be taken as a proxy of this variable. Since the opportunity cost of sending children to school rises with poverty, educational status is generally found to be positively related to farm size. The larger farmer who is better educated may have more contact with the extension agents who supply this information. Thus the large farmer is expected to have a higher rate of adoption.

A number of other factors may, however, operate to encourage more adoption among the smaller farmers. The new crops use substantially more labor input per unit of land. In rice cultivation, which depends more on the use of casual workers (hired on a daily basis), this labor requirement makes the problem of labor management more difficult and may prevent adoption of the new crop by relatively labor-scarce large farmers. If the new crop increases the seasonal demand for labor, it is less attractive to farmers with a limited supply of family labor.

According to the Chayanovian theory of peasant economy,[76] the consumption unit of the family in relation to the production unit (land and worker) may be an important

[74] Feder, Just, and Zilberman, "Adoption of Agricultural Innovations," pp. 262-265.

[75] Pears, *Seeds of Plenty.*

[76] A. V. Chayanov, *The Theory of Peasant Economy,* ed. David Thorner (Homewood, Ill.: Richard D. Irwin, 1966).

determinant of the adoption of the new technology. This theory argues that the motive force behind the economic activity of a peasant family is the consumption need, which increases with the growth of the family. The peasant responds to the increased consumption requirement by substituting labor for leisure and by acquiring more land. In land-scarce countries, the possibility of accumulating land is limited for the peasant. In this situation, the yield- and income-raising technology provides the opportunity for increasing consumption from the same amount of land. Hence the new variety is more attractive to small farmers who have more family members relative to land.

The impact of tenurial arrangement on adoption decision is a matter of considerable controversy in the theoretical literature.[77] Bhaduri, citing the East Indian experience, argues that the landlord who derives income from rent as well as from usury is interested in keeping tenants perpetually indebted. Under these circumstances, it is in the landlord's interest not to allow tenants to adopt the new technology, since higher incomes from cultivation of the same amount of land would reduce the tenants' indebtedness, and the loss in usury income would outweigh the gain in rental income accruing to the landlord. This hypothesis has, however, been criticized on the ground that if the landlord has sufficient monopoly power to withhold adoption of the new technology, it should also be possible to siphon off the extra income of the tenant by increasing the rent. Newberry argues that under uncertain labor and product markets, sharecroppers would be interested in adopting the new technology. But Bardhan shows through a theoretical model that land-augmenting technical change and higher labor intensity—the characteristics of the new rice varieties—would induce a higher incidence of tenancy. The risk-aversion theory implies that share tenancy may be a preferred arrangement for adoption of the new technology, since the risk can be shared by the tenant and the landlord. Also, since the tenant is usually a small farmer with more surplus labor and higher subsistence pressure, adoption of the new technology may be easier for the tenant than for the owner-cultivator.

The availability of complementary inputs can also influence adoption behavior. In the case of new varieties of rice, an important factor is the assured and regulated supply of water (that is, irrigation) without which the new variety would be more risky and less profitable. In Bangladesh, with small farms and fragmented and scattered holdings, irrigation seems to be exogenously determined, since the facilities are developed by the government largely with externally funded projects. Even with private ownership of irrigation equipment by large landowners, which has increased somewhat since the late 1970s, the small and medium farmers have an equal chance of having some of their plots located within the command area because of the random location of fragmented holdings. Under these circumstances, the differential adoption among farmers and regions would depend on the location of irrigation projects and on access of the different groups of farmers to irrigation facilities.

[77] Amit Bhaduri, "A Study in Agricultural Backwardness under Semi-feudalism," *Economic Journal* 83 (March 1973): 120-137; David Newberry, "Tenurial Obstacles to Innovations," *Journal of Development Studies* 11 (July 1975): 263-277; Ajit K. Ghose and Ashwani Saith, "Indebtedness, Tenancy and the Adoption of New Technology in Semi-feudal Agriculture," *World Development* 4 (April 1976): 305-320; Pranab K. Bardhan, "Agricultural Development and Land Tenancy in a Peasant Economy: A Theoretical and Empirical Analysis," *American Journal of Agricultural Economics* 61 (No. 1, 1979): 48-56; and Pranab K. Bardhan and T. N. Srinivasan, "Crop Sharing Tenancy in Agriculture: A Theoretical and Empirical Analysis," *American Economic Review* 61 (No. 1, 1971): 48-64.

Pattern of Adoption

Farm Size and Adoption of MVs

Table 32 summarizes the observed pattern of adoption of new crop varieties among different groups of sample farmers in the study villages. About three-fourths of the farmers cultivated the new varieties, although only about one-third of the sown area was allocated to them. The proportion of adopter farmers is not found to be significantly different among different size and tenurial groups. The gains from the new technology thus appear to be widely distributed, irrespective of the landholding and tenurial status of the farmer.

The intensity of adoption is, however, found to vary inversely with farm size. The farmers who own less than 2.5 acres of land (henceforth called small farms) devoted about 43 percent of the cropped area to modern rice varieties; among farmers who own 5.0 acres or more (large farms), the proportion was 33 percent. The same pattern is observed even if the intensity of MV adoption is measured as a proportion of sown area under rice. The result appears contradictory to the general findings on this issue in the South Asian context. The previous studies on the extent of adoption for Bangladesh, however, found a similar pattern. One of the more rigorous earlier studies (based on data for 1972), conducted by Asaduzzaman, found that small farmers devoted about 28 percent of the aman rice area to the new crops compared with only 14 percent for large farmers.[78] Herdt and Garcia reviewed findings of seven studies conducted between 1969 to 1981 and noted that five of these reported higher intensity of adoption among smaller farmers.[79] The 1983-84 agricultural census also supports this finding.[80] The census found about 26 percent of the net cropped area for the small farms was under rice MVs, compared with 23 percent for medium farms and 18 percent for large farms.

Table 32—Adoption of modern varieties of rice, by farm size and tenancy, 1982

Farm Group	Share of Farms Adopting Modern Varieties	Share of Area Under Modern Variety Rice: Total Cropped Area	Share of Area Under Modern Variety Rice: Rice Area
		(percent)	
Size of farm			
Small (less than 2.5 acres)	75	43.2	51.7
Medium (2.5–5.0 acres)	74	35.8	44.6
Large (5.0 acres or more)	77	32.5	42.4
Tenurial status			
Owner	77	35.7	44.1
Tenant or owner with tenants	74	38.1	48.1
All farms	75	36.8	46.0

Source: Based on data from Bangladesh Institute of Development Studies/International Food Policy Research Institute field survey.

[78] M. Asaduzzaman, "Adoption of HYV Rice in Bangladesh," *The Bangladesh Development Studies* 7 (No. 3, 1979): 23-49.

[79] Herdt and Garcia, "Adoption of Modern Rice Technology."

[80] Bangladesh, *Census of Agriculture and Livestock.*

Tenancy and Adoption of MVs

The adoption of MVs is not found to be significantly different between owner and tenant farmers. In Bangladesh, pure tenants, that is, those who rent the entire holding, are rare. Most of the tenants are part-tenants who own some land and rent some to make the holding viable. As can be noted in Table 32, 75 percent of the owner-tenants cultivated some land with MVs, compared with 77 percent for the owner-cultivators. The intensity of adoption was about 38 percent for tenants, compared with 36 percent for owners. For rice, tenants devoted 48 percent of the sown area to MVs, compared with 46 percent for owners.

Table 33 shows the incidence of tenancy in the cultivation of different varieties of rice. It is found that tenants are the larger proportion of farmers cultivating MVs in all three rice-growing seasons. The proportion of area under tenancy is also found to be higher in the cultivation of MVs in all three seasons. This indicates a positive effect of the new technology on tenancy cultivation.

In Bangladesh the predominant tenancy arrangement is sharecropping, under which the gross output is shared equally between tenant and landowner, while most of the cost of cultivation is borne by the tenant.[81] It can be argued that under these circumstances, the tenant would be discouraged from adopting the new technology because he would have to bear the large incremental cost of labor, fertilizer, and irrigation, while the incremental output would be shared equally between tenant and landowner. The empirical observation thus appears inconsistent with this hypothesis. Under certain circumstances, however, the hypothesis cannot be tested by comparing the performance of the owner and tenant cultivator, particularly when the tenant also cultivates some owned land. If markets (such as those of labor and capital) are imperfect, the resource position of the cultivator may determine the opportunity cost, which would vary among cultivators. The tenant who has some underemployed resource (human or animal labor) that cannot be sold in the market may hire land. Since the new technology is labor-using, the tenant may want to maximize family income by devoting more land to the new crops than the owner-cultivator. The disincentive effect of share tenancy thus can only be assessed by comparing the rate of adoption on owned and sharecropped portions of the holding under the same cultivator. This is done in Table 34. It is noted that

Table 33—Incidence of tenancy, by season and technology, 1982

Season	Proportion of Farmers Renting Land		Rented Area as a Proportion of Sown Area	
	Traditional Variety	Modern Variety	Traditional Variety	Modern Variety
	(percent)			
Aus	24.6	30.7	14.3	15.9
Aman	27.9	44.7	19.0	20.1
Boro	16.0	35.0	7.5	16.9

Source: Based on data from Bangladesh Institute of Development Studies/International Food Policy Research Institute field survey.

[81] Mahabub Hossain, "Nature of Tenancy Markets in Bangladesh Agriculture," *Journal of Social Studies* 3 (No. 1, 1979): 1-24; F. Tomasson Jannuzi and James T. Peach, *Agrarian Structure of Bangladesh: An Impediment to Development* (Boulder, Colo.: Westview Press, 1980).

Table 34—Adoption of modern varieties on owned and rented land for mixed-tenant farmers, by season, 1982

Season	Owner Farms	Owner-with-Tenant Farms	
	Share of Land Under Modern Varieties	Share of Owned Land Under Modern Varieties	Share of Rented Land Under Modern Varieties
		(percent)	
Aus	33.3	38.8	36.1
Aman	33.5	42.1	35.1
Boro	76.7	82.6	89.0
All seasons	44.1	49.8	46.5

Source: Based on data from Bangladesh Institute of Development Studies/International Food Policy Research Institute field survey.

tenants devoted a larger proportion of their owned land to MVs than did owner-cultivators, which is a reflection of the negative farm-size effect on MV cultivation, since most tenants are small farmers. But tenants allocated a smaller proportion of rented land than of owned land to the new crops during the aman and aus seasons. This distinction supports the hypothesis of disincentive effect of crop-sharing arrangements. Only during the boro season did tenants grow MVs more on their rented land than on their owned land. This may be due to a stipulation by the landowner that the land can be rented only if it is cultivated with MVs. It was found during the field survey that in many cases the land is only rented seasonally, and seasonal tenancy is more prevalent during the boro season.

Irrigation and Adoption of MVs

The sample villages under study differ widely in access to irrigation, types of irrigation, and length of experience with irrigation. In three villages located in Comilla District, irrigation facilities were developed and MVs introduced in the late 1960s during experimentation with the Comilla model of "cooperative capitalism." Two of the sample villages are under the Ganges-Kobtak project—the first large-scale irrigation project developed in Bangladesh—where irrigation is provided by gravity canals. These two villages got access to the irrigation canals in 1972. Two other villages irrigated part of the land by fielding low-lift pumps on canals developed by the food-for-work program in 1978. In another two villages, irrigation was introduced only two years before this survey by a few large landowners who invested in shallow tubewells. At the time of the survey, five villages did not have any access to irrigation facilities—three of them located in the coastal district of Khulna, where intrusion of saline water during the dry season makes irrigation development difficult. This diversity in the sample allows investigation of the role of irrigation in adoption among different groups of farmers in the early- and late-adopter villages.

The importance of irrigation in the adoption of MVs was shown earlier (Table 25) in the analysis of the pattern of land use for irrigated and unirrigated plots. Further analysis of the use of owner-operated plots shows the crucial importance of land elevation and access to irrigation in the intensity of adoption of MVs (see Table 35). Only 6 percent of the unirrigated plots were used for growing MVs, compared with 77 percent of the irrigated plots. MVs were grown much more on the plots located on the medium-elevation land than on extremely high and extremely low-lying plots, because the

Table 35—Adoption of modern varieties, by land elevation and access to irrigation facilities, 1981

Type of Land	Number of Plots in Sample	Plots Having Irrigation Facilities	Plots Not Growing Modern Varieties	Plots Growing Modern Varieties Once	Plots Growing Modern Varieties Twice
			(percent)		
Elevation					
Extremely high	1,063	14.6	89.6	7.7	2.7
Medium high	1,383	52.3	52.4	24.2	23.4
Medium low	941	44.3	62.3	33.0	4.7
Extremely low	181	16.0	83.4	13.3	3.3
Access to irrigation					
Unirrigated	2,242	0.0	94.0	5.5	0.5
Irrigated	1,326	100.0	23.0	47.4	29.6
All plots	3,568	37.2	67.6	21.1	11.3

Source: Based on data from Bangladesh Institute of Development Studies/International Food Policy Research Institute field survey.

physical characteristics of the extreme elevations do not generally allow regulation of water supply. About half of the plots located on medium-high land were reported to be irrigated, compared to only one-sixth of the plots located on extremely high and low-lying land. Almost one-third of the irrigated plots were used for growing MVs twice during the year, and it appears that land elevation is the most important factor determining intensity of use. More than 23 percent of the plots located on medium-high land were used to grow MVs twice during the year, compared with less than 5 percent for the other land categories. The second MV crop is grown during the monsoon season, so the low-lying plots that remain deeply flooded cannot be used to raise the dwarf MVs. Since the importance of the different types of plots in the landholding portfolio may vary across villages and farmers, the above findings point to the importance of dissociating the effect of physical characteristics of the land in analyzing the effect of socioeconomic factors on the adoption behavior of farmers.

Table 36 compares the pattern of adoption among different farm-size groups between irrigated and unirrigated villages. About 19 percent of the farmers in the unirrigated

Table 36—Adoption of modern varieties in irrigated and unirrigated villages, by farm size, 1982

Farm Size[a]	Share of Adopter Farms		Share of Cropped Area Under Modern Varieties	
	Unirrigated Villages	Irrigated Villages	Unirrigated Villages	Irrigated Villages
		(percent)		
Small	20	87	3.7	59.6
Medium	20	93	2.7	51.4
Large	15	93	0.7	49.5
All farms	19	90	2.2	53.5

Source: Based on data from Bangladesh Institute of Development Studies/International Food Policy Research Institute field survey.

[a] Small, less than 2.5 acres; medium, 2.5-5.0 acres; large, 5.0 acres or more.

villages allocated some land to MVs, compared with about 90 percent in the irrigated villages, where the proportion of adopters is 87 percent in the small-farm category and 93 percent among medium and large farms. Once irrigation facilities are developed in a village, the gains are widely distributed across the farm-size scale. Even in the late-adopter villages, where only about 27 percent of the cropped land is cultivated with MVs, more than 80 percent of the farmers are adopters (see Table 37). In the late-adopter villages, the smallest proportion of adopters is among small farmers, while in the early-adopter villages, almost all farmers grew MVs. This supports the contention that, with experience, small farmers catch up with the large ones.

The intensity of adoption is observed to be inversely related to farm size, even in the irrigated villages. About 54 percent of the cropped land in these villages is allocated to MV rice—60 percent for the small farms, compared with 50 percent among the large ones (Table 36). The inverse size effect prevails, even in the early-adopter villages (Table 37), indicating that the large farmers remained laggards even with the passage of time. Presumably, facing a shortage of family labor, the large farmers adopted MVs partly through tenants.

The type of irrigation itself may contribute to the differential rate of adoption among farmers. If the irrigation equipment is privately owned, as is often the case with tubewell irrigation in Bangladesh, a large-farmer monopoly in the supply of water can be expected, since the size of the command area and the high initial cost of investment would prohibit tubewell ownership by smaller farmers.[82] In this case, a direct relationship can be expected between farm size and adoption of MV rice. On the other hand, the communal development of irrigation, as in the case of the Water Development Board's large-scale canal irrigation project, may lead to a more egalitarian system of distribution of water supply, and other things remaining constant, the intensity of adoption would be invariant with farm size. To test this hypothesis, the rate of adoption along the farm-size scale was also estimated for different types of irrigation (Table 37). In the case of villages receiving water from canals, no systematic pattern of adoption was found, but with both tubewell and low-lift pump irrigation, the small farmers adopted more, which is contrary to the above hypothesis.

Table 37—Adoption of modern varieties by type of irrigation and length of experience, 1982

Village Group	Share of Adopter Farms: Small Farms	Medium Farms	Large Farms	Share of Cropped Area Under Modern Varieties: Small Farms	Medium Farms	Large Farms
			(percent)			
Type of irrigation						
Low-lift pumps	84	95	87	32.6	33.6	23.2
Canals	91	100	100	58.0	49.8	58.9
Tubewells	87	89	92	68.9	60.7	61.3
Length of experience						
Early adopter	98	100	100	74.8	69.3	71.3
Late adopter	79	88	85	29.6	26.5	24.9

Source: Based on data from Bangladesh Institute of Development Studies/International Food Policy Research Institute field survey.

[82] Pears, *Seeds of Plenty,* p. 107.

Adoption of Fertilizers

Nearly nine-tenths of the sample farmers used fertilizers during 1982, although only about half of the plots were treated with fertilizers. The nonusers were mostly among those who grew only traditional varieties of rice. All farmers growing MV boro and aus rice, and 98 percent of those growing MV aman, used fertilizers. The proportion of user farmers was 74 percent for local transplanted aman, 73 percent for local aus, 19 percent for local broadcast aman, and only 6 percent for local boro. Fertilizer adoption is thus very much variety-specific and depends on the type of land and environment.

The pattern of adoption of fertilizers among different groups of farmers can be reviewed in Table 38. The adopter farmers are proportionately more among the larger size groups. But the intensity of use per acre of land is inversely related to farm size. This apparent inconsistency exists because the number of plots under cultivation is higher for the larger farmer, hence the probability of one of the plots falling under the command area of irrigation—and therefore being suitable for growing MV and applying fertilizer—grows with the size of the farm. The amount of fertilizer used per unit of land is thus a more appropriate indicator of adoption behavior than the proportion of user farms. Compared with large farmers, small farmers use about 35 percent more fertilizer per unit of cropped land, and medium farmers about 20 percent more. The extent of use is similar for owner and tenant farmers. Similar findings on differential adoption of fertilizer were noted by the IFDC from its countrywide survey.[83]

A major factor behind the inverse farm-size effect on fertilizer use is that small farmers have a larger proportion of land under MVs (Table 32), which are much more fertilizer-intensive than traditional varieties of rice. To dissociate the cropping-pattern effect, the adoption pattern for specific crop varieties has also been reviewed (Table 38). The inverse size effect prevails in the case of MVs for all three seasons and is highly pronounced in the case of MV boro. For local varieties on which fertilizers are used in small amounts, no systematic pattern of use across the farm-size scale is found. Owner-farmers tend to use more fertilizer on local varieties than do tenants, but no systematic pattern is found for MVs.

Table 38—Use of chemical fertilizers, by farm size and tenancy, 1982

	All Crops		Amount Used in Major Crops				
			Modern Variety			Local	
Farm Group	Farmers Using Fertilizers	Amount of Nutrients Used	Boro	Aus	Aman	Aus	Aman
	(percent)	(kilograms/acre)	(kilograms/acre)				
Farm size[a]							
Small	85.5	24.4	68	47	38	9	8
Medium	92.3	21.9	64	47	39	7	8
Large	95.0	18.1	51	46	30	13	6
Tenurial status							
Owner	87.8	22.2	63	47	36	10	11
Tenant	90.8	21.6	65	46	38	7	4
All farms	89.2	21.9	64	47	37	9	8

Source: Based on data from Bangladesh Institute of Development Studies/International Food Policy Research Institute field survey.

[a] Small, less than 2.5 acres; medium, 2.5-5.0 acres; large, 5.0 acres or more.

[83] For a summary of the findings of previous studies in this regard, see Herdt and Garcia, "Adoption of Modern Rice Technology;" and Hossain, "Fertilizer Consumption," pp. 197-206.

Adoption Behavior: An Econometric Analysis

The size and tenurial status of a farm are often surrogates for other factors that affect the adoption behavior of farmers. To explain the observed pattern of adoption reported in the previous sections, it is thus necessary to do a multivariate analysis of the factors that determine the adoption behavior and the importance of these factors for different groups of farmers. This is attempted here through the use of the multivariate regression technique. First, a probit model is used to identify the factors that affect the decision to adopt MV rice, and then a tobit model is used to explain the extent of adoption.

The following model was estimated by using the probit method to identify factors that affect the farmers' decision on whether to adopt MVs or not:

$$ADPT = f(OWNL, TNC, IRGP, CRDTI, CRDTN, LBR, LNDPC, NAGRI, INFR), \quad (10)$$

where

ADPT	= dichotomous adoption variable that takes value 1 for adopter farms and zero for non-adopter farms,
OWNL	= amount of land owned by household (in acres),
TNC	= proportion of land rented,
IRGP	= proportion of land irrigated,
CRDTI	= amount of loans received from institutional sources (in Tk 100/acre),
CRDTN	= amount of loans received from noninstitutional sources (in Tk 100/acre),
LBR	= amount of land cultivated per worker (in acres),
LNDPC	= amount of land owned per member in household (in acres),
NAGRI	= income from trade and industry per acre of cropped land (in Tk 100/acre),
INFR	= index of underdevelopment of infrastructure at the village level.[84]

LBR and LNDPC are measures of labor scarcity and subsistence pressure in the household and are expected to negatively influence the decision to adopt MVs. CRDTI,

[84] This is a composite index of infrastructure underdevelopment constructed by Ahmed and Hossain from the village-specific information on access to a number of elements, such as roads, markets, and financial and educational institutions, for a separate study of the effect of infrastructure on rural development. The infrastructure variable significantly affects a number of endogenous variables investigated in the present study, but the results have not been reported here in order not to preempt the findings of the other study. The conclusions of this study remain valid even after inclusion of the infrastructure variable. See Raisuddin Ahmed and Mahabub Hossain, "Infrastructure and Development of a Rural Economy," International Food Policy Research Institute, Washington, D.C., 1987 (mimeographed).

