Market Analysis, Technical Change and Income Distribution in Semi-Subsistence Agriculture: the Case of Bangladesh

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Abstract

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For the first time, the model developed by Hayami and Herdt is applied to determine gains from modern varieties of rice in Bangladesh and the distribution of these gains between consumers and producers. The results suggest that consumers' surplus is much greater than it would have been had the high yielding crop varieties (HYVs) not been introduced. By keeping the real price lower than it would have been otherwise, the modern varieties have tended to be income equalizing for urban consumers. The Hayami–Herdt partial model even suggests that, given the relatively inelastic demand for rice in Bangladesh, the real cash income of producers has risen slightly as a result of these new technologies. In reality, however, the impact of these changes on incomes of farmers and the distribution of income between those involved in production is more complex. It is suggested that if a less partial view is taken and if account is taken of lower cost of obtaining home-consumed produce, the increase in income may be greater. In any event, there are dangers in using such a partial model to predict the developmental consequences of technological changes affecting a staple crop, and attention needs also to be given to the possibility that the supply curve may not have the simple form and pivot in the way supposed by Hayami and Herdt. While the Hayami–Herdt model is simple to apply, it is best used as a first approximation or starting point rather than a final solution. It ignores a number of criteria that could be important in assessing new agricultural technologies, such as their impact on the variability of benefits to producers and consumers and their consequences for sustainability of production. Furthermore, the Hay-

ami–Herdt model does not deal specifically with changes in factor shares in farm production. Nor does it consider the impact on income distribution of the ownership and control of critical input like irrigation and imperfection in the rural credit market. It is pointed out in our paper that the adoption of HYVs has been associated with important variations in factor shares in Bangladeshi rice production. Analysis of available farm level data indicates that the relative share of labour has fallen, suggesting an uneven distribution of gains from technological changes between the owners of non-labour resources and those of labour resources. However, the absolute share of labour has increased, and it seems that rural employment has risen as result of the new technologies.

Introduction

During the last two decades many less developed countries (LDCs) have been transforming their traditional agriculture through the "green revolution". New seed–fertilizer–irrigation technology, involving high yielding crop varieties (HYVs), has been rapidly adopted in many parts of the world; this has brought significant increases in the output of cereals and has changed cropping patterns (Dalrymple, 1977; Herdt and Capule, 1983; Hayami and Ruttan, 1985).

The introduction of new technology in Bangladesh appears to have been slower than in other countries of the Indian subcontinent. Nevertheless, substantial transformation of agricultural production is well under way. New technology (designed to intensify cultivation) was introduced in several phases: it commenced with the distribution of chemical fertilizers and the introduction of modern irrigation in the early 1960s. High-yielding varieties of rice and wheat suitable for cultivation during the dry (rabi) season were introduced in the late 1960s. Subsequent years saw the introduction of HYVs of rice suitable for the wet (kharif) season. In the late 1960s IR-8, IR-5 and IR-20 varieties of rice were introduced through direct import of seed. In the late 1960s and early 1970s there was a material transfer of wheat technology from such organizations as CIMMYT, through the import of seeds of new varieties. Design transfer also occurred, as the Bangladeshi national agricultural research system adapted and indigenously developed different varieties of rice and wheat (Hayami and Ruttan, 1985; Alauddin and Tisdell, 1986a). By 1980–82 (average for the years 1980–81, 1981–82 and 1982–83), over 26% of the total foodgrain area had been brought under HYV cultivation, compared to less than 2% during 1967–69 (average for the years 1967–68, 1968–69 and 1969–70). During this period the quantity of chemical fertilizers applied rose from just over 9 kg of nutrient per hectare of gross cropped area to over 33 kg. Nearly 70% of the dry-season rice area is now under HYV cultivation. Practically all the wheat area is under HYV cultivation and over 16% of the rainy season foodgrain area is

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under HYV cultivation. The proportion of the foodgrain area irrigated increased from about 8% in 1969–70 to over 13% in 1980–82.

No aspect of the green revolution has been the subject of more controversy than its impact on income distribution. According to Frankel (1971), Wharton (1969), Cohen (1975), ILO (1977), Griffin (1979) and Pearse (1980), in some countries it appears to have led to tenant displacement, growing income inequality and enclaves of development, although Ruttan (1977), Hayami (1981), Hayami and Kikuchi (1981), Prahladachar (1983) and Hayami and Ruttan (1985) take a somewhat different view. A recent study by Chambers (1984) suggests that the "positive optimists" see the green revolution as having the potential of banishing hunger whereas the "negative pessimists" argue that gains in production are offset by losses in equity. Based on the recent evidence from farm level data as well as an aggregate demand–supply model, Hayami and Ruttan (1985) found no evidence of increase in inequality following the green revolution. They argue that "the commonly assumed trade-off between growth and equity appears to be more relevant as an issue for ideological debate than a description of contemporary development experience" (Hayami and Ruttan, 1985, p. 358).