CRDTN, and NAGRI are expected to ease the capital constraint and hence should have a positive influence on adoption decision.

The results of the exercise are presented in Table 39. Estimated equation 1 in the table incorporated only the farm-size and tenancy variables, and they are found statistically insignificant with an extremely low $\bar{R}^2$ for the regression equation (obtained in the OLS estimate of the parameters). The labor-scarcity and subsistence-pressure variables have right signs of the estimated parameters but they are also statistically insignificant. An alternative labor-scarcity variable was measured by the proportion of hired labor (LBRH), but the negative value of the coefficient is also statistically insignificant (equation 3 in the table). Institutional-credit and nonfarm-income variables, in fact, have opposite signs but are not statistically significant. Only irrigation and development of infrastructure are significantly positively associated with the adoption of MVs. When the effects of the other variables are controlled, the proportion of area under tenancy is significantly positively correlated with the adoption variable.

A large number of variables and their measurements were experimented with to select the variables that best explain the extent of adoption of MVs. After careful scrutiny of the results of alternative estimates, the following model is found to best explain the variation of MV adoption in the sample:

Table 39—Factors influencing decision to adopt modern varieties, probit estimate

Variable	Equation 1	Equation 2	Equation 3
Constant	0.452 (4.89)	−0.105 (−0.46)	−0.038 (−0.16)
OWNL	−0.016 (−0.98)	0.015 (0.56)	0.012 (0.47)
TNC	0.802 (0.42)	0.914[a] (3.70)	0.871[a] (3.54)
IRGP	. . .	4.171[a] (10.57)	4.164[a] (10.62)
CRDTI	. . .	−0.371 (−0.25)	−0.056 (−0.04)
CRDTN	. . .	0.324 (0.75)	0.316 (0.73)
LBR	. . .	−0.040 (−0.90)	. . .
LNDPC	. . .	−0.206 (−0.83)	−0.302 (−1.51)
NAGRI	. . .	−0.098 (−0.64)	−0.087 (−0.56)
INFR	. . .	−0.047[b] (−2.08)	−0.047[b] (−2.08)
LBRH	. . .	. . .	−0.239 (−0.82)
$\bar{R}^2$	0.01	0.33	0.33

Notes: The sample consists of 470 farm households. Figures in parentheses are asymptotic t-values. Values of $\bar{R}^2$ are for OLS estimates.
[a] This number is significant at the 0.01 level.
[b] This number is significant at the 0.05 level.

MVP = f(IRGP, LBR, FSZ, CRDTI, CRDTN, NAGRI, EDNH, OWNL, TNC), (11)

where

MVP = proportion of cultivated area under MVs,

FSZ = number of members in family, which is a measure of consumption pressure in the household, and

EDNH = level of education of head of household (completed years of formal schooling).

Other variables are as explained earlier.

The equation was estimated separately for two seasons. For the overlapping aus and boro seasons, irrigation is a prerequisite for adoption of MVs because the rainfall is scanty and paddling of soil for transplantation of seedlings cannot be done without irrigation. This is also a relatively slack season for agricultural activity, since a significant proportion of land remains fallow. So factors like labor shortage may not be binding constraints for adoption during this season. During the aman season, rainfall is plentiful, so MVs can be grown under rain-fed conditions. But a physical control is imposed by land elevation, since low land remains deeply flooded throughout the season and is thus unsuitable for growing MVs. Since most of the land is cropped during this season, occasional labor shortages may appear. Owing to these differences, the analysis at the seasonal level was thought to be more appropriate. The proportion of medium-high land was used as another explanatory variable, but the coefficient was not found to be statistically significant and, in fact, had a negative sign in the equation for aus and boro seasons. Since irrigation was highly correlated with this variable, the land-elevation variable was dropped in the final estimated equation to avoid the problem of high multicollinearity.

Care must be taken in selecting the method of estimating the parameters of the specified model, since the observed value of the dependent variable has a limited range. This is the case of a limited dependent variable model, and the application of the least square method to the observed data may lead to seriously biased estimates. Since the dependent variable is observed in the range of zero to one, that is, it is censored in both tails, the "two-limit probit" (tobit) model appears to be the most appropriate technique for its estimation. The software LIMDEP developed by Greene[85] for estimation of the tobit model was applied to the data set to get the values of the parameters of the model.

The estimated parameters are reported in Table 40. As expected, irrigation is found to be the most significant variable in determining the adoption rate. The asymptotic t-value for the estimated coefficient is the highest for irrigation compared with all other variables included in the model. Dropping this variable from the equation reduces the value of the adjusted coefficient of determination ($\bar{R}^2$) from 0.47 to 0.08. The comparison of the t-value for this coefficient for the two seasons indicates that for adoption of MVs, irrigation is more important for the boro and aus seasons than for the aman season.

[85] William H. Greene, *LIMDEP: User's Manual,* May 1986; William H. Greene, "On the Asymptotic Bias of the Ordinary Least Squares Estimator of the Tobit Model," *Econometrica* 49 (No. 2, 1981): 505-513; and G.S. Maddala, *Limited Dependent and Qualitative Variables in Econometrics* (Cambridge: Cambridge University Press, 1984).

Table 40—Determinants of adoption of modern varieties of rice, 1982

	Boro and Aus Seasons		Aman Season		All Seasons	
Variable	OLS Estimate	Tobit Estimate	OLS Estimate	Tobit Estimate	OLS Estimate	Tobit Estimate
OWNL	−0.291 (−0.65)	−0.484 (−0.99)	0.036 (0.08)	0.002 (0.004)	−0.255 (−0.41)	−0.429 (−0.74)
TNC	0.130[a] (2.74)	0.137[a] (2.99)	0.183[a] (4.00)	0.190[a] (3.73)	0.314[a] (4.70)	0.283[a] (4.64)
IRGP	0.609[a] (14.09)	0.651[a] (11.10)	0.527[a] (12.57)	0.547[a] (10.02)	1.137[a] (18.69)	1.084[a] (12.56)
LBR	−1.305 (−0.95)	−1.639 (−0.88)	0.733 (0.55)	0.581 (0.45)	−0.572 (−0.30)	−0.550 (0.25)
FSZ	0.539 (0.92)	0.743 (1.07)	0.311 (0.55)	0.264 (0.43)	0.850 (1.04)	0.337 (0.38)
EDNH	−0.403 (−1.02)	−0.396 (−0.80)	−0.248 (−0.65)	−0.269 (−0.65)	−0.650 (−1.169)	−0.416 (−0.66)
CRDTI	0.351[b] (1.71)	0.518[c] (2.36)	0.442[c] (2.21)	0.459[c] (2.48)	0.793[a] (2.74)	0.743[a] (2.74)
CRDTN	0.423[a] (4.64)	0.625[a] (5.07)	−0.108 (−1.23)	−0.113 (−0.87)	0.315[a] (2.46)	0.695[a] (3.82)
NAGRI	0.137 (−1.44)	−0.165 (1.46)	−0.126 (−1.368)	−0.134 (−1.10)	−0.264[c] (−1.97)	−0.290[c] (−1.99)
(Constant)	0.14[a] (3.36)	0.14[c] (2.38)	−0.004 (−0.10)	−0.004 (0.06)	0.14[c] (2.33)	0.17[c] (2.34)
(σ)	...	33.141[a] (24.58)	...	30.19[a] (25.88)	...	40.0[a] (19.67)
$\bar{R}^2$	0.36	...	0.28	...	0.48	...
Log-L	...	−2,037	...	−2,136	...	−1,768

Notes: The sample consists of 470 farm households. Figures in parentheses are asymptotic t-values.
[a] This number is significant at the 0.01 level.
[b] This number is significant at the 0.10 level.
[c] This number is significant at the 0.05 level.

The value of the coefficient (in the equation for all seasons) indicates that a 10 percent increase in the area under irrigation may increase the proportion of land under rice MVs by about 11 percent.

The coefficient of the family-worker variable is positive for the aman season, indicating that—given the amount of land to be cultivated—the higher the availability of family labor, the greater the tendency to cultivate MVs. The value of the coefficient, however, is not found to be statistically significant. For the aus and boro seasons, the coefficient of this variable has an opposite sign, but it is not statistically significant. As indicated earlier, this is the slack season for agricultural activity, so households with a lower endowment of labor relative to land may not be constrained in growing more labor-intensive crops, as they can count on easy availability of hired labor.

The coefficient of family size is positive for both seasons, thus supporting the Chayanovian hypothesis that the higher the subsistence pressure, the greater the tendency to adopt the new technology. The relationship, however, is weak. The value of the coefficient is not statistically significant.

In the context of a small-farmer peasant economy as in Bangladesh, the shortage of working capital is often emphasized as a major constraint to adoption of the new technology. In this exercise, the amount of loans received per unit of land has been taken as a proxy of the availability of liquid funds, which may ease the capital constraint. The variable, however, could not be measured as season-specific, so it is difficult to interpret the value of the coefficient of this variable in the equations for different seasons. The value of the coefficient of institutional credit is positive for both seasons, which suggests that the availability of institutional credit facilitates adoption. The coefficient is found to be statistically significant in all the equations at less than 5 percent probability of error. This result may seem surprising, since the access of small farmers to agricultural-credit institutions is still limited, although the supply of agricultural credit from institutional sources increased about eight times (at real value) during 1975-84. During 1983/84, the amount disbursed was about 7 percent of the value added in agriculture and 2.3 times the cost of fertilizer consumed in the country.[86] The credit is concentrated in the hands of the medium and large farmers. In the present sample, only 13 percent of the farm households received institutional loans during 1982, and the amount of institutional loans was about a quarter of the total loans received by them.

The incidence of borrowing from noninstitutional sources was found to be widespread. Nearly two-thirds of the farmers borrowed from friends and relatives—most often without any interest—and also from local moneylenders, who charge very high rates of interest. Nearly 40 percent of the loans from noninstitutional sources were free of interest. The coefficient of the noninstitutional credit variable is found to be positive and statistically significant at less than 5 percent probability of error for the aus and boro seasons. For the aman season, however, the coefficient has an opposite sign, but it is not statistically significant. Because of the need for irrigation and more-intensive use of fertilizer, the working capital requirement for the cultivation of MV crops is significantly higher for the boro and aus seasons than for the aman season (Chapter 4). The proportion of holdings allocated to MVs is also less for the aman season. Thus farmers who do not have access to formal credit institutions may tap noninstitutional loans to cultivate MVs during the dry season, while their own resources may be sufficient for cultivating the small amount of land that they currently allocate to MVs during the aman season.

Farmers who earn some income from nonagricultural sources may have less liquidity constraint than those who depend mostly on agriculture, so access to nonagricultural income may ease the capital constraint to adoption of MVs. The amount of income earned from trade and industry per unit of cultivated land was related to the intensity of adoption in order to test this hypothesis. The value of the coefficient is found to be negative irrespective of the season, which is contrary to the hypothesis. The negative value is statistically significant for all seasons. In fact, it is found in further tests that if the service incomes are added, the t-value for the negative coefficient increases. This indicates that farmers who cannot adopt MVs because of technical constraints (such as nonavailability of irrigation) try to augment household incomes in alternative ways; for example, by self-employment in various nonagricultural activities and by taking

[86] The supply of agricultural credit from institutional sources increased about eight times (at real value) during 1975-84. During 1983/84, the amount disbursed was about 7 percent of the value added in agriculture, and 2.3 times the cost of fertilizers consumed in the country. See Mahabub Hossain, "Institutional Credit for Rural Development: An Overview of the Bangladesh Case," *The Bangladesh Journal of Agricultural Economics* 8 (No. 1, 1985): 1-16.

temporary low-income employment (such as public works programs). (See Chapter 7 for further details.)

Another variable for which the result is found to be contrary to the a priori hypothesis is the level of education. The value of the coefficient is found to be consistently negative in all equations, thus indicating that the less educated adopt MVs more intensively. This finding tends to support the contention that the type of education provided in schools is not agriculture oriented. Education provides better opportunities for nonagricultural employment, which may be higher paying and less arduous than agricultural employment. Thus, although education gives better access to information about the new technology, it may not necessarily facilitate adoption of the technology.

When the effects of other socioeconomic variables are controlled, the size of landownership does not seem to affect the intensity of adoption. The coefficient of the landownership variable is positive for the aman and negative for the boro season, but the values are not statistically significant. The estimated t-value is less than one for all cases. The tenancy variable, however, still remains highly statistically significant. The positive value of the coefficient indicates that the extent of adoption of MVs is higher on rented land than on owned land. Since MVs are labor-intensive, and tenants rent land to minimize underutilization of family workers, the large landowners may gain more by having sharecroppers cultivate MVs than by self-cultivating them with wage laborers. Since there is so much excess demand for land, the tenancy market may be governed more by the interests of the landowners than by those of the tenants, who would be discouraged by the crop-sharing arrangements from cultivating MVs on rented land.

The higher intensity of adoption on smaller farms, as reported in the previous section, comes mainly through availability of irrigation and incidence of tenancy. Irrigation in Bangladesh is mostly exogenously determined. It is developed by the government, often with foreign assistance. Irrigation has spread mostly in areas where the average farm size is low (the eastern and southeastern parts of the country). In the coastal and flood-prone districts where there are physical constraints to development of irrigation, concentration of land in the hands of large farmers is generally higher. So the proportion of irrigated land is found to be higher on small farms (see Table 41).

Table 41—Incidence of irrigation and tenancy for different groups of farmers

Farm Group	Share of Land Irrigated: Sample Farmers, 1982[a]	Share of Land Irrigated: Bangladesh Agricultural Census, 1983-84[b]	Share of Cropped Area Under Tenancy of Sample Farmers, 1982
		(percent)	
Farm size			
Small	32.3	22.8	37.9
Medium	32.9	19.0	9.9
Large	28.3	18.3	4.0
Tenurial group			
Owner	33.6	n.a.	0.0
Tenant	29.6	n.a.	35.4
All farms	31.7	19.9	15.9

Sources: Bangladesh, Bureau of Statistics, *The Bangladesh Census of Agriculture and Livestock: 1983-84* (Dhaka: Ministry of Planning, 1986); and data from Bangladesh Institute of Development Studies/International Food Policy Research Institute field survey.

Note: n.a. means not available.

[a] As a percentage of owned land.

[b] As a percentage of cultivated holding. Medium farms are defined in the census as those with 2.5-7.5 acres of operated area.

The same pattern is noted for the country as a whole in the latest agricultural census (1983-84).[87] Tenancy cultivation is also more prevalent among the smaller farmers. It was found in the present survey that about one-sixth of the cropped land was tenant cultivated; the proportion was 38 percent for small farms, compared with only 4 percent for large ones.

Size, Land Productivity, and Prices

The observation that adoption of the new technology is inversely related to farm size does not necessarily imply that in Bangladesh the income distribution effect associated with diffusion of the new technology would be favorable to the smaller farmers. The impact on income distribution would also depend on the variation in productivity and prices among different groups of farmers.

For Bangladesh, many studies show an inverse relationship between farm size and land productivity.[88] Most of the findings are, however, for areas that did not experience significant diffusion of the new technology and refer to time periods (mostly the late 1960s and early 1970s) when the technology was in early stages of adoption. Some of the studies for India,[89] where the size-productivity relationship is also found to be inverse in the case of the traditional crops,[90] argue that this relationship may not hold for the new technology, as it gives considerable scope for using capital. Since the larger farmers have more accumulated savings and also have better access to financial markets, they are in a better position to apply purchased inputs like fertilizer and water more intensively than the smaller farmers. Thus a positive size effect on the yield rates for MVs may be expected, depending on the importance of the new inputs in cultivation of the variety.

The differences in land productivity among the size groups of farms observed in the survey may be reviewed in Table 42. Since the productivity may also vary, depending on the stage of development of the new technology, the sample villages have been classified into two equal groups according to the proportion of area under MVs. The developed villages have about 60 percent higher rice yields than the underdeveloped villages. In the cultivation of MVs the yield is about 14 percent lower in the developed villages, which may be due to diffusion of MVs to marginal farmers and marginal land, as well as to production of two rice crops per year on some land, which reduces the yield of each crop. In the cultivation of local varieties the yield is about 20 percent higher for the developed villages.

The yield is found to be inversely related to farm size in both groups of villages and for both the traditional and modern varieties of rice. The difference in yield between

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[87] Bangladesh, *Census of Agriculture and Livestock.*

[88] See, among others, Mahabub Hossain, "Farm Size, Tenancy, and Land Productivity: An Analysis of Farm Level Data in Bangladesh Agriculture," *The Bangladesh Development Studies* 5 (No. 3, 1977): 285-348; and M. A. Sattar Mandal, "Farm Size, Tenancy and Productivity in an Area of Bangladesh," *The Bangladesh Journal of Agricultural Economics* 3 (December 1980): 21-42.

[89] Prannoy Roy, "Transition in Agriculture: Empirical Indicators and Results," *Journal of Peasant Studies* 8 (No. 2, 1981): 212-241; and G. S. Bhalla and G. K. Chadha, *Green Revolution and the Small Peasant* (New Delhi: Concept, 1983).

[90] Krishna Bharadwaj, *Production Conditions in Indian Agriculture,* Department of Applied Economics Occasional Paper 33 (Cambridge: Cambridge Unversity Press, 1974); Biplob Dasgupta, *The New Agrarian Technology and India* (New Delhi: Macmillan, 1977); and Pranab K. Bardhan, "Size, Productivity, and Returns to Scale: An Analysis of Farm-Level Data in Indian Agriculture," *Journal of Political Economy* 81 (No. 6, 1973): 1370-1386.

Table 42—Farm size and land productivity, by technology, 1982

Farm Size[a]	Technologically Developed Villages: Local Varieties	Modern Varieties	All Rice Varieties	Technologically Underdeveloped Villages: Local Varieties	Modern Varieties	All Rice Varieties
	(metric tons/acre)					
Small	0.72 (0.08)	1.29 (0.13)	1.10 (0.11)	0.63 (0.09)	1.53 (0.38)	0.73 (0.10)
Medium	0.71 (0.09)	1.13 (0.13)	0.93 (0.08)	0.53 (0.07)	1.37 (0.41)	0.58 (0.09)
Large	0.61 (0.14)	1.09 (0.24)	0.86 (0.20)	0.51 (0.12)	1.06 (0.77)	0.57 (0.13)
All farms	0.71 (0.06)	1.23 (0.09)	1.03 (0.08)	0.58 (0.06)	1.43 (0.26)	0.64 (0.07)

Source: Based on data from Bangladesh Institute of Development Studies/International Food Policy Research Institute field survey.
Note: Figures in parentheses are standard errors of estimate.
[a] Small, less than 2.5 acres; medium, 2.5-5.0 acres; large, 5.0 acres or more.

the small and large farmer is, however, less pronounced for the technologically developed villages than for the underdeveloped ones, suggesting that with diffusion of the technology, the productivity gap narrows to some extent. Still, in the developed villages, the productivity for small farmers is about one-fifth higher than for large farmers, and the difference is statistically significant.

The income from cultivation may also differ across farms due to variation in prices. The new technology has increased the dependence of the farmers on the market for acquisition of the new inputs and also for labor. The prices of the inputs may vary across farms, especially under conditions of underdeveloped infrastructure facilities and monopoly control on the supply of the new inputs. The prices paid by different groups of farmers for the major agricultural inputs can be reviewed in Table 43. The fertilizer prices are reported separately for the dry and monsoon seasons because the prices, which are government controlled, were raised on July 1, 1982, so farmers

Table 43—Prices of major agricultural inputs, by farm size and tenancy, 1982

Farm Group	Fertilizer Price: Boro and Aus Seasons	Fertilizer Price: Aman Season	Irrigation Charge in Boro Season	Wage Rate
	(Tk/kilogram)		(Tk/acre)	(Tk/day)
Farm size[a]				
Small	3.20	3.64	672	20.22
Medium	3.23	3.55	583	19.43
Large	3.18	3.51	544	17.73
Tenurial status				
Owner	3.20	3.58	589	18.91
Tenant	3.22	3.62	698	22.88
Total	3.21	3.60	627	19.59

Source: Based on data from Bangladesh Institute of Development Studies/International Food Policy Research Institute field survey.
[a] Small, less than 2.5 acres; medium, 2.5-5.0 acres; large, 5.0 acres or more.

growing aman crops faced higher prices than those growing boro and aus crops, and the effect of this factor needs to be dissociated.

The fertilizer prices seem to be invariant with the size and tenurial status of the farm, but the water charge and the wage rate vary considerably across farms. The small farmers paid about 24 percent higher prices for water than the large farmers. Tenant farmers paid about 19 percent higher water charges than did owner farmers. This is expected because the ownership and management of irrigation equipment is controlled more by the large landowners. The government started selling deep tubewells and low-lift pumps to individuals and cooperatives in 1979/80. By the end of 1983, some 43 percent of the operating deep tubewells and 56 percent of the low-lift pumps were owned by the private sector. Nearly two-thirds of such machines were owned by households with 5 acres of land or more.[91] The small farmers and tenants also paid substantially higher wage rates than the large landowners. Since the tenants and small farmers come to the labor market during busy periods, when the wage rates are higher, the weighted average wage rate is expected to be higher for them, although for a particular day all farmers may face the same wage rate.

The cost of working capital may also be higher for small farmers because they have to borrow more from the high-cost, noninstitutional sources. This survey found that nearly three-fourths of the small farmers took loans from noninstitutional sources, compared with two-fifths among the large farmers. The institutional sources accounted for 20 percent of the total loans taken by small farmers, compared with 44 percent for the large farmers.

Conclusions

In Bangladesh, small farmers and tenants have adopted the modern technology at least as much as have large farmers and owner-cultivators. The scale neutrality of adoption may have been the result of the government investment for development of irrigation, which is the main vehicle for diffusion of the modern technology. Even under private investment on tubewells and power pumps, small farmers have as much access to irrigation facilities as the large ones because of the randomness with which the extremely fragmented and scattered farm holdings are distributed.

The small farmers, however, pay higher prices for inputs, particularly for water, labor, and working-capital loans. The ownership of privately owned machines and the management of the irrigation cooperatives is controlled by large farmers, who take a sizable markup from the irrigation market. The small farmers paid a water charge about 25 percent higher than the large farmers, and a 10 percent higher wage rate, presumably because the small farmers have to go to the labor market during busier periods of agricultural operations. Since the small farmers have to borrow more from the high-cost informal markets than do the large farmers, the average cost of working capital may also be higher for the small farmers. The variation in the prices of agricultural inputs would thus put a negative pressure on income distribution, which might outweigh the effect of the inverse relationship between farm size and adoption rates.

[91] M. Abul Quasem, "Impact of the New System of Distribution of Irrigation Machines in Bangladesh," *The Bangladesh Development Studies* 13 (September-December 1985): 127-140.

7

LABOR MARKET AND EMPLOYMENT EFFECTS OF MODERN TECHNOLOGY

In Bangladesh, nearly a third of rural households do not own any cultivable land, and about a half own less than 0.5 acre; for them, farming is only a marginal source of income.[92] Having no access to land, most of these households are at the bottom of the rural income scale. Their income depends on conditions in the labor market, that is, duration of employment and wage rate. The new technology would affect the agricultural-labor market by changing the labor intensity of cultivation, the productivity of labor, which in turn would influence the wage rate, and the income of the farmer, which would affect his labor/leisure choice. The technology could also indirectly affect the nonagricultural labor market, since the expenditure of the increased agricultural income would generate additional demand for nonagricultural goods and services, some of which might be produced within the locality.[93] The objective of this chapter is to trace these employment effects of the new technology. Although the main focus is on employment generation for the landless and the marginal farmers, employment for the landowning groups has also been studied, since their self-employment behavior would affect the labor market.

Employment in rural Bangladesh consists mainly of self-employment, and most of the agricultural workers are hired on a daily basis. Workers change jobs from one day to another, from self-employment to wage employment and from agriculture to other forms of employment. Under these circumstances, accurate information on employment can be obtained only through a large number of regular surveys covering a short period, so that respondents can recall what they did during this period. To collect accurate information for the whole year, it would be better to conduct 52 weekly surveys, but that would have been extremely expensive and taxing for the respondents. Considering the trade-offs, this survey collected information for all members of the sample households who participated in productive work for each day of the week preceding the day of interview, for eight weeks scattered throughout 1982. The periods were selected on the basis of a priori knowledge of the cropping pattern of the area so as to represent the normal, busy, and slack periods of employment. The supply of labor for the whole year and the composition of employment has been estimated by extrapolating the data for the eight weeks. The demand for agricultural labor has been estimated from labor

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[92] According to the land occupancy survey of 1978, the first attempt in the country to get information on landownership, 15 percent of rural households did not own any land, and 29 percent owned only homestead land. But households that claimed no more than 0.5 acre of land other than the homestead, and are considered in Bangladesh as "functionally landless," constituted 50 percent of rural households in that year. In 1983/84, according to the latest agricultural census, 9 percent of the households did not own any land and 46 percent owned less than 0.5 acre. About 40 percent of the households reported agricultural wage labor as their main occupation; two-thirds of them owned less than 0.5 acre. See Jannuzi and Peach, *Agrarian Structure of Bangladesh,* p. 110; and Bangladesh, *Census of Agriculture and Livestock,* pp. 81, 267.

[93] John W. Mellor, *The New Economics of Growth: A Strategy for India and the Developing World* (Ithaca: Cornell University Press, 1976). For detailed empirical investigations see, among others, Peter B. R. Hazell and Ailsa Roëll, *Rural Growth Linkages: Household Expenditure Patterns in Malaysia and Nigeria,* Research Report 41 (Washington, D.C.: International Food Policy Research Institute, 1983); and Mahabub Hossain, "Agricultural Growth Linkages: The Bangladesh Case," *The Bangladesh Development Studies* 15 (No 1, 1987).

use in crops, as reported by farmers in three rounds of interviews conducted at the end of each crop season during 1982.

Participation in Economic Activities

A worker has been defined as a person who was available for work in income-earning or expenditure-saving activities (henceforth called economic activities) during any of the eight weeks of the survey. These activities included supervision of farm labor, crop cultivation, postharvest processing and marketing, livestock and poultry raising, commercial and subsistence fishing, vegetable growing in kitchen gardens, cottage industries, house construction and repair, earthwork, collection of fuel, and trade, transport, and other services. Domestic labor for women should also be regarded as expenditure saving for the household, but it was not considered in this definition. The average number of workers, thus defined, is 1.88 persons per household out of a household size of 6.34 persons for the entire sample. Thus the labor force participation rate (workers divided by members) is 29.7 percent of the rural population, which is very close to the 29.4 percent activity rate reported in the national labor force survey of 1983-84.[94] The low rate of participation in economic activities is partly because of the large proportion of the young population (up to age 15), but is mainly due to the virtual absence of women from the country's labor force. About 35 percent of the population in the sample was below age 10, and only 8 percent of the female population participated in economic activities. The rate of participation of women in income-earning activities is estimated at 5.1 percent by the 1981 population census and 7.9 percent by the 1983-84 labor force survey.

The labor force participation rates for different landholding groups can be reviewed in Table 44. The impact of the new technology is assessed by comparing the information

Table 44—Labor force participation in developed and underdeveloped areas, by landholding, 1982

Landownership Group[a]	Average Number of Persons in Family	Average Number of Workers (Age 15 and Over) in Family	Participation Rate	Male Workers as Proportion of Family Members	Female Workers as Proportion of Family Members
			(percent)	(percent)	(percent)
Underdeveloped villages	6.19	1.84	29.7	27.3	7.9
Landless	4.82	1.55	32.2	28.8	10.4
Small	5.98	1.82	30.4	27.7	8.9
Medium	7.04	2.09	29.7	28.4	4.2
Large	8.87	2.21	24.9	22.9	8.0
Developed villages	6.52	1.93	29.6	25.8	12.8
Landless	5.45	1.88	34.5	27.3	21.0
Small	5.93	1.70	28.7	24.6	13.9
Medium	7.38	2.08	28.2	26.0	8.1
Large	9.08	2.52	27.8	26.6	3.9

Source: Based on data from Bangladesh Institute of Development Studies/International Food Policy Research Institute field survey.

[a] Landless, less than 0.5 acre; small, 0.5-2.5 acres; medium, 2.5-5.0 acres; large, 5.0 acres or more.

[94] The crude activity rate is estimated at 30.0 percent for the country as a whole, 34.2 percent for urban areas, and 29.4 percent for rural areas. See Bangladesh, *Final Report: Labour Force Survey, 1983-84*, p. 25.

for two groups of villages, equally divided according to the scale of the adoption rate of the new technology (see Chapter 2). The average number of persons in the household was about 5 percent higher in the developed villages, and the difference is statistically significant. This difference is, however, mainly due to the landless category. The difference for other groups is not significant. Presumably, better economic conditions in developed villages reduce mortality rates and increase family size for the landless category.

The participation rate is similar in the two groups of villages. The participation of women is, however, marginally higher in the technologically developed villages and is significantly higher for the landless and small farmer groups. The proportion of female workers in landless households is about 21 percent in the developed villages, compared with 10 percent in the underdeveloped villages. This difference may be due to more employment opportunities being generated for women in nonagricultural activities in the developed villages. The number of male workers as a proportion of the total population is about 25.8 percent in the developed villages, compared with 27.3 percent in the underdeveloped villages.

Size of landholding has a strong influence on the participation rate. In the underdeveloped villages, the participation rate is about 32 percent for the landless and marginal landowners compared to 25 percent for the large landowners. Similar differences are found in the developed villages. The female participation rate is also higher among the landless and the marginal landowners, significantly so in the developed areas. With technological advancement, the participation of males in the labor force appears to decline.

The participation rate can be taken as a proxy indicator of the supply of labor in the stock sense. The findings that technological advancement and size of landownership have a negative influence on the participation rate indicate that leisure is substituted for labor at higher levels of income. It appears that the very poor households supply as many workers as possible to the labor force in order to earn a subsistence income for the family, subject to job availability and limitations imposed by socioreligious factors.[95] As income increases with technological progress or a larger amount of land, or both, a household may withdraw the women and children from the labor force in order to have higher social status and better education for the children.

The above point is further demonstrated in Table 45, which shows occupations of family members aged 10 to 25—the age group that participates in the labor force, attends educational institutions, or takes up domestic duties as housewives. The labor force participation rate in this age group is about 27 percent in the developed villages, compared with 37 percent in the underdeveloped villages. Although a larger proportion of the female population in this age group is married and takes up domestic work, the main reason behind the lower participation rate in developed villages is greater participation in educational institutions. The proportion of students in this age group is 36

[95] In Bangladesh there is a social stigma against women working in the field or performing manual labor for others. The women from very poor families, however, try to earn or to save expenditures by organizing production around the homestead. About 75 percent of the people who took loans in 1986 from the Grameen Bank, an institution created for providing credit to landless households, were women. They took loans mostly for livestock and poultry raising, cottage industries, and shopkeeping activities. A large survey in 1979 found that nearly two-fifths of the workers employed in cottage industries were women and 84 percent of them were unpaid family laborers. As agricultural incomes increase, the demand for these activities in which the poor women can find employment may also go up. See Mahabub Hossain, *Credit for Alleviation of Rural Poverty: The Grameen Bank in Bangladesh,* Research Report 65 (Washington, D.C.: International Food Policy Research Institute, 1988); and Mahabub Hossain, "Employment and Labour in Bangladesh Rural Industries," *The Bangladesh Development Studies* 12 (March-June 1984): 1-24.

Table 45—Occupation of family members aged 10 to 25, by landownership and sex, 1982

Group	Underdeveloped Villages				Developed Villages			
	Students	Housewives	Inactive	Workers	Students	Housewives	Inactive	Workers
	(percent)							
Landownership[a]								
Marginal	16.4	39.7	9.3	34.6	23.0	37.2	7.5	32.2
Small	18.9	37.8	3.0	40.2	32.1	34.0	3.3	30.6
Medium	27.2	34.7	1.9	36.2	46.2	32.1	2.7	19.0
Large	50.0	24.0	6.0	20.0	57.5	21.3	4.3	17.0
Sex								
Male	29.9	. . .	3.6	66.5	49.6	. . .	7.1	43.3
Female	16.3	71.5	6.4	5.8	22.1	65.6	3.1	9.2
Total	23.1	36.4	4.9	35.7	36.0	32.9	4.7	26.5

Source: Based on data from Bangladesh Institute of Development Studies/International Food Policy Research Institute field survey.

[a] Marginal, less than 0.5 acre; small, 0.5-2.5 acres; medium, 2.5-5.0 acres; large, 5.0 acres or more.

percent in the developed villages, compared with 23 percent in the underdeveloped villages. A larger proportion of males than of females attends school. With technological progress, the student population increases for both sexes, but the increase is more pronounced for males—about 50 percent in the developed villages, compared with 30 percent in the underdeveloped villages. Size of landownership also significantly influences school attendance. In underdeveloped villages, students compose less than one-fifth of this age group in households owning less than 2.5 acres, but about one-half in households with 5.0 acres of land or more. Even after controlling for the effect of landownership group, school attendance is higher in developed villages.

Education increases the quality of labor and provides opportunity for taking higher-paid nonagricultural employment. Even self-employment in trade, services, and processing activities requires functional knowledge of reading, writing, and arithmetic. Considering the above, the downward pressure of technological advancement on labor force participation should be taken as a positive development. With improved economic conditions, the lower-income groups can afford to send more children to school and have better education, which may promote occupational mobility and increase lifetime earnings.

Extent and Composition of Employment

Since the average number of hours of work per day may vary across villages, and a worker may be engaged in a number of activities during a day, the information on duration of employment was collected in the survey in hours, by activity, for each of the workers in the sample households. The information was collected on a daily basis for seven days preceding the date of the interview and may contain some margin of error due to memory recall. The estimate of total employment at the household and worker levels has been built up from the data and is measured in average weekly employment hours for the eight weeks of the survey. The information can be converted to standard eight-hour days of employment for the year 1982. It may be mentioned here that the figures measure only the supply of labor by the sample households, both on own and others' account, which may not necessarily be equal to total employment generated in the study areas. The estimation of total employment would have required data on in- and out-migration of labor in flow terms, which were not collected by the survey.

The average duration of employment estimated from the survey is about 39 hours per week, or about 253 standard eight-hour days during the year of the survey. About 62 percent of the employment was generated in agricultural activities. Self-employment accounted for about 68 percent of the total employment. The respondent workers reported that they were available for work 345 days a year. On this basis the rate of underemployment is estimated at about 27 percent.[96] However, if six days of work a week is taken as a full-employment norm, then the rate of underemployment on the time criterion is estimated at only 19 percent.

The duration of employment for different landownership groups in the technologically developed and underdeveloped areas can be reviewed in Table 46. It appears from the data that the supply of labor declines with technological advancement. Compared with underdeveloped villages, the supply of labor in developed villages is about 13 percent lower at the worker level and 9 percent lower at the household level. The duration of employment is also inversely related to the size of landownership, reflecting that at higher levels of income, people substitute leisure for labor. The workers belonging to landless households worked, on average, for about 42.4 hours a week, compared with 38.2 hours for workers belonging to households owning 5 acres of land or more—a difference of about 11 percent. With technological advancement, the difference becomes more pronounced—the landless putting in about 24 percent more labor than the large landowners. The reduction in duration of employment is less for the landless than for the landowning groups. In fact, at the household level, the landless in developed villages supply about 14 percent more labor than their counterparts in underdeveloped villages. Thus, by raising incomes, technological progress puts a downward pressure on the supply of labor. As the higher-income groups demand more leisure, the increase in labor demand generated by the new technology is met by increased supply from the lower-income groups; some of it may even be supplied by migrant workers from villages where the technology has not yet developed. In that sense, the comparison of the duration of employment between developed and underdeveloped areas underestimates the positive employment effect of the new technology on the lower-income groups.

The substitution of leisure for labor at higher income levels is more pronounced for arduous agricultural activities. This is shown in Table 47. Labor supply in agriculture is positively related to the amount of land owned, because of greater opportunities for self-employment on larger farms. But with technological advancement, the workers who belong to farm households put in less labor in agriculture than do their counterparts in underdeveloped villages. In contrast, the workers in the landless group supply about 80 percent more labor in the developed villages than in the underdeveloped ones. The total supply of labor in agriculture is about 7 percent more in the developed villages.

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[96] In rural Bangladesh open unemployment is rare, because family members share the household work, but underemployment is considerable. Estimates of the rate of underemployment for the country as a whole are not available. Estimates from different microstudies for the recent period vary from 28 to 43 percent. A part of the difference is due to regional variations, as most of the studies cover only a few villages in different areas of the country, but a large part of the variation can also be attributed to differences in concepts and definitions, particularly regarding the full employment norm. See Atiq Rahman and Rizwanul Islam, "Labor Use in Rural Bangladesh: A Study with Micro-Level Data," International Labour Organisation, Asian Employment Programme, Bangkok, 1985 (mimeographed); Iqbal Ahmed, "Unemployment and Underemployment in Bangladesh Agriculture," *World Development* 6 (December 1978): 1281-1296; and Mahmud Khan, "Labor Absorption and Unemployment in Rural Bangladesh," *The Bangladesh Development Studies* 13 (September-December 1985): 67-88.

Table 46—Duration of employment in technologically developed and underdeveloped areas, by landownership group, 1982

Landownership Group[a]	Average Employment per Household			Average Employment per Worker		
	Underdeveloped Villages	Developed Villages	Difference	Underdeveloped Villages	Developed Villages	Difference
	(hours/week)		(percent)	(hours/week)		(percent)
Landless	65.37	74.39	13.8	42.40	40.09	-5.5
Small	75.47	63.87	−15.4	42.36	37.26	−12.0
Medium	87.79	66.67	−24.1	41.34	32.53	−21.3
Large	83.87	80.83	−3.7	38.24	32.33	−15.5
Total	76.38	69.62	-8.8	41.59	36.12	−13.2

Source: Based on data from Bangladesh Institute of Development Studies/International Food Policy Research Institute field survey.
[a] Landless, less than 0.5 acre; small, 0.5-2.5 acres; medium, 2.5-5.0 acres; large, 5.0 acres or more.

The poor cannot afford to remain unemployed. Since the landless do not get enough employment on the land, they tend to engage more in nonfarm rural activities. In underdeveloped villages, about 64 percent of the employment for landless households was generated in nonagricultural activities, compared with only 22 percent for the large landownership group (Tables 46 and 47). As agricultural income increases with technological advancement, more demand is generated for nonfarm goods and services, some of which may be produced in rural areas (see Chapter 8). This may increase demand for labor in nonagricultural activities. It appears from the data that the additional employment is taken up by households in underdeveloped villages and by large landowning groups in developed villages. The supply of labor in nonagricultural activities is about one-third lower in the developed villages. The rate of decline increases with size of landownership but only up to the medium-sized farm group. The supply of labor to nonagriculture from the large landowning group is, in fact, greater in the developed villages.

Table 47—Duration of employment in agricultural and nonagricultural activities, by technology and landownership group, 1982

Landownership Group[a]	Agriculture			Nonagriculture		
	Underdeveloped Villages	Developed Villages	Difference	Underdeveloped Villages	Developed Villages	Difference
	(hours of labor/week/household)		(percent)	(hours of labor/week/household)		(percent)
Landless	23.61	42.43	79.7	41.76	31.96	−23.5
Small	42.16	41.03	−2.7	33.31	22.84	−31.4
Medium	60.66	53.24	−12.1	27.13	13.43	−50.5
Large	65.42	60.53	−7.5	18.45	20.30	10.0
Total	43.54	46.67	7.2	32.84	22.95	−30.1

Source: Based on data from Bangladesh Institute of Development Studies/International Food Policy Research Institute field survey.
[a] Landless, less than 0.5 acre; small, 0.5-2.5 acres; medium, 2.5-5.0 acres; large, 5.0 acres or more.

Employment in some of the nonfarm activities whose market is expanded by increased rural incomes may require investment in working capital and some basic skills, such as functional reading, writing, and arithmetic, that can be acquired in schools. The poor may be constrained in taking up nonagricultural employment opportunities by widespread illiteracy and lack of access to financial institutions. Thus they may engage more in farming and in those nonfarm activities that require more manual labor than physical or human capital. This may often be distress employment, that is, very low productivity jobs taken by a worker when he has nothing else to do. As technological progress generates opportunities for additional employment in farming and increases the productivity of agricultural labor, employment in nonfarm activities is replaced by employment in agriculture.

Table 48 gives a detailed breakdown of employment by activity for all workers in the sample. The complete lack of specialization in rural employment is striking. Even farming does not generate enough employment for a household to keep one worker busy throughout the year. Rice farming poses the additional problem of the seasonal pattern of demand for labor, so even in large landowning households, family workers may remain unemployed during slack seasons of the year. A household may be engaged simultaneously in a number of agricultural and nonagricultural activities, and a worker may be engaged in a number of activities during the same week. It will be noted from the table that although 95 percent of the households participate in agricultural work, more than 90 percent also have some nonagricultural occupations. Nearly half of the households in the underdeveloped villages report miscellaneous nonagricultural activities (such as fencing and collection of fuel), which generate less than six hours of employment on average in a week for the households participating in such activities.

The activities for which the duration of employment declines with technological advancement are agricultural wage labor, cottage industry, trade and shopkeeping, earthwork, and miscellaneous jobs. Agricultural labor and earthwork are arduous and

Table 48—Labor supply in different activities in developed and underdeveloped areas, for all rural households, 1982

	Share of Households Engaged in the Activity		Average Weekly Employment: Households Engaged in the Activity		Average Weekly Employment: All Households	
Activity	Underdeveloped Villages	Developed Villages	Underdeveloped Villages	Developed Villages	Underdeveloped Villages	Developed
	(percent)		(hours)			
Agriculture	93.7	95.9	46.46	49.15	43.53	47.13
Cultivating family farms	81.1	80.3	34.34	34.64	27.85	27.82
Wage labor	45.3	40.1	23.54	22.98	10.66	9.21
Livestock and poultry raising	41.2	53.2	8.25	9.73	3.40	5.18
Fishing	18.6	26.4	8.76	18.60	1.63	4.91
Nonagriculture	92.5	90.5	35.52	25.62	32.86	23.19
Cottage industry	12.3	7.3	27.14	8.83	3.34	0.65
Trade and shopkeeping	31.1	26.1	24.74	21.31	7.70	5.56
Construction and transport	41.2	38.2	20.09	15.80	8.28	6.04
Services	21.7	38.9	26.40	19.20	5.73	7.46
Earthwork	27.4	14.0	14.48	13.61	3.97	1.91
Other	56.0	43.6	6.87	3.56	3.85	1.55

Source: Based on data from Bangladesh Institute of Development Studies/International Food Policy Research Institute field survey.

are also considered socially degrading if the work is performed for others. With increases in income, some households can afford to avoid this type of work. Miscellaneous activities may be performed when there is nothing else to do, so with increased employment opportunities, these are replaced by other work. The decline in labor supply to industry and trade, however, is surprising. Presumably, with increases in income, people tend to replace some low-quality products of cottage industries (often called dying industries) with competing products of formal industries, located mostly in urban areas. Also, labor productivity in many cottage industries and in petty trade is very low—even lower than the agricultural wage rate.[97] So when people do not find any work, they engage in these activities as self-employed workers. As the demand for, and the productivity of, agricultural labor increases with technological progress, these activities may be relocated to the underdeveloped villages where they may increase employment opportunities for the lower-income groups. Further investigation is necessary to test this hypothesis.