Against the background of this acrimonious debate, and given technological change in Bangladeshi agriculture and the resulting increase in agricultural production, it is worthwhile trying to examine the distributional implications of technological change in Bangladeshi agriculture. To what extent have technological changes benefited consumers and producers? Which group of producers has benefited more from technological change? Has the green revolution accentuated income inequality? All these questions are worth considering in the Bangladeshi situation. In this paper we consider a model employed by Hayami and Herdt (1977) and subsequently used by Hayami and Ruttan (1985) as a possible relevant analytical framework. We adopt the Hayami and Herdt approach for two reasons. First, this model has not been applied to Bangladeshi data. It has been applied to the Philippine rice economy and it is useful to have a comparison between the Philippines and Bangladesh. Secondly, our objective here is to test the adequacy of this type of model for analysing income distributional consequences of technological change.

The present paper critically reviews the Hayami and Herdt (H–H) model. It identifies a number of shortcomings and suggests that inappropriate economic inferences can be drawn from it. After the basic model is presented in terms of geometry and algebra, it is applied to Bangladeshi data. Our findings are then compared to those of the H–H study. Shortcomings are then considered and their significant limitations are illustrated by data from Bangladesh. It is contended that the H–H model fails to provide a realistic assessment of the income distributional consequences of the green revolution. This follows from the conclusions reached via reinterpretation of the H–H model and is supported by other evidence.
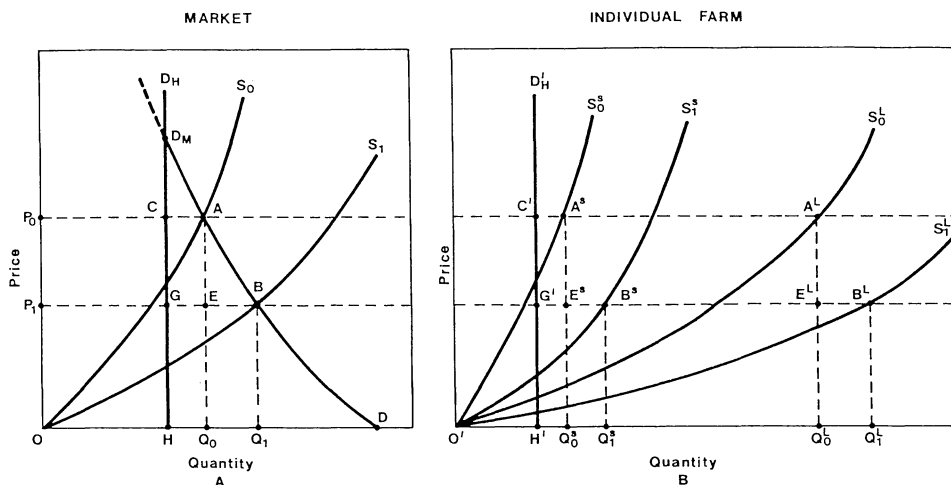
Fig. 1. The distributional impact on market and individual farm of technological innovations in a semi-subsistence crop, after Hayami and Herdt (1977).

Analytical framework: the H–H model

The investigation into the impact of technological change on the distribution within the framework of a demand–supply model involves an examination of the distribution of welfare gains between (a) consumers and producers, (b) small and large producers and (c) rural and urban consumers. To provide the analytical background to our Bangladeshi study we briefly outline the H–H model (for details, see Hayami and Herdt, 1977).

Consumers vs. producers

Figure 1A presents market demand and supply curves as well as the demand curve of the producers for home consumption of a semi-subsistence agricultural commodity ($D_H H$). $D_H D_M D$ represents the total demand curve with $D_M D$ as the market demand curve. The quantity purchased by the non-farm households is measured by the lateral distance between $D_H H$ and $D_M D$. The supply curve before a technological change (OS_0) shifts to OS_1 after the change. The quantity consumed increases from OQ_0 ($=q_0$) to OQ_1 ($=q_1$) consequent to a fall in price from OP_0 ($=p_0$) to OP_1 ($=p_1$). Consumers' surplus increases by the area ACGB. Producers' cash revenue changes from area $ACHQ_0$ to areas $BGHQ_1$ with producers' home consumption remaining unchanged at OH. The cost of production changes from AOQ_0 to BOQ_1.

Assuming that the real income value of home consumption of the product by producers is represented by the quantity consumed, income changes to producers are reflected in changes in their cash income. Whether producers' cash

income (= revenue − cost) is increased by technical change depends on the demand and supply functions. Let us provide a more formal mathematical treatment of the above relationships. We assume a constant elasticity of demand function for the relevant range of the total demand function $D_H D_M D$:

$$q = a p^{-\eta} \qquad (1)$$

where p and q respectively represent price and quantity demanded of a subsistence crop while income and other demand shifters are relegated to the constant term a and η is the price elasticity of demand.