Labor Market

General Conditions

The size of the labor market is found to be quite small. Only about 32 percent of the labor hours were supplied against wages—22 percent in the agricultural sector and 49 percent in the nonagricultural sector (see Table 49). This is not surprising, since the typical holding in agriculture is too small to provide full employment for family workers, and many agricultural workers generate nonfarm employment on their own account in response to the lack of employment in the crop-production sector.

Table 49—Size of labor market from the supply side, by sector, 1982

Sector	Share of Households Supplying Labor in the Market			Wage Labor as a Share of Total Labor		
	Underdeveloped Villages	Developed Villages	Both Groups	Underdeveloped Villages	Developed Villages	Both Groups
	(percent)					
Agricultural	49.9	40.1	43.0	25.0	19.9	22.3
Nonagricultural	56.3	50.0	53.2	48.2	49.1	48.6
Total	67.9	63.4	65.7	35.0	29.5	32.3

Source: Based on data from Bangladesh Institute of Development Studies/International Food Policy Research Institute field survey.

[97] On estimates of productivity of labor in cottage industries and petty trade, see Mahabub Hossain, "Productivity and Profitability of Bangladesh Rural Industries," *The Bangladesh Development Studies* 12 (March-June 1984): 127-161; and Mahabub Hossain, *Credit for the Rural Poor: The Grameen Bank in Bangladesh,* Research Monograph 4 (Dhaka: Bangladesh Institute of Development Studies, 1984), pp. 77-94. The former study found that if the cost of family labor is imputed by the agricultural wage rate, the profit becomes negative for a large number of cottage industries, such as net and rope making, cane and bamboo works, mat making, and rice processing by indigenous methods, which account for about one-third of cottage industry employment. These activities are undertaken to raise household income through employment of female labor and of male labor during off-peak agricultural seasons. Such labor has very little opportunity cost.

Although the labor market is small, most of the cultivators hire labor at some time or other during the year (see Table 50). The labor-hiring households are a large majority, even among small farmers cultivating less than 2.5 acres. This may be the result of seasonality in the demand for agricultural labor. At busy periods labor must be hired to supplement family labor, while during slack periods members of the same household will seek jobs in the labor market.

Because of the seasonal variation in demand and supply, the rural labor market is generally informal in nature, and most workers are hired casually, on a daily basis, according to the need. During the survey year, only one-eighth of all farmers and one-half of the large farmers hired workers for a season or for the year. Two-fifths of those hired on a regular basis were children who looked after livestock and were mostly employed for wages in kind—free board, meals, and clothing. Such employment is often determined by the level of absolute poverty in a village rather than by the demand for regular workers by an employer.

Impact of Technology

Technological progress increases the demand for labor in the agricultural sector. In the crop production activity, labor hired on a casual basis accounts for 47 percent of the total labor used in the technologically developed villages, compared with 41 percent in the underdeveloped villages (Table 50). The proportion of hired labor increases even for the small-farmer group. So there is a downward pressure on the supply of hired labor from farming households. This is one of the reasons why the proportion of labor supplied in the agricultural market is lower in the technologically developed villages (20 percent) than in the underdeveloped villages (25 percent), while the labor supplied in the nonagricultural market remains unchanged (Table 49).

Table 51 shows that most of the agricultural labor in the market is supplied by the landless and marginal landholding groups. In the underdeveloped villages, 68 percent of the landless participate in the labor market and 74 percent of their employment is generated by others; the proportions are 13 and 3 percent, respectively, for the large landownership group. In the developed villages, labor supplied against wage is lower than in underdeveloped villages for all landholding groups, and the difference is more pronounced for large landowners. In the nonagricultural sector, also, the participation rate in the market is inversely related to the size of landownership. But unlike in

Table 50—Nature and size of agricultural labor market from the demand side, by landownership group, 1982

Landownership Group[a]	Share of Farmers Hiring Long-Term Workers: Underdeveloped Villages	Share of Farmers Hiring Long-Term Workers: Developed Villages	Share of Farmers Hiring Daily Labor: Underdeveloped Villages	Share of Farmers Hiring Daily Labor: Developed Villages	Hired Labor as a Share of Total Labor: Underdeveloped Villages	Hired Labor as a Share of Total Labor: Developed Villages
	(percent)					
Small	4.6	2.0	76.2	87.1	30.3	34.4
Medium	17.5	14.3	90.2	96.0	36.0	47.1
Large	54.8	33.3	100.0	100.0	55.9	60.2
All groups	15.4	9.5	84.5	91.1	40.6	46.7

Source: Based on data from Bangladesh Institute of Development Studies/International Food Policy Research Institute field survey.

[a] Small, less than 2.5 acres; medium, 2.5-5.0 acres; large, 5.0 acres or more.

Table 51—Participation in labor market for different landownership groups, 1982

Landownership Group[a]	Agriculture				Nonagriculture			
	Share of Households Supplying Wage Labor		Share of Labor Supplied Against Wage		Share of Households Supplying Wage Labor		Share of Labor Supplied Against Wage	
	Underdeveloped Villages	Developed Villages	Underdeveloped Villages	Developed Villages	Underdeveloped Villages	Developed Villages	Underdeveloped Villages	Developed Villages
	(percent)							
Landless and marginal	67.7	73.7	74.0	52.5	74.0	69.5	51.8	58.3
Small	50.0	39.4	29.0	15.0	66.4	51.9	54.2	47.3
Medium	27.2	17.3	7.8	2.9	37.0	32.1	41.7	40.8
Large	12.9	2.9	2.9	0.3	16.1	32.4	10.0	27.1

Source: Based on data from Bangladesh Institute of Development Studies/International Food Policy Research Institute field survey.

[a] Landless and marginal, less than 0.5 acre; small, 0.5-2.5 acres; medium, 2.5-5.0 acres; large, 5.0 acres or more.

agriculture, the supply of labor in the market does not change much with technological advancement. In fact, the supply of wage labor in the nonagricultural market is higher in developed villages for the landless and large landowner groups. Thus the tendency to avoid agricultural wage employment at higher levels of income and to shift to nonagriculture in response to higher employment opportunities puts a downward pressure on the supply of agricultural labor when technology progresses. These forces operate to provide more employment and income to the lower-income groups.

The wages received for hired-out labor (excluding payment in kind) in the two groups of villages are shown in Table 52. The wage rate was higher for nonagricultural labor than for agricultural and higher for male workers than for female. The agricultural wage rate for women was 44 percent lower than for men in the underdeveloped

Table 52—Wage rate received for hired labor, by technology, landholding, and sex of workers, 1982

Technology/Family Landholding	Male Workers		Female Workers	
	Agriculture	Nonagriculture	Agriculture	Nonagriculture
	(Tk/hour)			
Underdeveloped villages	1.53	1.95	0.68	1.16
Less than 0.5 acre	1.46	1.74	0.53	1.21
0.5–2.5 acres	1.61	2.15	1.34	1.25
2.5 acres or more	1.68	2.25	[a]	0.72
Developed villages	1.82	2.86	1.22	1.52
Less than 0.5 acre	1.86	2.46	1.21	1.13
0.5–2.5 acres	1.79	3.03	[a]	1.75
2.5 acres or more	1.63	3.29	[a]	1.91

Source: Based on data from Bangladesh Institute of Development Studies/International Food Policy Research Institute field survey.

Notes: The wages exclude meals as payment in kind. The estimates for female workers for different landholding groups would be unstable, as they are based on a very small number of cases because female participation in the labor market is negligible.

[a] There was no case in this category.

villages. The comparison suggests that technological progress has a positive effect on the wage rate. For male workers, the agricultural wage rate in developed villages was 19 percent higher than in underdeveloped villages, and the nonagricultural wage rate was 47 percent higher.

The wage rate paid by sample farmers for agricultural labor was about 25 percent higher in technologically developed villages than in underdeveloped ones (see Table 53). The difference in wage rate was higher for the small landowners (30 percent) than for large ones (16 percent). Thus, while the landless gain from the higher wages following technological progress, this factor increases inequality in agricultural incomes across the farm-size scale.

Operation of the Labor Market—A Multivariate Analysis

An important limitation of the analysis presented above is that it is based on a partial approach, since only two factors—the size of landownership and technology—are taken into account. The labor market would be affected by a host of other factors, including the wage rate, whose effects also need to be controlled for in assessing the impact of the new agricultural technology. This section attempts to broaden the analysis by applying the multivariate regression technique.

Determinants of Labor Supply

Following Yotopoulos and Lau, and Bardhan,[98] the supply of labor by a rural household is assumed to be governed by the following function:

$$SLBR = f(OWNL, TECH, CPTL, FSZ, WRKR, FEM, EDCN, LVNG, VWAGE), \qquad (12)$$

where

SLBR	=	average weekly hours of labor put in by household,
OWNL	=	amount of land owned by household (in acres),
TECH	=	amount of land cropped with MVs (in acres),
CPTL	=	amount of nonland fixed assets owned by household (in Tk 1,000),
FSZ	=	number of members in household,
WRKR	=	number of family workers in household,

[98] Yotopoulos and Lau derive a labor supply function of the household from an indirect utility function, while Bardhan employs a pragmatic approach to explain the labor market participation behavior of peasant households. See Pan A. Yotopoulos and Lawrence J. Lau, "On Modeling the Agricultural Sector in Developing Economies," *Journal of Development Economics* 1 (No. 1, 1974): 105-127; and Pranab K. Bardhan, "Labor Supply Functions in a Poor Agrarian Economy," *American Economic Review* 69 (March 1979): 73-83. Other major works that cover this issue are Lawrence J. Lau, W. L. Lin, and Pan A. Yotopoulos, "The Linear Logarithmic Expenditure System: An Application to Consumption-Leisure Choice," *Econometrica* 46 (July 1978): 843-868; and Mark R. Rosenzweig, "Rural Wages, Labor Supply, and Land Reform: A Theoretical and Empirical Analysis," *The American Economic Review* 68 (December 1978): 847-861.

FEM = number of female workers in household,

EDCN = educational level of head of household (completed years of schooling),

LVNG = standard of living in the village as measured by per capita consumption expenditure, and

VWAGE = wage rate prevailing in the village (in taka per day).

In the utility function of an individual, leisure is considered as one of the consumer goods. Its cost is the wage income that has to be sacrificed if leisure is consumed. This cost would reduce the purchasing power of other consumer goods. So the choice between leisure and consumer goods will be determined by their relative prices, that is, the wage rate and the prices of consumer goods. An increase in income from nonwage sources will shift the indifference curve upward; hence the individual can have more leisure and consumer goods at the same level of relative prices. Thus labor, which is the residual of the time available for work after the consumption of leisure, would be determined mainly by the wage rate, the prices of consumer goods, and the income from nonwage sources. It would be positively related to the wage rate and negatively related to the prices of consumer goods. Owing to the difficulty of measuring the index of the prices of a large number of consumer goods, it has not been possible to incorporate this variable in the labor supply function. Since the labor market is more fragmented, owing to the difficulty of worker mobility, a much larger variation is expected in the wage rate among the cross-section of households than in the prices of consumer goods. The omission of this variable thus may not seriously affect the results.

The main determinants of nonwage income are the assets owned by the household. The variables OWNL, TECH, CPTL, and EDCN have been incorporated to take care of the effect of this factor. The larger the amount of land owned by the household and the proportion of the land devoted to cultivation of MVs, the higher would be nonlabor agricultural income. The nonland fixed assets would provide scope for generating

Table 53—Wage rate paid by sample farmers for agricultural labor in technologically developed and underdeveloped villages, 1982

Landownership Group[a]	Underdeveloped Villages: Number of Farmers Hiring Labor	Underdeveloped Villages: Wage Rate	Developed Villages: Number of Farmers Hiring Labor	Developed Villages: Wage Rate	Difference in Wage Rate (Developed Over Underdeveloped)
		(Tk/day)		(Tk/day)	(percent)
Small	86	17.19	128	22.26	30
Medium	74	17.63	72	21.28	21
Large	27	16.34	32	18.90	16

Source: Based on data from Bangladesh Institute of Development Studies/International Food Policy Research Institute field survey.

Note: The wages include imputed value of payments in kind. The mean wage rate for the entire sample was Tk 19.59, and the standard error of estimate was Tk 0.26. The difference in wage rate between developed and underdeveloped villages was statistically significant for all groups. The Bangladesh Bureau of Statistics estimated the wage rate for the country as a whole at Tk 17.05 for 1982/83.

[a] Small, less than 2.5 acres; medium, 2.5-5.0 acres; large, 5.0 acres or more.

self-employment in nonagricultural activities, while education might open up opportunities for shifting to relatively higher-paid employment in service activities and hence for earning higher income from the same amount of labor. Thus, while capital and education may have a positive effect on nonagricultural employment, the higher-income effect would put negative pressure on the supply of labor. The net impact would depend on the magnitude of these two opposite effects.

The decision regarding the consumption of goods and services and the supply of labor is determined at the household level, so the composition of the household and of the working members may also affect the supply of labor. The higher the number of consumers (FSZ) relative to workers, the lower would be the per capita income from labor in the household, and hence the higher would be the supply of labor. The larger the proportion of female workers, the lower would be the supply of labor, since women also have to supply domestic labor and would have less time available for productive work. Thus, other things remaining constant, labor supply would be positively associated with family size and negatively associated with the number of female workers.

In estimating labor-supply functions, questions are raised about appropriate measurement of the wage rate as an independent variable.[99] The wage rate derived from the information on wage earnings and labor hours worked outside the household, if incorporated in the function where the latter is used as the dependent variable, would pose well-known measurement-error problems. For households that do not sell labor, the variable cannot be observed. The problem of simultaneity is also involved because, at the household level, both the amount of labor supplied and the wage rate may be jointly determined by other variables. To avoid these problems, the prevailing wage rate for agricultural labor in the village has been used for all households. As Bardhan points out, the village wage rate may be more exogenous to the individual household than the wage actually received, which may be determined by such factors as the amount of labor supplied and the level of income of the household.

The labor supply functions estimated from the data for all households in the sample, for agriculture and nonagriculture, and for self-employment and wage employment, are reported in Table 54. The total supply of labor seems to be significantly related to all the variables included in the function. The model explains about two-thirds of the variation in the supply of labor among the sample households. A worker supplies on the margin about 30 hours a week, about three-fifths of which are on own account of the household (self-employment) and in the agricultural sector. A larger number of dependents seems to necessitate more work by the earner. This additional work is, however, generated mainly in agriculture and on own account of the household. The coefficient of the family size variable is statistically insignificant and has an opposite sign in the equation for nonagriculture and wage employment. This indicates that such employment may be demand-determined; that is, even if the household is willing to supply additional labor to satisfy the consumption needs of a larger number of dependents, the employment may not be available in the market. A female worker puts in about 11 hours fewer per week than an average worker if she is employed in agriculture, but in nonagriculture the difference is insignificant.

The larger the amount of land owned by the household, the smaller is the supply of labor, which supports the a priori expectation about labor/leisure substitution. Ownership of land, however, gives scope for generating more employment in agriculture, particularly on own account. The value of the coefficient of land in the equation

[99] Bardhan, "Labor Supply," pp. 74-75.

Table 54—Estimates of labor supply functions for all rural households, 1982

Variable	All Activities	Agriculture	Nonagri-culture	Self-employment	Hired Employment
VWAGE	1.10[a] (4.71)	0.07 (0.29)	1.03[a] (3.73)	0.58[b] (2.12)	0.52[c] (1.93)
LVNG	−1.47[a] (−6.51)	−0.97[a] (−4.00)	−0.50[c] (−1.88)	−0.33 (−1.22)	−1.15[a] (−4.44)
OWNL	−1.09[a] (−2.80)	0.77[c] (1.83)	−1.86[a] (−4.04)	1.36[c] (2.97)	−2.45[a] (−5.49)
TECH	−2.18[a] (−2.95)	1.86[a] (2.34)	−4.04[a] (−4.65)	0.04 (0.46)	−2.57[a] (−3.05)
CPTL	0.34[a] (3.89)	0.16[c] (1.74)	0.18[c] (1.72)	0.58[a] (5.58)	−0.23[b] (−2.31)
FSZ	1.28[a] (3.34)	1.55[a] (3.78)	−0.27 (−0.61)	1.99[a] (4.42)	−0.71 (−1.63)
WRKR	31.06[a] (27.73)	18.34[a] (15.23)	12.72[a] (9.47)	18.03[a] (13.68)	13.03[a] (10.18)
FEM	−11.27[a] (−4.76)	−11.13[a] (−4.38)	−0.14 (−0.05)	−2.39 (−0.86)	−8.88[a] (−3.29)
EDCN	−0.66[b] (−2.42)	−1.44[a] (−4.91)	0.78[b] (2.43)	−0.23 (−0.71)	−0.43 (−1.39)
Constant	32.60[a] (4.38)	28.34[a] (3.54)	4.26 (0.88)	−4.77 (−0.54)	37.36[a] (4.39)
$\bar{R}^2$	0.67	0.47	0.21	0.47	0.27
N	624	624	624	624	624
F	140.6	62.2	19.8	62.4	26.4

Note: Figures in parentheses are estimated t-values. The sample size consists of 624 households, with valid observations for all variables.

[a] This number is significant at the 0.01 level.
[b] This number is significant at the 0.05 level.
[c] This number is significant at the 0.10 level.

of self-employment shows that an additional acre of landownership generates 1.36 hours of additional self-employment a week (about 9 days a year). But the positive income effect of landownership reduces the supply of labor in the market by about 2.45 hours a week (16 days a year). Thus, on balance, the total supply of labor is reduced.[100] The results also indicate that the larger the amount of land owned, the less is the need to work in nonagricultural activities. Education gives additional scope for working in the nonagricultural sector, but the higher-income effect of education and the higher social status of the educated worker operate to reduce the worker's supply of labor in agriculture. On balance, the better educated supply less labor in

[100] Values of regression coefficients reported in the table are those obtained by the OLS method. Since some of the cases have zero values for the dependent variable (the number was large for the category of hired employment), the censored regression method is more appropriate for estimation of the supply functions for different categories of employment. The equations were estimated using the tobit method and the parameter values were found to be somewhat different, but the general conclusions remained valid. The OLS estimates were chosen for presentation because the values of the parameters of the specific variables in functions for different categories of labor add up to the parameter for that variable in the supply function for total labor.

agriculture and on others' account. Among the income variables, only capital seems to increase the supply of labor. It reduces supply for the market, but the positive effect on creation of employment on own account more than compensates for the negative effect, in both agricultural and nonagricultural activities.

The supply of labor responds positively to the wage rate, but mostly for nonagricultural labor. For agricultural labor, the coefficient of the wage variable is statistically insignificant. This is found to be the case for all landownership groups from separate estimates of the supply functions for agricultural labor. The estimated coefficient of the wage rate, valued at the arithmetic mean of the variable, gives an elasticity of supply of nonagricultural labor at 0.71.

Another variable that is found to significantly affect the supply of labor is the standard of living in the village. This variable is measured by the per capita consumption expenditure at the village level. The value of the coefficient is negative and highly statistically significant, indicating that the higher the standard of living in the villages, the smaller is the supply of labor by its households. This variable affects mostly the supply of labor for the market—the negative coefficient in the equation for wage employment is statistically highly significant. The coefficient for self-employment is also negative but not statistically significant. This result suggests that improvement in economic conditions in a village—from whatever sources—would reduce the supply of labor for the market, which would give scope for more employment for workers from neighboring low-income villages or put an upward pressure on the wage rate, or both.

For the present purpose, the coefficient of the technology variable is the point of interest. After controlling for the effects of other variables, the coefficient of the technology variable is negative, indicating that diffusion of the modern technology would depress the supply of labor. The value of the coefficient suggests that an increase of 1 acre under MVs would reduce the supply of labor on the margin by 2.2 hours a week (14 days a year). Technological progress creates opportunities for more employment in agriculture. The value of the coefficient in the equation for agriculture is found to be positive and statistically significant. But by raising incomes, it reduces the need to work in nonagricultural activities. The negative effect on nonagricultural labor is more pronounced than the positive effect on agricultural labor. The difference is presumably due to the income effect of technological progress. Technological progress also reduces the supply of labor for the market. The value of the technology coefficient in the equation for wage employment indicates that an increase of 1 acre under the new technology would reduce the supply of wage labor by 2.6 hours a week (17 days a year).

Table 55 reports the estimated labor supply functions for the landless and marginal landowning households. A close scrutiny of the results shows a behavioral pattern similar to that for all households in the sample, with a few exceptions. The coefficient of the size of landownership is not significant in either of the equations, which is understandable as this group owns only up to 0.5 acre of land. A worker in this group supplies about 30 hours of labor a week, only 2.2 percent less than other groups, but unlike the landowning groups, two-thirds of the labor is supplied to the market—mostly in agricultural activities. The total supply of labor is positively related to the wage rate, but the response is mostly for labor on own account. It appears that when the wage rate goes up, this group reduces hiring of outside labor and replaces it with more self-exploitation of family labor.

Technological progress generates more additional agricultural employment for the landless than for the landowning groups. This is achieved by substituting agricultural for nonagricultural labor. The positive effect on agricultural labor is more pronounced than the negative effect on nonagricultural labor. On balance, the technology has a

Table 55—Estimates of labor supply functions for landless and marginal landowning households, 1982

Variable	All Activities	Agriculture	Nonagri-culture	Self-employment	Hired Employment
VWAGE	1.40[a]	0.57	0.89[c]	1.55[a]	−0.15
	(3.25)	(1.41)	(1.67)	(2.74)	(−0.27)
LVNG	−1.41[a]	−1.55[a]	0.14	0.02	−1.42[a]
	(−3.92)	(−3.71)	(0.31)	(0.03)	(−3.00)
OWNL	−5.00	−2.21	−2.80	0.24	−5.25
	(0.68)	(0.26)	(−0.30)	(0.03)	(−0.54)
TECH	1.14	8.24[b]	−7.10[a]	4.76	−3.61
	(0.36)	(2.21)	(−1.68)	(1.13)	(−0.85)
FSZ	3.52[a]	3.12[a]	0.40	3.96[a]	−0.44
	(3.74)	(2.85)	(0.32)	(3.20)	(−0.36)
WRKR	30.38[a]	19.93[a]	10.45[a]	10.43[a]	19.95[a]
	(12.52)	(7.07)	(3.28)	(3.27)	(6.23)
FEM	−2.41	−13.75[a]	11.34[b]	14.85[a]	−17.26[a]
	(−0.58)	(−2.89)	(2.08)	(2.71)	(−3.14)
EDCN	−0.15	−1.31[c]	1.15	0.88	−1.03
	(−0.23)	(−1.76)	(1.38)	(1.05)	(−1.23)
Constant	12.51	15.09	−2.58	−44.88[a]	57.39[a]
	(0.99)	(1.02)	(−0.16)	(−2.67)	(3.42)
$\bar{R}^2$	0.68	0.41	0.17	0.31	0.26
N	191	191	191	191	191
F	52.28	17.02	5.81	11.49	9.35

Note: Figures in parentheses are estimated t-values.
[a] This number is significant at the 0.01 level.
[b] This number is significant at the 0.05 level.
[c] This number is significant at the 0.10 level.

positive effect on labor supply for the landless, although it is not statistically significant. It is also interesting to note that, like the landowning groups, the landless reduce the supply of labor to the market in response to technological progress.

Determinants of Demand for Agricultural Labor

The survey collected information on the demand for labor only for crop-production activity. The information was collected from the farming households at the crop level for three agricultural seasons. Table 56 presents the information for different groups of farm households. The total demand for labor in the crop production activity in the developed villages was about 27 percent higher than in underdeveloped villages. Most of the increase, however, was on account of hired labor. Compared with underdeveloped villages, an average household in the developed villages used 42 additional days of labor, 34 days being met by employment of hired workers. The additional self-employment for family labor is mostly on account of small-farm households. The demand for hired labor was about 56 percent higher in developed villages, and the additional employment was generated more on the small farms (131 percent) than on the large ones (19 percent). It appears that large farmers kept the upward pressure on the wage rate low (Table 53) by hiring labor relatively less than small and medium farmers.

Table 56—Use of labor in crop production in developed and underdeveloped villages, by amount of land owned, 1982

Landownership Group[a]	Family Labor			Hired Labor			Total Labor		
	Underdeveloped Villages	Developed Villages	Difference	Underdeveloped Villages	Developed Villages	Difference	Underdeveloped Villages	Developed Villages	Difference
	(8-hour days/household)		(percent)	(8-hour days/household)		(percent)	(8-hour days/household)		(percent)
Small	52.7	72.0	36.6	19.8	45.8	131.1	72.5	117.8	62.5
Medium	118.4	106.3	−10.2	66.5	94.8	42.6	184.9	201.1	8.8
Large	155.1	155.5	0.3	196.6	234.4	19.3	351.7	389.9	10.9
All groups	90.9	98.5	8.4	61.3	95.3	55.5	152.2	193.8	27.3

Source: Based on data from Bangladesh Institute of Development Studies/International Food Policy Research Institute field survey.

Note: The table excludes the functionally landless households. A few of them were engaged in farming and used farm labor, which is not accounted for.

[a] Small, less than 2.5 acres; medium, 2.5-5.0 acres; large, 5.0 acres or more.

The following demand function for hired labor was estimated from the data:

$$\begin{aligned} DLBR = {} & \underset{(4.23)}{68.29} + \underset{(10.74)}{8.72}\,LAND + \underset{(13.11)}{27.78}\,TECH - \underset{(-0.58)}{1.64}\,WRKR \\ & - \underset{(-2.99)}{2.27}\,VWAGE - \underset{(-4.00)}{0.48}\,TNC; \end{aligned} \quad (13)$$

$\bar{R}^2 = 0.49, \quad F = 95.9, \quad N = 461,$

where

DLBR = number of labor days hired from outside the household in the crop production activity,

LAND = total cropped area (in acres),

TECH = area devoted to cultivation of MVs,

WRKR = number of family workers in household,

TNC = total cropped area under tenancy (in acres),

VWAGE = wage rate estimated at the village level (in taka per day).

The figures within parentheses are the estimated t-values of the coefficient. As expected, the demand for labor is positively associated with cropped land but negatively associated with the proportion of area under tenancy. The wage rate, measured at the village level, affects the demand for labor. The coefficient of the variable is statistically significant at less than 1 percent probability of error. The value of the coefficient evaluated at the mean level of the variable gives a wage elasticity of demand for labor at −0.58. The coefficient of the technology variable suggests that technological progress would increase the demand for labor significantly. The estimated t-value of the regression is extremely high. The value of the coefficient indicates that an increase in area under the new technology by 1 acre would increase the demand for hired labor in crop production by about 28 days.

The labor demand function has also been estimated with the alternative specification of the wage rate at the household level. The results are the following:

$$\begin{aligned} \text{DLBR} = {} & \underset{(4.80)}{73.19} + \underset{(10.78)}{8.70}\,\text{LAND} - \underset{(-0.56)}{1.59}\,\text{WRKR} + \underset{(13.48)}{28.06}\,\text{TECH} \\ & - \underset{(-4.08)}{0.48}\,\text{TNC} - \underset{(-3.55)}{2.53}\,\text{HWAGE}; \qquad (14) \end{aligned}$$

$\bar{R}^2 = 0.51,\quad F = 97.4,\quad N = 408,$

where HWAGE is the wage rate in taka per day paid by the household and other variables, as defined earlier. The results are similar except that the value of the coefficient for the wage rate increases and its statistical significance improves. The wage elasticity of demand for labor at this value is estimated at −0.65.

Impact of Technology on the Wage Rate

As mentioned earlier, the survey did not collect information on in-migration of labor from outside the sample or on demand for labor in nonfarm activities, so it is not possible to balance the supply and demand for labor in order to estimate a simultaneous equation system for determination of the wage rate.

The single equation estimates of the supply and demand for agricultural labor, however, indicate that technological progress may significantly affect the wage rate. It generates opportunities for additional self-employment in agriculture, thus reducing the supply of labor in the market by the landowning households. On the other hand, it increases the demand for farm labor in the market, so a gap develops between the demand for and supply of labor by the landowning households in the technologically developed villages. The gap may be filled by a supply of more labor from the landless group within the villages or by out-migration of labor from labor-surplus households in villages where the technology has not yet made much progress. In this way, the forces in the labor market may operate to redistribute income from higher- to lower-income groups within the developed villages, and from developed to relatively underdeveloped villages. The results also show that as technology progresses, even the landless in the developed villages supply less labor to the market. This indicates the possibility of considerable in-migration of labor from underdeveloped villages, without which there would be an upward pressure in the wage rate for clearing the labor market.

In order to see the impact of the technology on the wage rate, a wage equation was estimated, incorporating all variables that significantly affect the supply and demand for agricultural labor. After elimination of the statistically insignificant variables, the following wage equation has been obtained:

$$\begin{aligned} \text{VWAGE} = {} & \underset{(46.95)}{19.32} - \underset{(-4.19)}{0.26}\,\text{LAND} + \underset{(10.59)}{1.25}\,\text{TECH} + \underset{(2.38)}{0.44}\,\text{TNC} \\ & - \underset{(-4.10)}{0.72}\,\text{WRKR} + \underset{(1.71)}{0.10}\,\text{EDCN}; \qquad (15) \end{aligned}$$

$\bar{R}^2 = 0.22,\quad F = 26.1,\quad N = 408.$

Figures within parentheses are estimated t-values. If wages are exogenously determined, all variables would be expected to be statistically insignificant. But nearly a fifth of the variation in wage rate across the villages is explained by the above variable. Technology seems to be the most important variable affecting the wage rate. This is also found to be the case when wage rate is measured at the household level, as shown by the following equation:

$$\text{HWAGE} = \underset{(51.12)}{19.50} - \underset{(-3.56)}{0.23}\,\text{LAND} + \underset{(9.84)}{1.24}\,\text{TECH} - \underset{(-3.72)}{0.68}\,\text{WRKR} + \underset{(2.01)}{0.39}\,\text{TNC}; \qquad (16)$$

$\bar{R}^2 = 0.18, \quad F = 26.5, \quad N = 408.$

Conclusions

Modern technology affects the labor market mainly through the income variable. At higher levels of income, households substitute leisure for labor and supply less labor in the market. This redistributes employment from higher- to lower-income groups. Even the poor supply less labor in the market as income increases with technological progress. But the demand for agricultural labor goes up because of the higher labor intensity of MVs, thus putting an upward pressure on the wage rate and increasing wage earnings from the same amount of labor. These forces in the labor market may also operate, by promoting rural-rural migration, to redistribute some employment and income from technologically developed to underdeveloped villages. Unfortunately, the survey did not collect any information on migration, so a direct testing of the hypothesis is not possible.

8

LINKAGE EFFECTS OF AGRICULTURAL GROWTH

It was shown in Chapter 4 that diffusion of the new technology would substantially increase the income from crop production. The crop sector accounts for about 77 percent of agricultural income in the country. Thus technological progress is expected to have a significant effect on the growth of agricultural income.

Agricultural growth involves linkages to nonfarm sectors, and the poor may gain indirectly through the generation of employment in these activities.[101] The linkages may be generated from the supply side through investment of the new surpluses by the landowners, or from the demand side through income-induced expenditure on nonfarm goods and services, or from both. The growth of agricultural income may also increase the opportunity for investment and employment in nonfarm rural activities through its effects on the demand for such items as (1) irrigation equipment and other modern agricultural inputs produced in the nonagricultural sector, (2) services for processing and marketing additional surplus produce, and (3) trade and transport services arising from the additional purchase of nonfarm products.

Empirical studies for a number of developing countries show that the linkage effects of agricultural growth can be substantial.[102] Bell, Hazell, and Slade concluded from a study of the Muda irrigation project in Malaysia that for each dollar of agricultural income created directly by the project, an additional 80 cents of value added was created indirectly in the local nonfarm sector. In a study of interrelationships between agricultural and industrial growth performance in India, Rangarajan found that a 1.0 percent addition to the agricultural growth induced a 0.5 percent incremental growth of industrial output and 0.7 percent additional growth of national income. Recognizing the importance of such expenditure-induced growth linkages, Mellor argued that, contrary to conventional wisdom, agriculture can play the role of the leading sector in the development process.[103]

This chapter attempts to assess the nature and extent of such linkage effects by analyzing the expenditure pattern of the sample households in the technologically developed and underdeveloped villages. The data on expenditures were collected from two types of interviews. Information on daily necessities was collected on a weekly basis by asking households about consumption and purchases of these items for the week preceding the interview. This survey was conducted 8 times in 1982 during busy, normal, and slack seasons of economic activity in the sample villages. The expenditure on these items for the whole year was then estimated on the basis of the eight weeks' data. The information on expenditures on major items, such as clothing, household effects, education, recreation, health, and acquisition and repair of fixed assets, was collected four times during the year, retrospectively on a quarterly basis.

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[101] Mellor, *The New Economics of Growth.*

[102] Clive Bell, Peter Hazell, and Roger Slade, *Project Evaluation in Regional Perspective* (Baltimore and London: Johns Hopkins University Press, 1982); C. Rangarajan, *Agricultural Growth and Industrial Performance in India*, Research Report 33 (Washington, D.C.: International Food Policy Research Institute, 1982).

[103] Mellor, *The New Economics of Growth.*

Expansion of the Market: An Analysis of Consumption Patterns

Methodology

The commodities and services consumed have been classified into the following groups for study of the consumption-induced linkages:

Crops:	Rice, wheat, other grains, roots, vegetables, pulses, fruits, spices, betel nuts and betel leaves, rice husks, jute sticks
Forestry:	Firewood, leaves
Livestock:	Meat, milk, eggs, cow dung
Fishery:	Raw and dried fish
Rural processing:	Gur (raw sugar), bidi (indigenous cigarettes), tobacco, mustard oil, sweets, handloom clothes, tailoring
Urban processing:	Sugar, tea, cigarettes, soybean oil, coconut oil, kerosene, electricity, matches, soap, soda, toiletries, mill-made clothing, ready-made garments, imported new and old clothes, shoes
Services:	Education, health, transport, personal services, social services, religious services.

The impact of the growth of income on demand for the various goods and services has been studied by estimating an Engel function of the following type on the cross-section data:[104]

$$E_i = \alpha_i + \beta_i E + Y_i E \log E + \mu_i \log F + \lambda_i E \log F, \qquad (17)$$

where E is the per capita expenditure of the household, E_i is the amount of expenditure incurred on the consumption of goods in the ith group, and F is the number of persons in the household. This is a nonlinear function that allows for variation in the marginal budget share for the ith group, MBS_i, at different levels of income, which can be derived as follows:

$$MBS_i = \beta_i + Y_i(1 + \log E) + \lambda_i \log F \qquad (18)$$

The size of the family would have an important bearing on the economic position of the household at a given level of income, so it has been included in the equation as an important socioeconomic variable influencing consumption behavior of the household.

[104] For details of this form of the Engel function and its characteristics, see Hazell and Roell, *Rural Growth Linkages.* pp. 22-24.

To avoid the problem of heteroscedasticity, that the variability in the E_i increases with the explanatory variable E, the function has been fitted in the following expenditure-share form, which is derived from equation (18).

$$S_i = \beta_i + \alpha_i/E + Y_i \log E + \mu_i \log F/E + \lambda_i \log F, \quad (19)$$

where $S_i = E_i/E$ is the share of the expenditure. The disadvantage of estimating the share equation is that the value of $\bar{R}^2$ is typically small,[105] but it ensures the desirable property that the sum of the marginal budget share is equal to unity.[106]

Since per capita income is a better measure of the economic standing of the household than is household income, the expenditure variable has been measured in per capita terms. But the household size has been included so that the model permits this variable to influence both the intercept and the slope of the individual Engel functions.

Discussion of Results

The estimated parameters for the Engel function are reported in Table 57. As the function is estimated in the expenditure-share form, the value of $\bar{R}^2$ is, in general, low.

Table 57—Estimates of Engel function for rural households, 1982

Commodity Group	Estimated Values of the Parameter					
	α	β	Y	μ	λ	$\bar{R}^2$
Crops	−230.00 (4.73)	2.779 (18.15)	−0.2575 (−14.86)	−2.251 (−0.64)	−0.0017 (−0.99)	0.44
Forestry	23.70 (1.43)	0.031 (0.60)	−0.0012 (0.20)	−0.650 (0.54)	−0.0021 (−3.53)	0.08
Livestock	−0.38 (−0.02)	−0.116 (−2.39)	0.0195 (3.54)	1.286 (1.157)	0.0004 (0.76)	0.08
Fishery	−40.90 (−3.53)	0.061 (1.68)	−0.0007 (−0.02)	2.660 (3.18)	−0.0016 (−3.93)	0.09
Rural processing	92.80 (3.79)	−0.342 (−4.44)	0.0502 (5.76)	−3.010 (−1.71)	0.0020 (2.25)	0.06
Urban processing	39.90 (1.41)	−0.409 (−4.61)	0.0596 (5.92)	1.530 (0.75)	−0.0005 (−0.49)	0.12
Services	114.70 (3.29)	−0.990 (−9.03)	0.1255 (10.10)	0.380 (0.15)	0.0033 (2.64)	0.28

Source: Estimates based on data from Bangladesh Institute of Development Studies/International Food Policy Research Institute field survey.

Notes: The function was estimated in the following form:

$$S_i = \beta_i + \alpha_i/E + Y_i \log E + \mu_i F/E + \lambda_i F,$$

where S_i is the share of the commodity group in total consumption expenditure, E is the per capita consumption expenditure, and F is the number of persons in the household. Figures in parentheses are estimated t-values.

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[105] The value of $\bar{R}^2$ for this equation measures the extent to which the variation of the average budget share of the commodity across the sample is explained by the variation in income. If the marginal budget share is equal to the average share, that is, the expenditure elasticity of demand is unity, the average budget share would be the same across the income level and the value of $\bar{R}^2$ would be zero.

[106] S. J. Press and H. S. Houthakker, *The Analysis of Family Budgets* (Cambridge: Cambridge University Press, 1971), pp. 55-56.

For forestry, livestock, fishery, and rural processing, the value of $\bar{R}^2$is less than 0.10, indicating that the share of these commodities in total expenditure does not vary much with the level of income, which suggests that the expenditure elasticity of demand is close to unity. But the value $\bar{R}^2$ is relatively high for crop-sector outputs and services, which indicates that the expenditure elasticity of demand for them deviates significantly from unity. The value of the coefficient, Y, shows what happens to the marginal budget share as the level of income changes. The estimated value of this variable is significantly negative for crop-sector output, which shows that the incremental expenditure on these commodities declines with increases in income. The value is significantly positive for livestock, manufactured goods, and services.

The estimates of marginal budget share and the expenditure elasticity of demand derived from the parameters of the Engel function are reported in Table 58. About two-thirds of the expenditure is allocated to commodities produced in the crop and forestry sectors, where the share of land in value added is very high. But the marginal budget share for these commodities is 53 percent, which suggests that with increases in income, people spent proportionately much less on these items. The expenditure elasticity of demand is estimated at 0.77 for crops and 0.79 for forestry products.[107] Among agricultural commodities, livestock and fishery products have elastic demand; the marginal share of these products is 11 percent, while the average share is 8 percent. Manufactured goods have a share of 17 percent of the total budget; nearly 56 percent of these goods are produced in rural areas. These commodities also have elastic demand; the share of them in the incremental expenditure is nearly 23 percent. The expenditure is, however, more elastic for goods produced in urban areas.[108] With increased income, the marginal share of manufactured goods of rural origin increases less than proportionately.

But the highest elasticity of demand is for rural service-sector activities, in which labor's share of income is very high. Nearly 13 percent of the enlarged market for

Table 58—Estimates of marginal budget shares and expenditure elasticity of demand, 1982

Commodity Group	Average Budget Share	Marginal Budget Share	Expenditure Elasticity of Demand
	(percent)		
Crops	64.94	50.26	0.77
Forestry	3.59	2.82	0.79
Livestock	4.22	5.80	1.38
Fishery	3.95	5.01	1.27
Rural processing	9.51	11.22	1.18
Urban processing	7.51	11.21	1.49
Services	6.21	13.46	2.17

Source: Estimated from Table 57.

[107] Not all commodities in this group have expenditure elasticity less than unity. Pulses and fruits have highly elastic demand, but their share of the budget was less than 4 percent. See Appendix, Table 73.

[108] The manufactured goods that have elastic demand are bidi (cigarettes), tobacco, kerosene, washing soda, and old readymade garments that are imported from abroad for the poor. As incomes increase, cigarettes are substituted for bidi and tobacco, soaps for washing soda, and electricity for kerosene in areas of developed infrastructure. The other substitute commodities are gur (raw sugar) and sugar; gur is produced in villages. While the expenditure elasticity of gur is lower than that of sugar, it is still higher than unity. See Appendix, Table 73.

goods and services goes to service activities. The expenditure elasticity is estimated at about 2.2, indicating that with a 10 percent increase in total expenditure, the demand for service-sector activities would increase by about 22 percent. All nonfarm goods and services together share about 47 percent of the incremental expenditure and have elasticity of 1.5.

To assess the impact of technological progress on the demand for various types of commodities, the Engel function has been estimated separately for the technologically developed and underdeveloped villages. The estimates of demand derived from the parameters for the two groups of villages are reported in Table 59. It will be noted from the results that for both groups of villages the pattern of expenditure is almost the same as that obtained earlier for the entire sample. Crops and forestry products have inelastic demand, while services and urban manufactured products have the most elastic demand. With technological progress, the difference becomes even more pronounced because of the increase in income. The per capita income in developed villages was 22 percent higher than in underdeveloped ones (see Chapter 9). In the underdeveloped villages, 42 percent of the incremental expenditure was for cereals, but in the developed villages the share was 31 percent. The expenditure elasticity of demand for cereal is 0.64 in the developed villages, compared with 0.79 in the underdeveloped villages. Roots and vegetables have inelastic demand; their marginal budget share and the value of elasticity are lower in the developed villages. Pulses have highly elastic

Table 59—Expenditure pattern of households in developed and underdeveloped villages, 1982

Commodity Group	Underdeveloped Villages: Average Share	Underdeveloped Villages: Marginal Share	Underdeveloped Villages: Expenditure Elasticity	Developed Villages: Average Share	Developed Villages: Marginal Share	Developed Villages: Expenditure Elasticity
	(percent)			(percent)		
Crops	67.0	56.5	0.84	62.9	45.0	0.71
Cereals	53.0	42.1	0.79	49.1	31.2	0.64
Pulses	1.1	1.3	1.24	0.8	1.2	1.56
Roots and vegetables	5.4	4.7	0.87	4.8	3.1	0.65
Fruits	2.1	3.4	1.62	1.9	3.0	1.57
Spices	3.4	2.9	0.84	3.7	3.3	0.91
Betel nuts and betel leaves	0.9	1.4	1.55	1.3	1.3	1.00
Rice husks and jute sticks	1.0	0.7	0.70	1.3	1.7	1.30
Forestry	4.1	3.2	0.78	3.1	2.7	0.88
Firewood	2.0	2.6	1.29	1.5	2.1	1.38
Leaves	2.1	0.6	0.30	1.6	0.7	0.43
Livestock	4.4	5.7	1.29	4.0	6.4	1.59
Meat and eggs	1.6	3.2	2.00	2.1	4.4	2.10
Milk	0.9	1.8	1.93	1.3	2.4	1.92
Cow dung	1.9	0.6	0.33	0.7	−0.4	−0.58
Fishery	3.6	4.2	1.19	4.4	5.3	1.22
Manufactures	16.7	22.9	1.37	17.5	22.7	1.29
Rural origin	9.5	12.4	1.30	9.5	10.3	1.09
Urban origin	7.2	10.5	1.46	7.8	12.4	1.56
Services	4.2	7.5	1.79	8.2	17.9	2.18

Source: Based on data from Bangladesh Institute of Development Studies/International Food Policy Research Institute field survey.