Assume a constant elasticity of supply function:

$$q = b p^{\beta} \qquad (2)$$

p and q being price and quantity supplied; b includes supply shifters except technical change and β is the elasticity of supply. Let us assume that technological change leads to a k per cent shift in supply, so that the new supply function $(0S_1)$ can be expressed as

$$q = b(1+k) p^{\beta} \qquad (3)$$

Employing eqns. (1), (2) and (3) and using Taylor's expansion (see Thomas, 1968, pp. 634–635), we can approximate p_1 and q_1 as follows:

$$p_1 \simeq p_0 [1 - k/(\beta + \eta)] \qquad (4)$$

and

$$q_1 \simeq q_0 [1 + \eta k/(\beta + \eta)] \qquad (5)$$

on the assumption that k is a relatively small percentage change.

Change in consumers' surplus can be expressed as

area $ACGB$ = area $AP_0 P_1 B$ − area $CP_0 P_1 G$

$$= \int_{p_1}^{p_0} a p^{-\eta} \mathrm{d}p - q_0 (1-r)(p_0 - p_1) \qquad (6)$$

$$\simeq p_0 q_0 (kr/\beta + \eta)$$

r being the ratio of marketable surplus, i.e. HQ_0/OQ_0.

Change in producers' cash revenue is given by

area $BEQ_0 Q_1$ − area $ACGE$

$$= p_1 (q_1 - q_0) - q_0 r (p_0 - p_1) \qquad (7)$$

$$\simeq p_0 q_0 k (\eta - r)/(\beta + \eta)$$

Equation (7) indicates that producers' cash revenue will increase only if $r < \eta$.

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Cost of production will change by

area $\mathrm{BOQ_1}$ − area $\mathrm{AOQ_0}$

$$= [p_1 q_1 - \int_0^{p_1} (1+k)bp^\beta \, \mathrm{d}p] - [p_0 q_0 - \int_0^{p_0} bp^\beta \, \mathrm{d}p] \qquad (8)$$

$$\simeq p_0 q_0 k [\beta(\eta-1)/(1+\beta)(\beta+\eta)]$$

Since $\eta < 1$, there will be a definite decline in cost. Consequently cash income of the producers will change by

change in cash revenue − change in cost

$$= p_0 q_0 k [(\eta-r)/(\beta+\eta)] - p_0 q_0 k [\beta(\eta-1)/(1+\beta)(\beta+\eta)] \qquad (9)$$

$$\simeq p_0 q_0 k [(\eta-r) + \beta(1-r)]/[(1+\beta)(\beta+\eta)]$$

Producers vs. producers

Figure 1B shows changes in equilibrium points of two types of individual producers corresponding to changes in market equilibrium in Fig. 1A. The supply curves before technological change for small and large farmers are represented by $\mathrm{O'S_0^s}$ and $\mathrm{O'S_0^L}$ respectively and correspond to $\mathrm{OS_0}$ in Fig. 1A. The supply schedules of the small and large producers after the change in technology ($\mathrm{OS_1}$) are represented by $\mathrm{O'S_1^s}$ and $\mathrm{O'S_1^L}$. Hayami and Herdt (1977) assume that the quantity of home consumption for small and large producers is identical.

As can be seen from Fig. 1B, the equilibrium point of the small producer moves from $\mathrm{A^s}$ to $\mathrm{B^s}$, while that for the large producer moves from $\mathrm{A^L}$ to $\mathrm{B^L}$. These movements lead to changes in cash revenues, cost of production and cash income of the producers for both groups of farmers. Following Hayami and Herdt (1977), we apply the same procedure as for changes in relative grains of consumers and producers (eqns. (7)–(9)) to derive the approximation formulae for analysing the impact of an aggregate supply shift by a factor of k on the ith producer. We have for the ith producer:

change in cash revenue $(\Delta \mathrm{CR}_i) \simeq p_0 q_{0i} [k_i - k(\beta_i+r_i)/(\beta+\eta)]$ $\qquad (10)$

change in cost $(\Delta \mathrm{C}_i) \simeq p_0 q_{0i} [(\beta_i)/(1+\beta_i)][k(1+\beta_i)/(\beta+\eta)]$ $\qquad (11)$

change in producer's income $\qquad\qquad\qquad\qquad\qquad\qquad\qquad (12)$
$$(\Delta \mathrm{PI}_i) \simeq p_0 q_{0i} [k - k_i/(1+\beta_i) - kr_i/(\beta+\eta)]$$

q_{0i} and r_i respectively being the output and marketable surplus ratio of the ith

producer prior to the introduction of technology. We have $\beta = \Sigma w_i \beta_i$ and $k = \Sigma w_i \beta_i$, w_i being the share of the ith producer in the total output. One needs to mention that eqns. (10)–(12) reduce to (7)–(9) if $k_i = k$ and $\beta_i = \beta$. Equation (12) indicates that the magnitude and direction of ΔI_i for the ith producer will be determined by two factors: (a) magnitudes of k_i and β_i relative to k and β; and (b) the magnitude of r_i. If r_i takes a smaller value, ΔI_i takes a larger value.