Notes: Figures are derived from commodity-specific Engel functions estimated from household-level data. Parts may not add to totals because of rounding.

demand but their average and marginal consumption are lower in developed villages, presumably because of reallocation of land from pulses to MV rice. Among food items, meat, eggs, and milk have expenditure elasticities of 2.0 and their share of the marginal budget is 6.8 percent in developed villages, compared with 5.0 percent in underdeveloped villages. The most significant difference in the marginal budget share is found for service-sector activities. In the underdeveloped villages only 7.5 percent of the incremental expenditure was for these items; in the developed villages, the share was about 18 percent. Only for rural manufacturing is the value of the expenditure elasticity lower in the developed villages, but the absolute value is still greater than unity. The above findings indicate that the market for livestock and fishery products, manufacturing, and services expands more than proportionately as technological progress increases rural income. The most significant effect is on service activities, where labor's share of income is high compared with other commodity groups.

Reinvestment of Surplus

Investment defined as additions to the value of fixed assets and working capital is classified here into two broad groups—directly productive investment and other investment. Investments in agricultural and nonagricultural enterprises are regarded as directly productive investment. Agricultural investment includes expenditures on land development (such as leveling land, fencing, clearing water hyacinths, raising small embankments in fields for improved water control, and digging field channels for irrigation); purchase of agricultural machinery and tools, equipment, and draft animals; purchase of cattle and poultry for rearing; and expenditures on pond digging and tree planting. Nonagricultural investment includes purchases of industrial machinery and tools, transport equipment, and shares and debentures, and additions to fixed and working capital for trade and business. Changes in the stock of output and raw materials for agriculture and industry could not be taken into account due to lack of information. Nonmonetary investment in the form of use of family labor has been imputed by the prevailing market wage rate.

The second group, other investment, includes expenditures on construction and improvement of housing and cattle sheds, education of children, digging of wells and tubewells for drinking purposes, and construction of latrines. These may be termed social investments for formation of human capital, which may increase the productivity of labor in the long run. Expenditures on household durables, such as furniture and fixtures, electrical goods, and metal and earthen utensils, have also been treated as investment.

A significant number of households have been engaged in transactions that may be called transfers. These include such items as purchase and sale of land, receipt and repayment of loans and interest, expenses on account of litigation, and theft of property. At the aggregate level the net transfers should be zero. For the sample under study, however, the net transfer was found to be significantly positive, indicating the possibility of an underreporting of negative transfers, which people tend to suppress. Because of the conceptual problems involved, these items have not been included in investment.

The pattern of investment in the technologically developed and underdeveloped villages can be reviewed in Table 60. Total investment per household was almost the same for the two groups, but because of higher levels of expenditure, the rate of investment was lower in the developed villages (14 percent) than in the underdeveloped villages (17 percent). The difference is mainly on account of the directly productive investments, which accounted for 11.7 percent of the total expenditure in under-

Table 60—Pattern of investment in technologically developed and underdeveloped villages, 1982

Type of Investment	Amount per Household: Underdeveloped Villages	Amount per Household: Developed Villages	As Share of Gross Investment: Underdeveloped Villages	As Share of Gross Investment: Developed Villages	As Share of Total Expenditure: Underdeveloped Villages	As Share of Total Expenditure: Developed Villages
	(Tk)		(percent)			
Directly productive investment						
Agriculture	1,039	881	32.9	28.2	5.6	3.9
Land development	106	135	3.4	4.3	0.6	0.6
Agricultural tools and equipment	408	75	12.9	2.4	2.2	0.3
Draft animals and livestock	494	645	15.6	20.6	2.6	2.9
Other agriculture	31	26	1.0	0.8	0.2	0.1
Nonagriculture	1,132	769	35.9	24.6	6.1	3.4
Industry	225	29	7.1	0.9	1.2	0.1
Business	874	711	27.7	22.7	4.7	3.1
Transport	33	29	1.1	1.0	0.2	0.1
Other investment	986	1,477	31.2	47.2	5.3	6.5
Housing	727	1,186	23.0	37.9	3.9	5.3
Sanitation	27	29	0.9	0.9	0.1	0.1
Consumer durables	232	262	7.3	8.4	1.3	1.2
Total investment	3,157	3,127	100.0	100.0	16.9	13.9
Total expenditure (consumption plus investment)	18,640	22,600	...	...	100.0	100.0

Source: Based on data from Bangladesh Institute of Development Studies/International Food Policy Research Institute field survey.

developed villages, compared with only 7.3 percent in the developed villages. Two items on which households in developed villages spent proportionately more are construction of housing and acquisition of livestock. But the rate of investment in agricultural equipment and tools, cottage industry, and business was significantly higher in the underdeveloped villages.

Table 61 shows the pattern of investment for different landownership groups. As expected, the rate of investment is positively associated with the size of landownership. For the landless and small landowning households, the rate of investment was almost the same in the technologically developed and underdeveloped villages. But the medium and large landowners in the developed villages accumulated proportionately much less than their counterparts in the underdeveloped villages. It is interesting to note that the large landowners invested relatively less for capital formation in agriculture than did the small and medium landowners. A similar finding was reported by Rahman from a survey of two areas in 1975.[109]

Capital formation in nonagricultural activities was significantly higher in the technologically underdeveloped villages. Since the scope for accumulation of land is limited in these villages, rural households try to increase income through accumulation in nonagriculture, as the market for nonfarm goods and services expands with technological

[109] Atiq Rahman, "Surplus Utilisation and Capital Formation in Bangladesh Agriculture," *The Bangladesh Development Studies* 8 (No. 4, 1980): 21-46.

Table 61—Pattern of investment for different landownership groups, 1982

Landownership Group[a]	Directly Productive Investment		Other Investment		
	Agriculture	Nonagriculture	Housing and Sanitation	Consumer Durables	Total
	(percent of household expenditure)				
Underdeveloped villages					
Marginal	2.3	3.8	1.7	0.7	8.5
Small	5.4	2.1	3.5	2.0	13.0
Medium	7.1	5.3	5.2	1.0	18.6
Large	5.8	14.3	4.9	2.0	26.3
Developed villages					
Marginal	1.2	2.2	4.0	1.1	8.4
Small	6.2	1.6	3.6	1.1	12.6
Medium	3.6	6.0	4.2	1.1	14.9
Large	3.5	2.7	10.4	1.4	18.0

Source: Based on data from Bangladesh Institute of Development Studies/International Food Policy Research Institute field survey.
[a] Marginal, less than 0.5 acre; small, 0.5-2.5 acres; medium, 2.5-5.0 acres; large, 5.0 acres or more.

progress. But this opportunity is taken up more by the upper-income households. In the underdeveloped villages, nonagricultural investment as a proportion of total expenditure is about 14 percent for the large landowning households, compared with 2-5 percent for the other landholding groups.

The information presented in this section thus leads to the following main conclusions. First, technological progress does not necessarily lead to higher capital formation in agriculture. The reason for this may be that investment in irrigation, which is the main vehicle of technological progress, is made by the government. Second, expansion of the market for nonfarm goods and services seems to stimulate the most nonagricultural investment in villages where technology has made the least progress. This may occur because the new technology provides an opportunity for increasing income from the land for households in the developed villages. Since such an opportunity is lacking in the underdeveloped villages, those households look for opportunities in the nonfarm sector to increase their incomes. Third, income from investment-induced linkages tends to be unequally distributed. Because of the higher levels of income, accumulated savings, and better access to financial institutions, the large landowners can respond more readily to opportunities of investment in the nonfarm sector than can the landless and small landowners, although the latter may gain from creation of additional employment in these activities.

Impact on the Land Market

A factor to which much emphasis has been given in the literature[110] to explain the negative income-distribution effects of modern technology is the impact of agricultural surplus on the rural land market. By increasing the profitability of cultivation, the new technology inflates the surplus of the large landowners and increases the value of land. On the other hand, it makes cultivation difficult for the marginal landowners, since the working capital requirement for cultivation of the new varieties is substantially

[110] See, for example, Pears, *Seeds of Plenty.*

higher, and the poor have little access to credit from financial institutions. It is argued that with technological progress these forces will operate to increase transactions in the rural land market, and the large landowners will buy out the marginal farms, leading to further accumulation of land by the rich and a higher concentration of income.

The survey collected information on the source of acquisition of each plot of land owned by the sample households. This information can be used to empirically test the above hypothesis. If technological diffusion is associated with high transactions in the land market, the proportion of land obtained through the market would be higher for households in the technologically developed villages than for those in the underdeveloped villages. The findings reported in Table 62 tend to support the hypothesis. In developed villages, 63 percent of total land owned at the time of the survey was inherited from parents, compared with 72 percent for households in the underdeveloped villages, which suggests that the households in developed villages had been engaged in land transactions after inheritance much more than those in underdeveloped villages. The proportion of land acquired through purchase was reported at 32 percent for the developed villages and 25 percent for the underdeveloped villages.

A more direct test of the hypothesis could be made with information on land purchases and sales during the year of the survey. An important limitation on this information is that investment in land is a large, indivisible expenditure, and the household may have to save for a number of years to buy a piece of land, so it is difficult to get a representative picture of the behavior of an individual household from information for one year. A representative picture may be obtained by looking at mean values for a large number of households in a homogeneous group that would incur such expenditures every year.

The proportion of households that participated in the land market in 1982, and the extent of transactions involved, can be reviewed in Table 63, which shows the following major points. The land market is very thin. Less than 10 percent of the households participated in the market during the survey year and the maximum amount of transactions (land sold or purchased) was less than 2 percent of the amount of land. The net transaction was positive in the developed villages and negative in the underdeveloped villages. The accumulation of land in the developed villages was partly at

Table 62—Sources of landholdings in technologically developed and underdeveloped villages, from inheritance to 1982

Source of Owned Land	Underdeveloped Villages: Land Owned per Household	Underdeveloped Villages: Share of Total Land	Developed Villages: Land Owned per Household	Developed Villages: Share of Total Land
	(decimals)	(percent)	(decimals)	(percent)
Inheritance from parents	162	72.0	142	62.8
Inheritance from in-laws	3	1.3	7	3.1
Purchased	57	25.3	72	31.9
Other	3	1.3	5	2.2
Total	225	100.0	226	100.0

Source: Based on data from Bangladesh Institute of Development Studies/International Food Policy Research Institute field survey.
Notes: A decimal is 1/100 of an acre. Parts may not add to totals because of rounding.

Table 63—Transactions in the land market in technologically developed and underdeveloped villages, 1982

Landownership Group[a]	Amount Transacted: As Share of Households: Purchased Land	Amount Transacted: As Share of Households: Sold Land	Amount Transacted: As Share of Owned Land: Purchased Land	Amount Transacted: As Share of Owned Land: Sold Land	Net Accumulation as Share of Owned Land
			(percent)		
Underdeveloped villages	8.8	8.2	1.11	1.79	−0.68
Marginal and small	4.9	8.8	2.05	4.98	−2.93
Medium	13.6	4.9	0.92	0.70	0.22
Large	22.6	2.9	0.85	1.31	−0.46
Developed villages	9.8	8.8	1.73	1.30	0.43
Marginal and small	5.0	7.0	1.32	2.18	−0.86
Medium	16.3	13.8	1.47	2.09	−0.62
Large	21.6	8.1	2.03	0.30	1.73

Source: Based on data from Bangladesh Institute of Development Studies/International Food Policy Research Institute field survey.
[a] Marginal, less than 0.5 acre; small, 0.5-2.5 acres; medium, 2.5-5.0 acres; large, 5.0 acres or more.

the expense of the small landowners. For the small farmer group, the proportion of land sold was much less in the developed villages than in the underdeveloped ones, which suggests that by increasing income per unit of land, technological progress reduces the necessity to sell land. The highest accumulation, however, was by the large landowning groups in the developed villages. They increased the size of landownership by 1.7 percent during the survey year.

The results seem to support the hypothesis of the negative effect of technological progress on income distribution through accumulation of land. The impact, however, is very small. During 1982, the households in the developed villages accumulated only 0.4 percent of the holdings. At the rate of accumulation (1.7 percent a year), even the large landowners would need 13 years to increase the size of large holdings by only a quarter. On the other hand, without technological progress the small and marginal landholdings would get smaller at a faster rate because of the distress sales of land by the poor.

Conclusions

The increase in agricultural income significantly expands the market for nonfarm goods and services, many of which are located in rural areas. The incremental budget share of these commodities is 52 percent for the technologically developed villages and 40 percent for the underdeveloped villages. The expansion of the market for cottage industry products and services, which are located mostly in rural areas, ia also proportionately greater than that of increases in income. Thus rural households may indirectly gain from employment generated in these activities. But the income growth does not promote capital accumulation in agriculture, presumably because the investment in irrigation, which is the main vehicle for technological progress, is made by the government. The opportunity for additional investment in nonagriculture is taken mainly by the higher-income groups in the technologically underdeveloped villages. Technological progress seems to follow more investment in the formation of human capital and more accumulation of land by large landowners in the developed villages. This suggests that unless the higher-income groups are induced to invest in production activities, or their surplus is siphoned off for acceleration of public investment, diffusion of the new technology may lead to further inequality in the distribution of landholding and agricultural incomes, both regionally and across income scales.

9

EFFECT ON INCOME DISTRIBUTION AND POVERTY

The impact of the differential rate of adoption of the new technology among farmers, the prices of products and inputs faced by them, and the effect of the technology on production, employment, and expansion of the market for nonfarm goods and services will ultimately bring about a change in the level and distribution of rural incomes. This chapter attempts to assess the impact from direct information on household incomes.

Since rural households do not keep records of their activities, it is difficult to estimate income accurately, particularly for activities conducted on a self-employed basis. Most rural households are also involved in many expenditure-saving activities such as producing fruits and vegetables in kitchen gardens, rearing poultry, fishing from nearby creeks and canals, processing food, and manufacturing personal and household effects, basically for family consumption. There is a tendency to underreport these activities, since the respondents do not generally consider them as sources of income.

In this survey, information has been collected as comprehensively as possible for estimating income. A detailed questionnaire on inputs and outputs for crop-production activities was administered three times during the survey year, at the end of each cropping season, to reduce errors attributable to faulty memory. Input-output information on processing, manufacturing, and trading activities was collected through quarterly surveys. The wage income and irregular expenditure-saving activities were recorded in a weekly consumption, expenditure, and employment survey that was administered eight times during the year. The annual incomes from these sources have been estimated by extrapolating from the estimates for the eight weeks.

Level and Structure of Income

The estimates of income obtained from the survey for households in technologically developed and underdeveloped villages can be reviewed in Table 64. For the entire sample, the average household income in 1982 is estimated at Tk 21,000 and per capita income at Tk 3,304. The latest national hosuehold expenditure survey conducted by the Bangladesh Bureau of Statistics estimates the per capita rural income for 1983/84 at Tk 3,883. At 1982 prices this yields Tk 3,347, which is very close to our estimate. The 1981/82 household expenditure survey, however, shows that the estimated rural per capita income was less than our estimate for 1982. This may be due to the selection of a larger proportion of the technologically developed area in our sample than in the country. In Bangladesh, 24 percent of the cropped area and 28 percent of the cereal area was under MVs during 1982/83. In our sample, the proportions were 37 and 46 percent, respectively.

The total household income was 29 percent higher in the technologically developed villages than in the underdeveloped villages, indicating a positive effect of the technology on the level of income. The number of persons per household is also higher in the developed area, so the difference in per capita income is less—about 22 percent. Compared with underdeveloped villages, the average size of the family in the developed villages was about 13 percent higher for the landless group but only 3 percent higher

Table 64—Structure of household incomes in technologically developed and underdeveloped villages, 1982

Sources of Income	Underdeveloped Villages: Annual Household Income	Underdeveloped Villages: Share of Source	Developed Villages: Annual Household Income	Developed Villages: Share of Source	Increase in Income in Developed Villages Over That in Underdeveloped Villages
	(Tk)	(percent)	(Tk)	(percent)	(percent)
Agriculture	11,178	61.0	15,644	66.2	40.0
Crop cultivation	6,258	34.1	9,265	39.2	48.1
Kitchen gardening	2,465	13.5	2,730	11.5	10.8
Livestock and poultry raising	1,272	6.9	1,511	6.4	18.8
Fishing	287	1.6	1,099	4.6	283.0
Agricultural wages	896	4.9	1,039	4.4	16.0
Nonagriculture	7,151	39.0	7,994	33.8	11.8
Cottage industry	726	4.0	268	1.1	-63.1
Trade	886	4.8	1,889	8.0	113.2
Services	3,268	17.8	4,417	18.7	35.2
Nonagricultural wages	2,271	12.4	1,420	6.0	-37.5
Total household income	18,329	100.0	23,638	100.0	29.0
Per capita income	2,961	...	3,626	...	22.4

Source: Based on data from Bangladesh Institute of Development Studies/International Food Policy Research Institute field survey.

Note: The average household size was 6.52 in developed villages and 6.19 in underdeveloped villages, a difference of 5.3 percent.

for other groups. This may be the result of a reduction in mortality rates following the increases in income in very poor households.

As expected, the new technology has a more pronounced effect on agricultural incomes than on nonagricultural incomes. Nearly 61 percent of household income in underdeveloped villages originates from the agricultural sector, 52 percent from crop and vegetable production, and 9 percent from livestock and fishing. In developed villages, the crop sector income (including agricultural wages) was 44 percent higher, and total agricultural income was 40 percent higher than in underdeveloped villages. The increase in agricultural income was 48 percent for crop cultivation, and 16 percent for agricultural wages. The absolute level of nonagricultural income was also higher in the developed villages, but the difference is substantially less than for agricultural income. The income from trade and other services was about 52 percent higher in the developed villages, but the income from cottage industry and nonagricultural wages was lower by about 44 percent, which pushed down the income difference from nonagricultural sources between these two groups of households. Many cottage industries are low-productivity activities, and a part of the nonagricultural wages is earned from domestic service and earthwork—the jobs that are least preferred at higher levels of income. As argued in the chapter on employment, the stimulus from agricultural growth for these activities appears to be taken by households in underdeveloped villages and by lower-income groups.

Table 65 measures the income effect for different landownership groups by comparing the estimates for the developed and underdeveloped villages. It is found that among farming households the positive income difference for developed villages is higher for the large landowning groups—34 percent for the large landowner compared with 22 percent for the small and 28 percent for the medium owner, which suggests a trend

Table 65—Estimates of household income in developed and underdeveloped villages, 1982

Income/Landownership Group[a]	Underdeveloped Villages	Developed Villages	Difference in Developed Villages Over Underdeveloped Villages
	(Tk/household)		(percent)
Agricultural income			
Landless and marginal	3,708	8,000	116
	(3,549)	(6,151)	(73)
Small	9,201	11,234	22
Medium	16,190	20,685	28
Large	29,437	39,435	34
Nonagricultural income			
Landless and marginal	6,036	6,264	4
Small	6,819	7,071	4
Medium	8,119	7,618	–6
Large	9,372	16,721	78
Total income			
Landless and marginal	9,743	14,264	46
	(9,585)	(12,415)	(30)
Small	16,020	18,305	14
Medium	24,309	28,303	16
Large	38,809	56,156	45

Source: Based on data from Bangladesh Institute of Development Studies/International Food Policy Research Institute field survey.

Note: Figures within parentheses are household incomes for the group, excluding the income from fishing. One of the villages under study has a high concentration of commercial fishermen, most of whom belong to the landless and marginal landowner group. This village is included in the developed area, so the high income of the landless from fishing in the developed villages may show a spuriously high positive impact of the new technology on the income for this group.

[a] Landless and marginal, less than 0.5 acre; small, 0.5-2.5 acres; medium, 2.5-5.0 acres; large, 5.0 acres or more.

toward inequality in the distribution of income among farm households. But the group that has gained the most is the functionally landless, the bottom one-third of the rural households on the landownership scale. For this group, the income from agricultural sources is more than double in the developed villages over the underdeveloped villages. Further disaggregation of results for this group shows that a major source of the difference in income is due to fishing. Commercial fishing in Bangladesh is highly localized and in the sample it was concentrated in one village where land per person is extremely low, but where a large proportion of land is irrigated and cultivated with high-yielding varieties. The poor in this village earn a large proportion of their income from fishing, which cannot be attributed to the new technology. But even if fishing is excluded, agricultural income for the landless was 73 percent higher for the developed villages than for the underdeveloped villages—still higher than the income difference for the large landowning groups. The difference is mostly on account of income from cultivation (204 percent) and agricultural wages (79 percent). The transfer of irrigated land to marginal landowners through the tenancy market for cultivation of the rice MVs was an important mechanism for increasing the income of the poor from cultivation. In the underdeveloped villages a large proportion of marginal landowners rented out their tiny holdings and were dependent on the agricultural labor market and nonfarm activities for their livelihood. Only 32 percent of the sample households that own less than 0.5 acre of land received income from crop cultivation in underdeveloped villages, compared with 58 percent in developed villages. For the farm households in this group, the average income from crop cultivation was 65 percent higher in developed villages than in underdeveloped ones.

The figures in Table 65 show that the income gains from the nonagricultural sources have been confined mostly to the large landowning group. Compared with underdeveloped villages, the income from nonagricultural sources in developed villages is about 78 percent higher for the large landowner but 6 percent lower for the medium landowning group. Because of this unequal distribution of incremental income from nonagricultural sources, the difference in gains for the landless and large landowning groups narrows. For these groups the household income in the developed villages was about 45 percent higher—about three times the gains for the small and medium landowning groups.

The transfer of income to various landholding groups through the operation of the labor market can be assessed from wage earnings from agricultural and nonagricultural labor. The survey estimates of income from this source for the two groups of villages are reported in Table 66. The findings are similar to those reported in Chapter 7 about employment effects of the new technology. The agricultural wage income is inversely related to the size of landholding, and large landowners earn very little from this source. The agricultural wage income is about 16 percent higher in developed villages, but this is exclusively due to the functionally landless group, whose income from this source was about 79 percent higher in the developed villages. With increases in income the landowning group participates less in the agricultural labor market; their income from this source was substantially lower in the developed villages than in the underdeveloped ones. Only for the large landholding group was the wage income from nonagricultural labor higher in developed villages. The smaller landholding group had lower nonagricultural wage earnings in developed villages, indicating that with increases in agricultural income they withdraw some of the labor from the nonagricultural labor market. The income loss from this source was more pronounced for the small and medium landowners than for the landless.

Income Effect of Technology: A Regression Estimate

The previous section assessed the income effect of the modern technology by comparing the estimates of income for households in technologically developed and

Table 66—Incomes earned through the labor market, by technology and landholding groups, 1982

Landownership Group[a]	Agricultural Wage Income: Underdeveloped Villages	Agricultural Wage Income: Developed Villages	Agricultural Wage Income: Difference	Nonagricultural Wage and Salary Incomes: Underdeveloped Villages	Nonagricultural Wage and Salary Incomes: Developed Villages	Nonagricultural Wage and Salary Incomes: Difference
	(Tk/household)		(percent)	(Tk/household)		(percent)
Landless and marginal	1,326	2,370	79	2,546	2,163	−15
Small	1,147	753	−34	2,850	1,364	−52
Medium	366	184	−50	1,835	761	−58
Large	31	94	[b]	349	1,000	187
All groups	897	1,039	16	2,271	1,420	−37

Source: Based on data from Bangladesh Institute of Development Studies/International Food Policy Research Institute field survey.

[a] Landless and marginal, less than 0.5 acre; small, 0.5-2.5 acres; medium, 2.5-5.0 acres; large, 5.0 acres or more.

[b] Not estimated because of very small income from wage earning for this group.

underdeveloped areas. A limitation of this approach is that besides technology, a host of other factors determine income, and their effects cannot be dissociated when comparing mean values of the variables for the two groups. A more appropriate method of assessing the income effect of the new technology would be to fit a regression model, relating income to its determinants and incorporating technology as an additional explanatory variable.

The following regression model was fitted to explain household income:

$$INCM = f(OWNL, TNC, CPTL, WRKR, EDCN, DPND, TECH, OWNL^2), \qquad (20)$$

where

INCM = annual income of household (in taka),
OWNL = land owned by household (in acres),
TNC = land rented in by household (in acres),
CPTL = value of nonland fixed assets (in taka),
WRKR = number of family workers,
EDCN = educational level of head of household (completed years of schooling),
DPND = dependency ratio as measured by the number of consumers per worker in household,
TECH = technology at the household level as defined below.

The adoption of the technology at the household level, TECH, has been measured by three alternative specifications of the variable: the amount of land irrigated, LIRGN; the amount of land sown under rice MVs, LMV; and the expenditure on chemical fertilizers (in taka), FERT. Owing to the strong correlation among these three variables, each variable has been entered alternatively in the model to explain agricultural incomes.

The dependency ratio has been included to test the Chayanovian hypothesis that, in a peasant economy, the motive force behind the economic activity is the consumer-worker balance in the family.[111] This balance has already been found to be a significant variable affecting the labor supply of the household.

The square of owned land has been added to allow the marginal return from land to vary with the size of landownership. It has already been observed that crop yield varies inversely with farm size and that larger landowners prefer more leisure, which indicates that the marginal return from land will decline with the increase in the size of landownership.

The estimated values of the parameters of the income equation for total household income, as well as for agricultural and nonagricultural incomes, are reported in Table 67. The model explains about 55 percent of the variation in agricultural income and 52 percent of the variation in total income within the sample households. Land, both owned and rented, number of workers, and use of the new technology are found to be significant determinants of agricultural income. The value of nonland fixed assets

[111] Chayanov, *Theory of Peasant Economy.*

Table 67—Determinants of rural household incomes: regression estimates, 1982

Variable	Agricultural Income: Equation (1)	Agricultural Income: Equation (2)	Agricultural Income: Equation (3)	Nonagricultural Income	Total Income
			(Tk)		
OWNL	...	3,244[a]	3,387[a]	3,486[a]	2,003,459[a]
	(14.24)	(14.87)	(14.63)	(1.08)	(11.26)
$(OWNL)^2$	−63[a]	−43[a]	−41[a]	−2.5	−43[a]
	(7.54)	(5.28)	(−4.82)	(−0.36)	(−3.93)
TNC	1,067[a]	627[b]	708[c]	−183	351
	(3.27)	(1.90)	(2.08)	(−0.66)	(0.78)
CPTL[d]	0.021	−0.005	0.015	0.205[a]	0.101[a]
	(0.54)	(−0.13)	(0.35)	(6.04)	(2.66)
WRKR	1,313[a]	975[a]	1,075[a]	2,095[a]	3,125[a]
	(3.64)	(2.65)	(2.82)	(6.68)	(6.22)
EDCN	−123	−113	−129	249[a]	172[a]
	(−1.50)	(−1.37)	(−1.51)	(3.50)	(1.52)
DPND	636	799[b]	848[b]	827[c]	1,649[a]
	(1.41)	(1.75)	(1.79)	(2.13)	(2.65)
LIRGN	2,468[a]	...	...	...	...
	(7.87)				
LMV	...	1,729[a]	...	375[b]	1,973[a]
		(7.22)		(1.89)	(6.13)
FERT	...	...	...	2.17[a]	...
			(3.57)		
Constant	1,757	1,978	1,980	256	2,045
	(1.43)	(1.56)	(1.53)	(0.24)	(1.20)
$\bar{R}^2$	0.55	0.55	0.53	0.19	0.52

Note: Figures in parentheses are t-values.
[a] This number is significant at the 0.01 level.
[b] This number is significant at the 0.10 level.
[c] This number is significant at the 0.05 level.
[d] Capital is measured as agricultural capital for the agricultural income equation, nonagricultural capital for nonagricultural income, and total capital for total income equation. The sample size consists of 629 households with valid observations for all variables in the equation.

does not significantly contribute to agricultural income. The coefficient of this variable is not statistically significant in either of the agricultural-income equations. The values of the regression coefficient for agricultural income (Table 67, equation 1) indicate that an acre of owned land contributes at the margin Tk 3,200, while one family worker at the margin earns about Tk 1,300 a year. The marginal contribution of rented land is less than one-third that of owned land. This is understandable in view of the stringent conditions of the sharecropping arrangement—the tenant bears all costs of nonland inputs and pays half of the gross produce to the landowner.

The coefficient of all three technology variables in alternative equations for agricultural income is statistically significant at less than 1 percent probability of error. As discussed in Chapters 3 and 6, irrigation, MV seeds, and fertilizers are highly complementary, so the separate effect of each variable is difficult to measure. The value of the regression coefficient of each of the three technology variables thus measures the composite effect of all of them.

The marginal return from an acre of irrigated land is estimated at Tk 5,712 (3,244 + 2,468).[112] Thus, irrigated land and the associated increase in MV area and fertilizer use increase agricultural income at the margin by about 76 percent over that of nonirrigated land. The value of the coefficients of land variables (table equation 2) for agricultural income indicates that an acre of land under MVs increases agricultural income on the margin by about Tk 5,116—about 51 percent higher than the income earned at the margin from land devoted to traditional crop varieties (Tk 3,387). One taka of expenditure on fertilizer seems to increase agricultural income on the margin by Tk 2.17.[113]

The main determinants of nonagricultural income are the number of workers in the family, accumulation of nonagricultural assets, education, and the consumption pressure of the family. The regression coefficients of these variables are statistically significant at less than 5 percent probability of error. However, the explanatory power of the model is weak, as indicated by the low value of $\bar{R}^2$. This suggests that there may be other variables that determine nonagricultural income, or that the estimate of nonagricultural income at the household level involves a large margin of error, or both. Education increases household income mainly through involvement of the worker in the nonagricultural sector. The estimated value of the coefficient suggests that an additional year of schooling increases nonagricultural income on the margin by Tk 250 a year, but the increase is achieved partly at the expense of agricultural income, so its effect on total household income is less. The rate of return on accumulation of nonagricultural capital appears to be 21 percent. The households that cultivate more land with MVs have higher levels of nonagricultural income. This may be the effect of reallocation of family labor from agricultural to nonagricultural activities, which was explained in Chapter 7. The value of this coefficient is statistically significant at less than 10 percent probability of error.

In the estimated equation for total household income, the coefficient of the technology variable is found to be highly statistically significant. The values of the coefficient of the land variable (OWNL and LMV) show that a shift of land from traditional to modern varieties would increase the marginal return from land by about 57 percent. The coefficient of the square term of land is negative and highly statistically significant. It indicates that the marginal income from land declines with increases in the size of landownership. This may be the result of the negative income effect on the supply of labor, as reported in Chapter 7, which operates particularly in the agricultural sector. This finding also supports the hypothesis that when income increases, the forces in the labor market may operate to redistribute some income from upper- to lower-income groups.

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[112] The equation is fitted in the following form:

$$Y = a_0 + a_1 (x_1 + x_2) + a_2 x_2,$$

where x_1 is the amount of unirrigated land and x_2 is the amount of irrigated land. It can be rewritten in the following form:

$$Y = a_0 + a_1 x_1 + (a_1 + a_2) x_2.$$

Thus a_1 is the coefficient of unirrigated land and $(a_1 + a_2)$ is the coefficient of irrigated land.

[113] The estimate is close to the incremental-benefit cost ratio of fertilizer estimated by the IFDC from the crop-specific fertilizer response functions fitted on the farm survey data for 1979-82. The weighted average value for six rice varieties evaluated at 1984 prices of fertilizer and paddy is 2.5. See Hossain, "Fertilizer Consumption," p. 195.

Distribution of Income

The sample households have been ranked on the basis of per capita income, and the income shares of successive decile groups have been estimated in order to see the pattern of income distribution in the sample. The impact of technological progress on income distribution has been assessed by comparing the income shares of various groups in the technologically developed and underdeveloped villages. The results can be reviewed in Table 68 and also in Figure 5, which shows a Lorenz curve depicting the pattern of income distribution across the landownership scale.

The income distribution is fairly unequal. The bottom 40 percent of the households in the per capita income scale get about 21 percent of the total income, while about 24 percent of the income accrues to the top 10 percent of the households. The pattern of distribution of income in developed villages was found almost the same as that estimated for rural Bangladesh by the national household expenditure survey of 1981-82. The income, however, appears to be more unequally distributed in the technologically developed villages. The income share of the top 10 percent of the household is about 26 percent in the developed villages, compared with 21 percent in the underdeveloped villages. But the position of the bottom 40 percent of the households does not change. Their share of income is 21.2 percent in the developed villages compared with 21.1 percent in the underdeveloped villages. So the middle 40 percent in the income scale (third and fourth quintiles) are squeezed, and their income share declines from 42 to 39 percent.

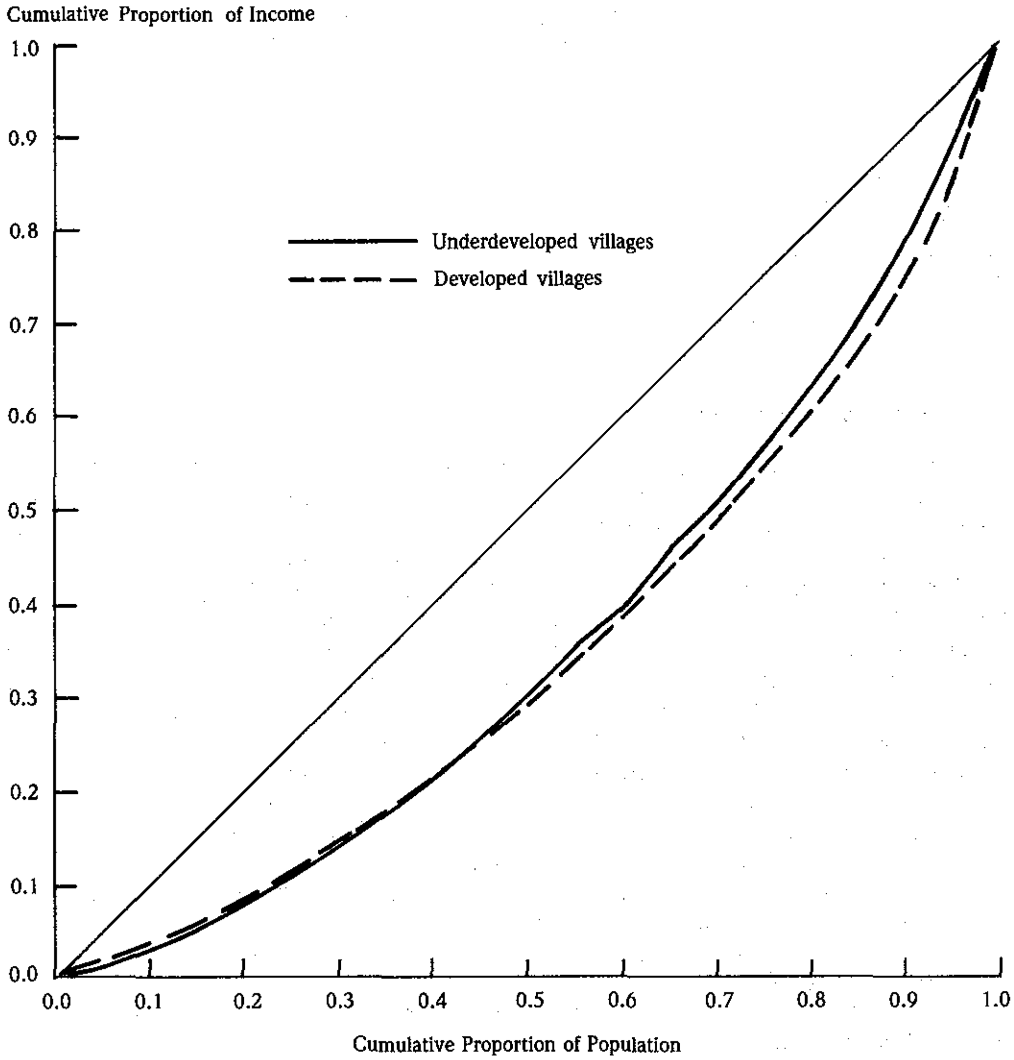
The degree of inequality in income distribution is often summarized by the Gini concentration coefficient. The estimated values of the coefficients, based on individual household data, are presented in Table 69. The concentration ratio is estimated at 0.39 for household income, but since higher-income households typically have a larger number of persons, the degree of concentration in per capita income is less, at 0.35. Agricultural income is highly unequally distributed; the concentration ratio is estimated at 0.62. This is, however, related mostly to unequal distribution of landownership, since land is the most important asset determining agricultural income. The degree of inequality in the distribution of nonagricultural income is 0.44. Households that have

Table 68—Distribution of household income in technologically developed and underdeveloped villages, 1982

Household Ranking by per Capita Income	Income Share of Sample Households, 1982: Underdeveloped Villages	Developed Villages	Rural Bangladesh 1981/82[a]
		(percent)	
Bottom 20 percent	7.7	8.0	7.1
Second 20 percent	13.4	13.2	11.7
Third 20 percent	18.4	17.0	16.2
Fourth 20 percent	24.0	21.9	22.6
Top 20 percent	36.5	39.9	42.4
Top 10 percent	21.4	25.8	26.7
Top 5 percent	10.7	15.6	16.8

Source: The figures for rural Bangladesh are from Bangladesh, Bureau of Statistics, *Report of the Bangladesh Household Expenditure Survey, 1981-82* (Dhaka: Ministry of Planning, 1986).
[a] The households have been ranked by total household income.

Figure 5—Lorenz curve showing the pattern of distribution of income in developed and underdeveloped villages along per capita income scale, 1982



less access to land, and hence to agricultural income, tend to compensate by involving themselves more in nonagricultural activities; thus the concentration of household income is lower than that of either agricultural or nonagricultural income.

Technological progress seems to improve the distribution of agricultural income. The concentration ratio is estimated at 0.60 in developed villages, compared with 0.63 in underdeveloped villages, while the concentration in the distribution of landownership is similar. But the distribution of nonagricultural income becomes more skewed, leaving the distribution of total household income unchanged. With increases in income, the family size of the lower-income group increases proportionately more than that of higher-income groups, presumably due to declines in mortality rates, thus making the distribution of per capita income relatively more skewed in the developed villages.

Table 69—Degree of inequality in distribution of income and landholding: Gini ratios for sample households, 1982

Variable	Underdeveloped Villages	Developed Villages	Entire Sample
Land owned	0.61	0.60	0.61
Agricultural income	0.63	0.60	0.62
Nonagricultural income	0.43	0.45	0.44
Household income	0.39	0.38	0.39
Per capita income	0.34	0.36	0.35
Per capita income with adjusted household size[a]	0.33	0.34	0.34

Source: Based on data from Bangladesh Institute of Development Studies/International Food Policy Research Institute field survey.
[a] Adjusted to adult equivalent consumption unit from age-sex composition of household members.

Alleviation of Poverty

From the welfare point of view, the most appropriate indicator of the effectiveness of a development policy is its effect on the poor. So in recent years there has been a great deal of interest in measuring changes in the incidence of poverty and judging programs and policies on the basis of their effect on the alleviation of poverty.

A conventional way to measure poverty is to establish a poverty line, defined as the threshold level of income needed to satisfy basic minimum food and nonfood requirements, and count the number of people living below that line—the "head-count method" of measuring poverty. For Bangladesh a number of studies have used this method to measure the changes in poverty over time. The usual approach has been to take the normative requirement of different kinds of food (as recommended by the FAO) as the minimum consumption bundle, which gives a per capita intake of 2,100 kilocalories per day, and estimate its cost by applying retail prices for these items. Some adjustment is then made for the requirement of nonfood necessities. Separate poverty lines are estimated for rural and urban areas by taking into account urban-rural differences in price levels. Using this method, the poverty line for rural households was estimated by the author[114] at Tk 1,800 per person for 1978/79. After adjustment for changes in the cost-of-living index for rural areas, the poverty line for 1982 was estimated at Tk 2,392.

Recently the Bangladesh Bureau of Statistics has made alternative estimates of the poverty line for different levels of calorie consumption in the population on the basis of household-level data on income and calorie intake of the population obtained from the 1981/82 national household expenditure survey.[115] To avoid the problems of (1) identification of the minimum needs for different types of food in the consumption basket, and (2) choice of representative items for different consumers, the poverty line was estimated by fitting an equation of per capita income to per capita calorie intake and then determining the income for the threshold calorie intake. For rural households the method yielded a poverty line of Tk 2,304 for a daily intake of 2,200 kilocalories

[114] Mahabub Hossain, Atiur Rahman, and M. M. Akash, *Agricultural Taxation in Bangladesh: Potential and Policies,* Research Report 42 (Dhaka: Bangladesh Institute of Development Studies, 1985).
[115] Bangladesh, Bureau of Statistics, *Bangladesh Household Expenditure Survey,* pp. 40-45.

per person, and Tk 1,680 for an intake of 1,800 kilocalories per person for 1981/82. The first may be referred to as the threshold income for moderate poverty and the second for extreme poverty. After adjustment for changes in the rural cost of living, the lines are estimated for 1982 at Tk 2,374 and Tk 1,731 per person per year for moderate and extreme poverty, respectively.

It may be noted that the two methods described above yield almost the same poverty threshold income for an intake of around 2,200 kilocalories per person per day. Since the Bureau of Statistics estimate is based on a recent survey of a large number of households and is available for two alternative intakes of energy, the Bureau of Statistics norm has been applied to the income distribution data for this sample to estimate the proportion of population living below the poverty line.

The estimates are reported in Table 70. For the sample as a whole, 39 percent of the population were below the line of moderate poverty and 21 percent below the line of extreme poverty. The estimates are somewhat lower than those for rural Bangladesh derived from the 1983/84 household expenditure survey data, which show that 44 percent of the population had income below the moderate poverty line and 29 percent below the extreme poverty line. The national-level estimates are, however, comparable with the findings here for the underdeveloped villages.