Consumers vs. consumers

As presented in eqn. (6), technological change leading to a fall in the price of a subsistence crop implies a clear gain in economic welfare (consumers' surplus) for non-producing households like urban consumers. Welfare gains, however, depend on the importance of foodgrains in their expenditure pattern. The percentage change in real income due to a fall in foodgrain price can be approximated as

$$\Delta y/y = e\Delta p_f/p_f \tag{13}$$

where $y = p_f q_{f} + p_{nf} q_{nf}$ and $e = p_f q_f/y$. Thus y is the total income expressed as the sum of expenses on food staple $(p_f q_f)$ and other commodities $(p_{nf} q_{nf})$ and e is the proportion of income spent on foodgrains. The symbols p and q respectively represent prices and quantities while the subscripts f and nf symbolize food and non-food.

Since, according to eqn. (4), percentage change in food price due to a shift in supply function by k per cent is $k/(\beta + \eta)$, eqn. (13) can be rewritten as

$$\Delta y/y \simeq ek/(\beta + \eta) \tag{14}$$

As e is inversely related to per capita income, a price decline flowing from technological change is likely to reduce income gaps among urban consumers.

Application of the H–H model to Bangladeshi data

Foodgrain production is central to the agricultural economy of Bangladesh. For the period 1980–82 (that is, on average for the years 1980–81, 1981–82 and 1982–83), rice and wheat together occupied over 83% of gross cropped area (BBS, 1984). Rice is the most important crop in Bangladesh. During 1980–82 about 80% of the total cropped area was planted to rice and this accounted for 93% of the total foodgrain production in the country. Foodgrains are the most important wage goods in the LDCs and the income elasticity of demand for food is very high, probably of the order of 0.60 or higher (Johnston and Mellor, 1961; cf. Mahmud, 1979). In the short run, changes in relative food prices materially alter the real incomes of individuals on low monetary incomes (Mellor, 1978).

Since the introduction of the new technology in the late 1960s, foodgrain yields per hectare of net and gross cropped land have increased considerably. (Alauddin and Tisdell, 1986c). Considering the averages of the last three years of the 1960s and the first three years of the 1980s, the two measures of yields have increased by 17% and 23%, respectively (Alauddin and Tisdell, 1986b, table 3). These figures can be considered as surrogates for lower and upper bounds of foodgrain supply shifts (k). In this paper we have used three alternative values for k: 0.15, 0.20 and 0.25.

Alamgir and Berlage (1973) estimated price elasticities of demand for foodgrains to be -0.172 and -0.177. Ahmed (1979) estimates a value of -0.19 for price elasticity of demand. In the present study we have used η values of -0.15, -0.20 and -0.25 with a view to evaluating the impacts of different price elasticities on the results. Based on a study by Cummings (1974), Ahmed (1978) estimates price elasticity of supply (β) to be 0.18. For the purposes of this study we have used 0.15, 0.20, 0.25 and 0.30 as a set of possible values for β. Ahmed (1978) uses a figure of 0.29 as ratio of marketed surplus. In a more recent study, Ahmed (1981) reports a marketable surplus ratio (r) ranging between 0.18 and 0.22. We have used a range of values for r: 0.15, 0.20 and 0.30.

The results of an exercise based on eqns. (6)–(9) and the values of the specified parameters are set out in Table 1. It can be seen that consumers' surplus increases due to decrease in price as a result of shifts in supply. In all the cases considered consumers stand to gain. A fall in price leads to decline in producers' cash income in some cases, but this is outweighed by decline in cost of production. However, consumers' gains seem to be higher in most cases, and with a larger shift in supply and greater commercialisation they tend to be more so. Thus both producers and consumers are likely to gain from technological change in a subsistence agriculture like Bangladesh's.

In order to analyse the impact of the new technology on the distribution of income among producers, one needs to compare changes in (1) cash revenue, (2) cost of production and (3) income of large and small farmers resulting from change in price following the supply shift. Such comprisons are to be based on eqns. (10–12).