Technological progress seems to have a significant impact on alleviation of rural poverty. The proportion of population below the moderate poverty line was 32 percent in the developed villages, compared with 47 percent in the underdeveloped villages, that is, about one-third of the poor has moved up the poverty line. The progress has been achieved mainly at the bottom of the income scale. The population under extreme poverty was only 15 percent in the developed villages, compared with 27 percent in the underdeveloped villages. For the landless group the proportion under moderate poverty was 63 percent for the entire sample; 51 percent in the developed villages, compared with 78 percent in the underdeveloped villages (Table 71). The proportion under extreme poverty for this group is down from 54 percent in the underdeveloped villages to 28 percent in the developed ones.

The head-count measure of poverty has the limitation of being insensitive to changes in the level and distribution of income among the poor. For a more significant assessment of the changes in poverty, two other indicators are suggested to supplement the head-count measure. These are the poverty-gap ratio, which measures the shortfall of the mean income of the poor from the poverty line, and the Gini concentration ratio of

Table 70—Estimates of incidence of poverty in technologically developed and underdeveloped villages, 1982

Indicator	Moderate Poverty			Extreme Poverty		
	Underdeveloped Villages	Developed Villages	All Villages	Underdeveloped Villages	Developed Villages	All Villages
Proportion of population in poverty	0.467	0.317	0.390	0.273	0.151	0.211
Poverty-gap ratio	0.329	0.264	0.303	0.262	0.216	0.246
Concentration of income among the poor (Gini ratio)	0.17	0.14	0.16	0.14	0.13	0.14
Sen's index of poverty	0.207	0.116	0.162	0.100	0.048	0.740

Source: Based on data from Bangladesh Institute of Development Studies/International Food Policy Research Institute field survey.

Table 71—Incidence of poverty, by landownership group and technology, 1982

Land Owned	Moderate Poverty			Extreme Poverty		
	Under-developed Villages	Developed Villages	All Areas	Under-developed Villages	Developed Villages	All Areas
(acres)	(proportion of total population in the group)					
0.50 or less	0.783	0.510	0.634	0.537	0.279	0.396
0.51–2.00	0.509	0.363	0.438	0.534	0.189	0.255
2.01 or more	0.285	0.174	0.228	0.089	0.080	0.081

Source: Based on data from Bangladesh Institute of Development Studies/International Food Policy Research Institute field survey.

income for the poor. Sen has suggested a weighted index of poverty incorporating all three indicators. The Sen index is given by

$$P = H[I + (1 - I)G],$$

where P is the Sen index, H is the head-count ratio, I is the income-gap ratio, and G is the Gini coefficient of the income distribution of the poor.[116]

The estimates of the supplementary indicators of poverty and of the Sen index are reported in Table 70. The results are similar to that assessed by the head-count measure. The Sen index of poverty for developed villages is almost half of that in the underdeveloped villages, whether one takes the moderate or the extreme poverty line.

Conclusions

The potential for increasing rural incomes through diffusion of the modern technology is substantial. In technologically developed villages, where nearly three-fifths of the cropped land was under rice MVs, income was about 40 percent higher than in the villages where less than 10 percent of the area had been covered. Among farmers the income difference was found to be higher for large landowners, indicating a trend toward inequality, but for the landless the income difference was as high as for the large landowners. The top 20 percent in the per capita income scale have gained in relative terms, the bottom 40 percent have remained unaffected, while the middle 40 percent have been squeezed—although the absolute gain has been positive for all income groups. The Gini coefficient of concentration for household income was found to be the same (0.39) for both groups of villages, but the coefficient for per capita income was only marginally higher for developed villages.

Technological progress seems to have made a significant impact on alleviation of rural poverty. The proportion of people living below the poverty line, the poverty-gap ratio, and the concentration ratio of income of the poor are all lower in the technologically developed villages than in the underdeveloped villages. For the landless, the proportion of population living below the line of moderate poverty was estimated at 51 percent for the developed villages, compared with 78 percent for the underdeveloped villages. The Sen index of poverty was 0.116 for the developed villages—a substantial reduction when compared with the 0.207 estimated for the underdeveloped villages.

[116] A. K. Sen, "Poverty: An Ordinal Approach to Measurement," *Econometrica* 44 (March 1976): 219-231.

10

POLICY IMPLICATIONS

Technological progress is the key to overcoming the land constraint to growth of foodgrain production in Bangladesh. Indeed, the country has maintained the food-population balance in the postindependence period mainly through technological progress. Between 1970 and 1985 the area cropped with MVs increased by more than five times, from 1.2 to 6.9 million acres, and the consumption of chemical fertilizers increased from 0.15 million tons of nutrients to 0.59 million tons. Although the land under cultivation has remained stagnant at about 22.2 million acres, technological progress has made possible an acceleration of the rate of growth of crop production from 2.5 percent a year during 1950-71 to 2.9 percent during 1971-85, and of growth of cereal production from 2.6 to 3.4 percent during the same period. Technological progress has cut the unit cost of production of rice by about one-fifth and has increased gross profits per unit of land by 1.2 times. The analysis of detailed household data for 16 villages at different levels of technological development shows that all this may have been achieved with a somewhat neutral income distribution effect and a significant reduction in the incidence of rural poverty.

There is a vast potential for further diffusion of the new technology that will have to be exploited to feed the fast-growing population of the country. The following major policy directions are suggested by the study for realization of the potential.

Strengthening Agricultural Research and Extension

Credit for the diffusion of modern technology to present levels is mainly due to the Bangladesh Rice Research Institute (BRRI), which has done a commendable job of developing MVs that are suitable for local agroclimatic conditions and acceptable to consumer tastes. Support for the research effort is essential in order to continue the search for higher-yielding varieties that will increase production from the fixed amount of land and keep down the cost of production.

The new varieties have been adopted mainly for the dry season under irrigated conditions. In Bangladesh, however, rice is grown mainly under rain-fed conditions and the MVs have not found much acceptance for this production environment. More attention should be given to cropping system research on the possibility of adjustments in the existing cropping pattern that would encourage use of MVs in the monsoon season, and to development of higher-yielding varieties suitable for rain-fed conditions.

Diffusion of the modern technology is also constrained by other agroclimatic factors; for example, continuous deep flooding of a large proportion of land during the rainy season and high levels of soil salinity in the large coastal area. More attention should be given to investigating whether cost-effective, higher-yielding varieties could be developed for these unfavorable production environments.

The development of modern technology for rice and wheat has reduced the competitiveness of some noncereal crops, such as pulses and oilseeds, that are important as a source of protein for the poor. This study finds that in technologically developed villages only 10 percent of the cropped land is allocated to pulses, oilseeds, jute, and sugarcane, compared with about 26 percent in underdeveloped villages. Nationally, the sown area under noncereal crops declined from 22 percent during 1965-70 to 17 percent during

1980-85. Additional support is needed for research to develop suitable varieties for noncereal crops in order to make them competitive with rice and wheat MVs.

Farmers have experienced a faster increase in prices of modern agricultural inputs relative to output because initially these inputs were introduced at highly subsidized prices and the subsidies have been gradually phased out. There is still considerable subsidization of irrigation, and the reduction of subsidies may continue for some time. This phasing out has increased the unit cost of production and reduced the profits. These changes in relative input-output prices have affected the MVs most severely because they are heavy consumers of fertilizer and irrigation. The changes have also reduced the profitability gap between the traditional and modern varieties. It is estimated that between 1975/76 and 1984/85 the rate of profit over investment in working capital (cost of production) declined from 77 to 55 percent for the new varieties and from 49 to 43 percent for the traditional varieties (Chapter 4).

The adverse effect of the price trends on profits can be mitigated to some extent by increasing the efficiency of input use through more effective extension services. Bangladesh has long experience with agricultural extension and recently has reorganized it on the lines of a "Training and Visit" system, greatly increasing the number of extension agents at lower administrative tiers. The effectiveness of agricultural extension, however, remains a controversial issue. The gap in the yield of MVs and the response to chemical fertilizers achieved on government experimental farms is large compared with the results realized by farmers. Results of Bangladesh Rice Research Institute experiments reported by Zaman show that with 32 kilograms of nitrogen per acre, the yield for MVs increased to 2.45 tons for the boro season and 1.80 tons for the aman season.[117] With similar levels of fertilizer application during 1980-82, farmers actually produced 1.51 and 1.11 tons, respectively, during the boro and aman seasons. The response to fertilizer at farmers' fields is estimated at 4.3 units of paddy per unit of nutrient, compared with a 10:1 ratio under experimental conditions.[118] The gap cannot be completely eliminated, since most experiments do not represent farmers' conditions, but more effective extension services can reduce the gap and increase the profitability of cultivation.

Public Investment for Irrigation

The main vehicle for diffusion of the new technology has been development of irrigation facilities. It is the single most important determinant of adoption of the new technology. About 96 percent of the plots growing the new crops are irrigated, and the villages where the new technology has not yet developed are those that do not have access to irrigation facilities. In Bangladesh, however, irrigation facilities have been developed mainly by the government and mostly with foreign aid. Only about a fifth of the land has so far been brought under modern irrigation, although it is estimated that about three-fifths of the land could be irrigated with available ground- and surface-water resources.[119] The small size of farms, fragmented and scattered plots, and the indivisible nature of investment for irrigation development suggest that the private

[117] S. M. H. Zaman, "Agronomic and Environmental Constraints on Fertilizer Effectiveness," in *Fertilizer Pricing Policy in Bangladesh,* ed. Bruce Stone (Washington, D.C.: International Food Policy Research Institute/Bangladesh Institute of Development Studies, 1987), p. 248.

[118] Hossain, "Fertilizer Consumption," pp. 183, 195.

[119] Bangladesh, Master Plan Organization, *National Water Plan, Summary Report* (Dhaka: Ministry of Irrigation and Flood Control, 1986), pp. 62-64.

sector cannot be relied upon for investment in this field. The government has to take the leading role, as it has done in the past. During 1975-85 the government spent over 40 percent of the total development budget for the agricultural sector on water resource development, and the area irrigated by modern methods increased from 7 percent of cultivated land in 1974/75 to 21 percent in 1984/85. To maintain a moderate growth in cereal production and agricultural incomes, the government will have to maintain or even accelerate the allocation of public resources for investment in irrigation.

The capacity of the government to accelerate investment in irrigation and to support agricultural research and extension will depend on the availability of finance. So far, the government has been largely dependent on external resources (foreign aid and loans) for financing such investment. The present low level of foodgrain prices in international markets and the political pressure from food-exporting developed countries suggest that it will be increasingly difficult to mobilize foreign aid for projects that increase foodgrain production. Uncertainty about the future availability of foreign aid and the increased cost of debt servicing suggest that it is advisable for the government to seek out internal resources.

In the past, the government has had limited success in mobilizing resources from the agricultural sector.[120] Direct agricultural taxes, collected mostly through land revenue, have lost considerable ground as a major source of government revenue since the early 1960s—the real value of tax receipts during 1979-82 was only about 30 percent of the level reached during 1958-61. In recent years, direct tax has tapped about 2.25 percent of nonagricultural incomes, whereas agriculture's terms of trade during 1975-85 did not show any consistent downward trend, and the recent level of domestic rice and wheat prices is considerably higher than the prices prevailing in international markets, indicating that producers are protected at the expense of consumers.

The government should take steps to mobilize additional resources from the agricultural sector. A move in that direction could be made by recovering the cost of public investment from the beneficiaries. Subsidies for fertilizer have been withdrawn, but the subsidy for irrigation is still large. Shallow tubewells are sold to farmers almost at a cost price, but in 1982/83 there was about a 73 percent subsidy on deep tubewells and 29 percent on low-lift pumps.[121] For large-scale irrigation projects implemented by the Water Development Board, both the capital and the current costs are borne almost entirely by the government. The benefits of the subsidy are reaped mostly by the owners of the irrigation equipment, who are large and medium landowners. The small farmers who buy water from the owners of the machines are charged almost the market clearing rates. Indeed, this study finds that the difference in the price of water is a major source of inequality in the distribution of income from the new technology (Chapter 6). The irrigation charge is one-fourth higher for the small farmers than for the large ones. Thus it may be advisable to withdraw the subsidy on sale of irrigation equipment, and also to reduce the budget share of large-scale irrigation projects for water resource development, since the cost recovery of large-scale projects has proved to be extremely difficult. The initial reaction of farmers to withdrawal of the subsidy may be adverse, which may temporarily slow the technological diffusion, but the adverse reaction should not last long. The difference in profits between cultivation of modern (irrigated) and traditional (unirrigated) varieties is about Tk 1,250 per acre at 1984/85

[120] Hossain, Rahman, and Akash, *Agricultural Taxation in Bangladesh,* pp. 10-27.
[121] Osmani and Quasem, "Pricing and Subsidy Policies," p. 205.

prices, and the withdrawal of irrigation subsidies would not eliminate this gap (Chapter 4). On the other hand, it would reduce the income disparities due to differential irrigation charges between farmers growing traditional and modern varieties, between technologically developed and underdeveloped regions, and between farmers with access to different irrigation projects and equipment.

Provision of Credit

The amount of loans obtained from both institutional and noninstitutional sources is found to be a significant determinant of adoption of the new technology (Chapter 6). This is understandable, since the working capital needs on account of purchased inputs—fertilizer, irrigation, and even hired labor—are much higher for the MVs than for the local varieties, for which most of the inputs are supplied from within the household. The cash cost of production at 1984/85 prices is estimated at Tk 2,120 per acre for MVs compared with Tk 800 for traditional varieties—an increase of about 165 percent. It is difficult for the small farmer to manage such a large investment from accumulated savings.

The government of Bangladesh recognizes the credit needs of the farmers. From 1975 to 1984, institutions that provide agricultural credit proliferated, and the number of bank branches operating in rural areas increased from 854 in 1975/76 to more than 3,200 in 1983/84. The supply of institutional credit at real value increased about eight times over this period. Credit disbursed during 1983/84 amounted to 7 percent of the value added in the agricultural sector—about 40 percent of the cost of material inputs and 2.3 times the cost of chemical fertilizers consumed in the country.[122] But owing to the weakness of the credit institutions, credit has remained concentrated in the hands of the medium and large farmers, and complicated loan-sanctioning procedures have led to untimely disbursement, which together with the spread of corruption among bank officials has promoted laxity in credit disciplines and poor recovery. The small farmers who need credit badly have suffered. They have to rely on noninstitutional markets where the cost of a loan is substantially higher, and to that extent they benefit less from utilization of the loan, compared with the medium and large farmers who have access to low-interest loans from institutional sources. Obviously, there is a need for overhauling the institutions and management of agricultural credit so that credit can be better targeted to smaller farmers. The government may consider elimination of subsidies on agricultural credit and a policy of variable cost of loan funds to banks, depending on the proportion of loans given to small and marginal farmers.

The findings of this study also point to the need for providing working capital loans to the poor so that they can generate more employment in the rural nonfarm sector. The increase in agricultural income from technological progress has a significant impact on the expansion of the market for nonfarm goods and services, which generates more employment opportunities in the nonfarm sector. But some working capital is needed for self-employment in these activities. The duration of self-employment in general, and in nonagriculture in particular, is found to be significantly related to the amount of nonland capital owned by the household (Chapter 7). Owing to the lack of capital, the poor cannot take full advantage of employment opportunities generated in nonfarm activities. The findings show that the additional employment in nonagriculture is taken up by the large landowning groups rather than by the landless (Chapter 7), and that

[122] Hossain, "Institutional Credit for Rural Development," pp. 3-5.

the incremental income from nonagriculture is distributed in favor of the higher income groups (Chapter 9).

Experiments conducted by the Grameen Bank show that if credit is provided to the poor, they can generate productive self-employment in the nonfarm sector and significantly improve their standard of living.[123] The Grameen Bank provides loans to the landless without any collateral and recovers about 98 percent of the loans on time. The borrowers utilize the loans in family-based enterprises for livestock raising, cottage industries, and trade and shopkeeping, generating employment mostly for women. Since technological progress stimulates demand for these activities, the expansion of working capital loans for the poor in technologically developed areas should be considered to help generate more employment for the poor and improve income distribution.

[123] Hossain, "Credit for Alleviation of Rural Poverty."

APPENDIX:

SUPPLEMENTARY TABLES

Table 72—Estimates of growth equations for crop production, 1950-85

Crops/ Dependent Variable	Regression Coefficients: Constant Term	Time (T-1949)	Dummy (1 for 1971-85)	Time × Dummy	$\bar{R}^2$	'F' Statistic
Cereals						
Area	8.973	0.0110 (8.52)	−0.0525 (−0.75)	0.0006 (0.22)	0.88	85.4
Yield	8.340	0.0152 (8.10)	−0.2519 (−2.46)	0.0068 (1.73)	0.87	80.0
Production	10.405	0.0262 (10.09)	−0.304 (−2.16)	0.0074 (1.36)	0.91	122.0
Noncereals						
Area	7.289	0.0127 (3.78)	0.335 (1.83)	−0.0200 (−2.84)	0.27	5.3
Yield	8.639	0.0089 (4.78)	−0.1470 (−1.46)	0.0038 (0.97)	0.69	26.4
Production	9.021	0.0215 (6.45)	0.1878 (1.03)	−0.0162 (−2.31)	0.59	17.6
All crops						
Area	9.145	0.0112 (8.59)	−0.0008 (−0.01)	−0.0022 (−0.82)	0.85	66.0
Yield	8.486	0.0140 (9.38)	−0.233 (−2.86)	−0.0062 (1.96)	0.90	104.5
Production	10.631	0.0252 (11.60)	−0.234 (−1.98)	0.0039 (0.86)	0.92	140.7

Source: Estimated from official statistics from Bureau of Statistics, Bangladesh.
Notes: Dependent variables are measured in logarithms. Figures in parentheses are estimated t-values.

Table 73—Marginal budget shares and expenditure elasticity of demand for different commodities, 1982

Commodity Group	Underdeveloped Villages			Developed Villages		
	Average Share	Marginal Share	Expenditure Elasticity	Average Share	Marginal Share	Expenditure Elasticity
	(percent)			(percent)		
Crops	66.97	56.47	0.84	62.91	44.95	0.71
Rice	44.55	42.33	0.95	43.78	32.81	0.75
Wheat	8.42	−0.27	−0.03	5.33	−1.57	−0.29
Pulses	1.07	1.32	1.24	0.75	1.16	1.56
Roots	1.75	1.33	0.76	1.55	1.19	0.77
Vegetables	3.68	3.39	0.92	3.27	1.95	0.60
Spices	3.44	2.88	0.84	3.66	3.33	0.91
Betel nuts and betel leaves	0.91	1.42	1.55	1.34	1.34	1.00
Rice husks	0.53	0.35	0.65	0.21	0.24	1.16
Jute sticks	0.51	0.30	0.59	1.11	1.47	1.33
Fruits	2.12	3.42	1.62	1.92	3.02	1.57
Forestry	4.12	3.21	0.78	3.08	2.72	0.88
Firewood	2.02	2.59	1.29	1.53	2.06	1.35
Leaves	2.10	0.62	0.30	1.55	0.66	0.43
Livestock	4.43	5.70	1.29	4.00	6.35	1.59
Meat	1.12	2.47	2.20	1.74	3.80	2.18
Milk	0.94	1.82	1.93	1.25	2.41	1.92
Eggs	0.44	0.77	1.75	0.32	0.55	1.70
Cow dung	1.93	0.64	0.33	0.69	−0.41	−0.58
Fishery	3.55	4.22	1.19	4.35	5.32	1.22
Rural manufacturing	9.54	12.40	1.30	9.48	10.29	1.09
Gur (raw sugar)	1.59	2.20	1.39	1.50	2.11	1.41
Bidi (cigarettes)	1.48	0.72	0.48	1.37	0.79	0.57
Tobacco	0.17	0.25	1.42	0.17	−0.08	−0.44
Mustard oil	2.13	2.31	1.09	2.31	2.39	1.04
Sweets	0.06	0.15	2.44	0.06	0.14	2.48
Handloom clothing	3.77	5.98	1.58	3.70	4.22	1.14
Tailoring	0.35	0.79	2.29	0.38	0.73	1.94
Urban manufacturing	7.20	10.50	1.46	7.97	12.44	1.56
Mill-made clothing	0.52	1.38	2.63	0.97	1.89	1.94
Imported clothing	0.81	2.57	3.19	0.48	1.28	2.69
Old garments	0.29	0.20	0.66	0.28	0.15	0.53
Ready-made garments	0.42	0.79	1.86	0.51	0.87	1.73
Shoes	0.24	0.46	1.96	0.33	0.63	1.95
Sugar	0.28	0.30	1.08	0.35	0.88	2.50
Tea	0.06	0.06	1.00	0.35	0.70	2.01
Cigarettes	0.13	0.34	2.60	0.35	0.90	2.58
Soybean oil	0.34	0.19	0.57	0.13	0.25	1.90
Coconut oil	0.40	0.36	0.90	0.36	0.35	0.98
Kerosene oil	1.86	1.75	0.94	1.90	1.67	0.88
Electricity	...	...	...	0.07	0.22	2.98
Matches	0.40	0.12	0.30	0.40	0.21	0.51
Soap	0.94	1.35	1.44	1.01	1.61	1.59
Washing soda	0.25	0.15	0.62	0.10	0.05	0.47
Toiletry and cosmetics	0.07	0.18	2.50	0.17	0.33	2.00
Other	0.19	0.30	1.58	0.21	0.45	2.14
Services	4.20	7.50	1.79	8.21	17.93	2.18
Education	0.63	1.72	2.74	1.00	2.58	2.57
Health	1.36	1.90	1.39	2.49	4.58	1.84
Transport	0.73	0.95	1.30	0.98	1.93	1.96
Personal services	0.35	0.39	1.11	0.50	0.53	1.06
Religious services	0.60	1.25	2.10	2.38	5.48	2.30
Other services	0.53	1.30	2.44	0.86	2.83	3.28

Source: Estimated by fitting Engel functions to data from Bangladesh Institute of Development Studies/International Food Policy Research Institute field survey.

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