For deriving results from eqns. (10)–(12), one needs to specify plausible values of the parameters k, β and r. Empirical evidence (e.g. Jones, 1984) suggests that there is little difference in the adoption of HYV technology among different farmer classes. It is reasonable, therefore, to assume k_i to be the same for both groups of farmers. However, it was thought interesting to test the effect of differential rates of supply shifts for the two categories of farmers. There does not seem to be any previous estimate of price elasticity of supply for different classes of producers. However, in the short run it is unlikely that β would be any different for different producer groups. The long-run situation is likely to be different. With greater command over resources, e.g. capital and credit, larger farmers are likely to be more responsive to price changes. It is

TABLE 1

Estimated percentage change in consumers' surplus and producers' income from technological progress in foodgrain production: Bangladesh, 1967–69 to 1980–82 using the H–H method

Changes in	Percentage changes with specified parameters A: $k=0.15, r=0.15$					
	$\eta=0.15$		$\eta=0.18$		$\eta=0.20$	
	$\beta=0.15$	$\beta=0.20$	$\beta=0.15$	$\beta=0.20$	$\beta=0.15$	$\beta=0.20$
Consumers' surplus	7.50	6.43	6.82	5.92	6.43	5.63
Producers' cash revenue	0.00	0.00	1.36	1.18	2.14	1.87
Production cost	−5.54	−6.07	−4.86	−5.39	−4.47	−5.00
Producers' cash income (producers' surplus)	5.54	6.07	6.22	6.57	6.59	6.87

Changes in	Percentage changes with specified parameters B: $k=0.20, r=0.25$				C: $k=0.25, r=0.30$
	$\eta=0.20$		$\eta=0.25$		$\eta=0.25$
	$\beta=0.20$	$\beta=0.25$	$\beta=0.20$	$\beta=0.25$	$\beta=0.30$
Consumers' surplus	12.50	11.11	11.11	10.00	13.64
Producers' cash revenue	−2.50	−2.22	0.00	0.00	−2.27
Production cost	−6.67	7.11	−5.56	−5.00	−7.87
Producers' cash income (producers' surplus)	4.17	4.89	5.56	5.00	5.60

therefore reasonable to assume a higher value of β for large farmers. The main difference between large and and small farmers lies primarily in the proportion of marketable surplus (r). Ahmed (1981) provides the results of a survey which indicates that large farmers sell around three-quarters of their produce in the market, while smaller farmers (including the medium farmers) have a marketable surplus of around a quarter.

In the light of the above arguments, we present our estimates of changes in cash revenue, cost of production and income for the two classes of producers. We assume the aggregate supply shift $(k=0.20)$ and the price elasticities of demand (η) and supply (β) to be 0.25 and 0.30, respectively. We also assume the following sets of alternative values for k_i, β_i, η_i and r_i to derive the corresponding estimates:

case 1: $k_L = k_s = k = 0.20,$ $\beta_L = \beta_s = \beta = 0.30$ $r_L = 0.80, r_s = 0.20$

case 2: $k_L = 0.25, k_s = 0.15,$ $\beta_L = 0.40, \beta_s = 0.20$ $r_L = 0.85, r_s = 0.15$

case 3: $k_L = 0.30, k_s = 0.12,$ $\beta_L = 0.45, \beta_s = 0.15$ $r_L = 0.90, r_s = 0.10$

TABLE 2

Estimated differential impacts of technical progress in rice production on large and small produc-
ers: Bangladesh, 1967–69 to 1980–83 using the H–H method

Farmer category	Specified parameters $k=0.20, \eta=0.25, \beta=0.30$			Percentage changes in.		
	r_i	β_i	k_i	Cash revenue	Production cost	Cash income
Case 1						
Small Farmers	0.20	0.30	0.20	1.82	−6.29	8.11
Large Farmers	0.80	0.30	0.20	−20.00	−6.29	−13.71
Case 2						
Small Farmers	0.15	0.20	0.15	2.27	−4.77	7.04
Large Farmers	0.85	0.40	0.25	−20.45	−6.55	−13.90
Case 3						
Small Farmers	0.10	0.15	0.12	2.19	−3.88	6.79
Large Farmers	0.90	0.45	0.30	−19.09	−7.13	−11.96

Table 2 sets out the results of the exercise. The results clearly indicate a gain
in favour of small farmers far in excess of that of larger farmers. Whereas the
incomes of large farmers show declines, the income position of small farmers
tends to improve even when the values of k_L are much higher than those of k_s.

To appreciate the gains for non-producer consumers we need to derive esti-
mates of eqn. (14). The gains obtained by various urban consumer groups vary
directly with the relative importance of foodgrains in their family budgets. The
differential impacts of technical change in the real incomes of urban house-
holds have been calculated using data from BBS (1980, p. 20; 1984, pp. 709,
717) to eqn. (14) with $\beta=0.30$ and $\eta=0.25$. A 20% shift in the aggregate supply
function is likely to lead to an 11% increase in the real income of the consumer
group with a monthly income of Taka 300. On the other hand, the same aggre-
gate supply shift increases the real income of those in the monthly income
bracket of over Taka 2000 by 5%. This indicates that the relative increase is
larger for those in the lower income bracket. These benefits are likely to accrue
to urban consumers and landless rural labourers for whom foodgrains occupy
the lion's share of the household expenditure.

Limitations of the H–H model

It should be pointed out that the H–H model presented above is subject to a
number of limitations. While the model does have some value, there is also a
risk of drawing unwarranted assessment and policy conclusions from it.

First of all, technological change can cause a supply curve to shift in diverse

ways, and the supply curve may not be of the mathematical form assumed in the H–H model. Hayami and Herdt (1977) only consider one type of shift. The nature of supply shift can significantly influence the distribution of benefits between consumers and producers. This has been widely discussed in the recent literature. Duncan and Tisdell (1971) demonstrated that the nature of the supply shift is a critical determinant of the distribution of benefits between producers and consumers, and more recent studies by Lindner and Jarrett (1978), Lund et al. (1980), Taylor (1980) and Wise (1978, 1981) have underlined this.

Second, the analysis is "excessively" partial. In consequence, for example, a loss in producers' surplus may appear to be the case from the single product model, but in reality no major loss to producers may occur. For instance, a movement from $0S_1$ to $0S_2$ reduces producers' surplus from the crop under consideration. However, yield-increasing technology may mean that *less land* has to be used for the production of same quantity of the crop. This will enable to grower to use more land for the output of another crop or crops. Thus the producers' surplus overall (given that production is mixed) may not fall to the extent indicated in Fig. 1. One can conceive of cases where producers' surplus goes up, since resources are released that are used to increase supplies of other crops. The outcome depends on substitutability of one crop for another in the cultivation process.

Third, the system is not closed. For example, if the income per head rises as a result of the technological change, its impact on population growth is not predicted. Population is an exogenous variable in the H–H model, unlike in Malthusian or Ricardian models. It could well be an endogenous variable. The possibility that technological change could, in the case of an important subsistence crop, increase income and population and shift the demand for the product is not considered. Take the equation $D = n + \epsilon g$ (see Johnston and Mellor, 1961), where D, n and g are annual rates of growth in demand for food, of population and in per capita income, respectively, while ϵ is the income elasticity of demand. The second term on the right-hand side is likely to be technology-induced, while the growth of population could contain endogenous as well as exogenous elements.

Fourth, it is unlikely that in reality the supply curve would pass through the origin. The relationship implies some supply at near zero prices. Some positive price is likely to be required to ensure supply to the market. This becomes important when areas above the supply curve are used for estimating variations in producers' surplus. It is also unlikely that the supply curves of larger producers are related to the smaller producers in the simple way assumed by Hayami and Herdt, and no evidence is given for such a simple relationship.

Fifth, these seems to be some implication in the writings of Hayami and Herdt that the more important the market element is the greater are the gains from technological change. But this overlooks the possibility that production

may become more specialized and market orientated as green revolution technology becomes established. Farmers may become more dependent on purchased inputs and require a constant stream of cash to purchase these. The risks associated with these becomes a major influence on producers. The technology may "lock them" into a market system and their subsistence demand curve may shift leftward.

Sixth, the H–H model does not consider the question of variability of production, which can also have influence on welfare. If technological changes lead to greater variability in production and hence supply of foodgrains, their prices may become more unstable. In the LDCs this can have important welfare consequences for low-income earners and increase fluctuations in incomes received by the grain producers (Mellor, 1978). Furthermore, the question of sustainability is an important aspect of technological change which has implications for income distribution (Douglass, 1984). While extreme critics view the development of modern varieties ". . . as a plot by multinational firms and foundations to make peasant producers . . . dependent on chemical fertilizers and pest control materials" (Hayami and Ruttan, 1985, p. 297), the moderate view points to the loss of genetic diversity and ecological balance. Two recent incidents, (a) the threat to the 1977 Mexican wheat crop by a large-scale outbreak of rust and (b) significnt reduction in the 1978 Pakistan wheat yields, underscore the narrow range of genetic materials (Biggs and Clay, 1981; Hayami and Ruttan, 1985). In other words, the green revolution may have resulted in reduction in genetic diversity. These global questions can be all too easily ignored when one focusses on the analysis used by Hayami and Herdt.

There are, however, further important limitations of the H–H model as far as income distribution is concerned in Bangladesh. These are taken up in the next section.

Further distributional consequences of new technology in Bangladesh

Hayami and Herdt emphasize that their model "abstracts from possible changes in the factor shares and factor ownership that might occur either as a result of technological change or at the same time for independent reasons. The final impact of such changes on the income distribution would reflect the net effect of the new factor shares and factor ownership distribution as well as the real income effects dicussed above" (Hayami and Herdt, 1977, p. 256). The objective of this section is to consider some of these aspects to make a realistic assessment of the distributional consequences of the new technology.

Table 3 sets out the relative share of various factors of production in the output of traditional and modern varieties of rice in Bangladesh. Aman rice has been taken as a proxy for rainfed kharif (wet) season rice varieties and boro rice for the irrigated foodgrains during the rabi (dry) season. Assuming

TABLE 3

Relative share of labour and other factor inputs in total output per hectare of traditional and modern varieties of aman and boro rice: Bangladesh, 1980–81 (figures in parentheses are gross returns per hectare in terms of takas)

Input category	Rice crop and variety							
	Boro (Bangladesh)[a]		Aman (Thakurgaon)		Aman (Rajshahi)		Aman (Joydevpur)[b]	
	Traditional	Modern	Traditional	Modern	Traditional	Modern	Traditional	Modern
Material input from								
agriculture[c]	0.226	0.106	0.141	0.086	0.168	0.135	0.269	0.150
non-agriculture[d]	0.250	0.174	0.023	0.075	0.025	0.053	0.137	0.099
Return to human labour								
Total	**0.476**	**0.288**	**0.218**	**0.196**	**0.280**	**0.322**	**0.254**	**0.174**
Family	0.283	0.159	0.167	0.145	0.139	0.192	0.151	0.084
Hired	0.194	0.130	0.051	0.051	0.141	0.130	0.103	0.090
Return to capital[e]	0.048	0.431	0.618	0.643	0.527	0.490	0.340	0.516
Gross Output	**1.000**	**1.000**	**1.000**	**1.000**	**1.000**	**1.000**	**1.000**	**1.000**
	(5760)	(11460)	(4917)	(7890)	(6220	(6666)	(7122)	(12646)

[a]Based on a survey of 12 districts in Bangladesh.
[b]For 1981–82.
[c]Including expenditure on seed and animal labour.
[d]Including expenditures on chemical fertilizer, pesticides and irrigation.
[e]Including rent of land, interest and net profit.
Sources: BMAF (1981), Hossain et al. (1981, 1982) and Hossain and Harun (1983).

prices to be the same for different groups of farmers, the differences in (relative) factor shares can be attributed to technological change. A few pertinent points emerge from the information presented in Table 3. First, compared to modern varieties, the traditional varieties use a higher percentage of material inputs from within the agricultural complex. Second, the relative share of labour in the total output per hectare is much higher for traditional compared to modern rice varieties in all areas except Rajshahi. The difference is much more striking in the case of irrigated rice. Similar differences can be noted in returns to capital. Third, traditional varieties have much higher returns to capital in some places than in others. The difference in returns to capital between Joydevpur and Rajshahi or Thakurgaon is due to (a) higher yields and (b) higher rice prices in 1981–82 compared to 1980–81. It may be that Joydevpur, being the centre for the Bangladesh Rice Research Institute (BRRI), has benefited more from rice research than either of the two other places which are far away from the BRRI headquarters.

Despite decline in the relative shares of labour in modern rice production compared to traditional varieties, the absolute income of labour has improved significantly during the rabi season. A recent study by Alauddin and Mujeri (1985) indicates that employment per hectare during the rabi season has increased considerably. Employment has not declined for the dry season between the late 1960s and the early 1980s. Without the introduction of new technology unemployment would most likely have increased. On the other hand,

even though the relative share of labour for rainfed HYVs is not significantly lower than for their traditional counterparts, one needs to be reminded that the cultivation of the HYVs of rice during the kharif season does have very little impact on the demand for labour. Rainfed HYVs of rice have virtually the same labour requirement per hectare as those for traditional varieties. Therefore, the replacement of traditional varieties by rainfed HYVs adds little to the overall demand for labour during the kharif season. Furthermore, the shift in cropped area from a more labour-intensive crop, jute, to different varieties of rice in recent years has had a depressing effect on the demand for labour (Alamgir, 1980; Alauddin and Mujeri, 1985).

From Table 3 it can be seen that the relative share of family labour in total output is higher than that of hired labourers who come from the landless, near-landless or the dispossessed classes. This seems to support the hypothesis that employment has increased more in terms of the demand for family labour and less so in terms of hired labour (Ahmed, 1981). This may have led to the reduction in underemployment rather than unemployment per se. This has implications for income disparities between landowners with family labour and the landless or near-landless who usually work as wage labourers (BBS, 1984; Cain, 1983).

Significant variations occur in the returns to family labour, depending on the mode of operation (e.g. owner operator or sharecropper) and technology (e.g. traditional or modern variety) as can be seen from Table 4. First of all, returns to family labour for the owner operator are far in excess of those for the sharecropper. Secondly, for irrigated varieties, returns are much higher for both groups of farmers. Thirdly, while for Joydevpur the returns to family labour (either owner or sharecropper) for modern aman variety are much higher than those for the traditional aman variety, there is little difference between those for the two varieties in the Thakurgaon and Rajshahi areas. Fourthly, returns to family labour for sharecroppers cultivating traditional varieties are in some cases higher than the market wage rate and lower in some others. One also observes significantly higher returns per hectare (on cash cost basis) for the owners compared to the sharecroppers. Thus the gap between the owner cultivator and sharecropper is likely to widen further with more widespread diffusion of the new technology.

Irrigation is a critical input in the modern technological package. The ownership and control of this component of the new technology has a significant impact on income distribution. First, smaller farmers have very little control over the ownership of this vital input. Secondly, through the patron–client relationship, the larger farmers who own irrigation equipment gain substantial revenues as rents for irrigation water sold to smaller farmers. Even when the ownership of irrigation is cooperative, the small holder usually becomes very much an unequal partner. The siting of tubewells normally takes place on the large farmer's plot, giving him control and easier access to irrigation water

TABLE 4

Returns to family labour for owner cultivator and sharecropper for traditional and modern varieties of boro and aman rice: Bangladesh, 1980–81 and 1981–82

	Owner cultivator		Sharecropper	
	Traditional	Modern	Traditional	Modern
Bora paddy, Bangladesh[a]				
Net income[b]	2464.00	7329.00	−420.00	1599.00
Family labour applied[c]	71.58	94.42	71.58	94.42
Returns to family labour[d]	34.35	76.76	−5.87	16.93
Wage rate[d]	15.25	15.73	15.25	15.73
Aman paddy: Thakurgaon				
Net income[b]	4376.00	6633.00	19.17.00	2718.00
Family labour applied[c]	83.80	102.60	83.80	102.60
Returns to family labour[d]	53.20	64.65	22.28	26.49
Wage rate[c]	10.59	10.59	10.59	10.59
Aman paddy: Rajshahi				
Net income[b]	4877.00	4703.00	1767.00	1370.00
Family labour applied[c]	64.60	63.90	64.60	63.90
Returns to family labour[d]	75.50	73.60	27.35	21.44
Wage rate[d]	13.57	13.57	13.57	13.57
Aman paddy: Joydevpur[e]				
Net income[b]	4045.00	8542.00	484.00	2219.00
Family labour applied[c]	53.94	53.32	53.94	53.32
Returns to family labour[d]	74.99	160.20	8.97	41.62
Wage rate[d]	19.98	19.98	19.98	19.98

[a]Based on a survey of 12 districts.
[b]Taka per hectare, cash cost basis.
[c]Man-days per hectare.
[d]Taka per day.
[e]For 1981–82.
Sources: BMAF (1981), Hossain et al. (1980, 1981) and Hossain and Harun (1983).

(Alam, 1977). The whole process seems to have resulted in the creation of a class generally known as "water lords" in the rural society.

Consequent upon inequality in the distribution of land (BBS, 1981, 1983), farmers have unequal access to social, political and economic power critical to the decision making process underlying the allocation of resources to promote agricultural development. The institutions that affect the adoption and diffusion of technological innovations are biased toward those farmers who are better endowed with land resources (see, for example, Khan, 1979). Thus the apparent "scale-neutrality" of the green revolution technologies may not be meaningfully manifested in the actual process of agricultural development.

The availability of agricultural credit affects the purchasing power of the farmers to adopt innovations. In general, the supply of credit is far below demand (Yunus, 1981). Moreover, institutional credit accounts for only a small fraction of the total credit supplied (Chowdhury and Ghafur, 1981). Because holders of larger farms have readier access to institutional credit, the bulk of

the credit obtained by smaller farmers come from the non-institutional sources, for which interest rates are 2–5 times higher (Chowdhury and Ghafur, 1981). A recent study by Alam (1981) provides evidence of substantial non-interest costs of borrowing from institutional sources. The inclusion of these costs brings the *effective* costs of borrowing from the institutional sources closer to those of the non-institutional sources. In percentage terms, these costs vary inversely with the amount of credit, which depends directly on size of land holdings owned. This makes investment in non-conventional inputs like fertilizer or irrigation water more expensive to the smaller farmers who finance a higher price (cf. Quasem and Hossain, 1979). Overall, therefore, the per hectare cash costs of cultivation are higher for smaller farmers than for larger ones. This leads to differential gains for small and large farmers. In recent study Jones (1984), using results of survey data from a village in the Dhaka district in Bangladesh, reports that "the smallest (group I) farmers take about 30% more credit per operated hectare than the average, mostly as interest-free loans from friends and relatives. Contrary to much theorising, then, small farmers do not appear to face severe enough resource constraints to seriously hamper their cultivation of HYVs" (Jones, 1984, p. 206). However, given the dominance of the non-institutional sources in the agricultural credit market of Bangladesh, Jones' findings may represent an isolated phenomenon.

An interesting question remains: why do adoption rates of innovations not differ significantly between smaller and larger farmers in Bangladesh? There seem to be two reasons for this: first, the small farmers are much better endowed with labour resources which, given the size of their holding, may remain under-employed during parts of the year. The adoption of HYVs alleviate this under-employment. secondly, because of subsistence pressure the smaller farmers (including tenants) may be forced to maximise their family incomes rather than profits (Quasem and Hossain, 1979).

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