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EQUITY AND PRODUCTIVITY EFFECTS OF A PACKAGE OF TECHNICAL INNOVATIONS AND CHANGES IN SOCIAL INSTITUTIONS : TUBEWELLS, TRACTORS AND HIGH-YIELDING VARIETIES*

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I

THE IMPORTANCE OF COMPLEX INNOVATIONS

There have been few attempts to analyse the economic impact of complex innovations. Theoretical and empirical research has instead sought to isolate the characteristics of separate innovations. In this way a taxonomy of technical changes has been constructed in terms of the productivity and equity effects of land and labour augmenting technologies. This may have fostered to some extent a naive view about desirable and undesirable forms of technical change for conditions of overall or periodic labour surplus, so that often "mechanization" is regarded as wholly bad. This simple approach is particularly unfortunate from the viewpoint of developing an appropriate technology policy because few innovations occur in isolation and different parts of the package have to be carefully selected. Technical change in the form of the substitution of new techniques for old, or the introduction of new inputs, regularly involves sequences and packages of innovations. It is the overall impact of a complementary package that is important and not necessarily the characteristics of one component. A labour augmenting innovation may be a necessary component of a technical package which raises output and employment.

Economic analyses of technological change have also tended to take as given the institutional context, ignoring the interaction of technical and institutional change. Land augmenting innovations, which on *ceteris paribus* assumptions will bring a substantial proportion of the benefits of technical progress to labour, may well provide the economic impetus to institutional changes which erode away the potential gains to labour which would have come through higher employment. Furthermore, because a suitable new type of output distribution institution, such as an effective taxation system does not exist, the government is unable to retrieve any of the increased output which, in many cases, it has assisted by high subsidies.

The following case study of a sequence of innovations associated with the introduction of tubewell irrigated cultivation of high-yielding wheat in the

* This paper is largely based on material from an unpublished doctoral thesis, Clay (6). The data base of the study is a random cluster sample of 54 tubewell investors drawn from a Survey of Mechanical Investment in the Kosi Region of Bihar carried out by the author in 1970-71 with the generous help of many members of the development administration in the region. The author would like to acknowledge helpful comments made by S. D. Biggs, I. Carruthers, C. D. Cohen, and V. W. Ruttan.

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Kosi Region of Bihar is presented as a contribution to the neglected subject of complex combinations of technical and institutional change, and to demonstrate that there is a need for a more comprehensive view on what will be the components of an appropriate agricultural technology. First, there is a brief survey of the socio-economic structure of production in the region. This is followed by a review of the sequence of innovation that occurred in the Kosi Region upto and including the development of the bamboo tubewell.[1] The role of mechanization, which was found to play an important part in the process of introducing tubewell irrigated farming, is next subjected to close scrutiny. This is done because mechanization of an agricultural operation is considered by some as an undesirable innovation where employment is a goal of economic policy. This leads to a micro economic analysis of the productivity and equity effects of the package of innovations and the implications both for future technical and institutional change in the economy of rural Bihar and for agricultural technology policy.

II

THE STRUCTURE OF AGRICULTURAL PRODUCTION

An appreciation of the distributional impact of technical change in the Kosi area requires a knowledge of the salient features of the agricultural structure of the region. Abstracting from many of the complexities of socio-economic behaviour in the region, one can recognize four broadly distinct socio-economic groups in terms of their control over economic resources and the forms of economic transaction between them. First, there are the very large landowners : former zamindars, their larger farmer tenants and some *nouveaux riches* with holdings from 20 acres upwards. Traditionally, this broad group has rented out large parts of their holdings on a share crop basis. Second, there is a class of larger peasant farmers largely self-cultivating with the aid of hired labour and producing substantial surpluses for sale. According to land type and technology, the group extends from those with around 5 to 25 acres overlapping with the first group. Below them is a large class of small farmers, with between 1 and 5 acres, many share cropping at least part of the land they cultivate. Until the introduction of the new technology this group was unable to generate a significant production surplus over own consumption needs and this surplus mainly flowed as rent or return on consumption and productive credit to group one. Fourth, there is the landless or almost landless agriculture labour which depends on wage employment for a livelihood.

These classes were also linked by socio-economic transactions. The most important agricultural transactions were the supply of land and credit in cash or kind especially by group one to groups three and four, and the return

1. For a detailed history of the bamboo tubewell, see Clay (5,6) and Appu (1). A brief account of the background to this innovation is given below in section III.

flow of draught services from group three and labour from group four to group one and to a lesser extent to group two. In addition there were *jajmani* relationships. There were very limited intra-group transactions within the rural sector, such as co-operation in ploughing amongst group three farmers. In considering the distributional and institutional impact of technical change, attention should focus on the differential impact of change on these groups and the induced change occurring in the relationships between and within groups.[2] The differential impact of tubewell irrigation on land holding groups is considered in section III and on the landed and landless in section V.

III

THE SEQUENCE OF INNOVATION, 1951-71

Tubewells, tractors and high-yielding varieties (HYV) (Table I) were introduced into the Kosi Region by private activity and public programmes. A number of shallow tubewells, to be powered by diesel or electric pumpsets were sunk from the mid-1950s onwards under a government programme of credit financed investment. The first tractors appeared in the early post-Independence period on the holdings of a few large landowners and former zamindars, some intending to become gentlemen farmers and others to secure land rights by increasing the area of direct cultivation. Neither of these innovations had significant impact within the region before the mid-1960s, nor was there any link between these innovations, except that some of those who experimented with mechanized cultivation also installed tubewells.

As there is limited need for supplementary tubewell irrigation during the main *kharif* season, tubewell irrigation would have to pay for itself through more intensive cultivation of dry season *rabi* or *summer* crops. From the viewpoint of an individual investor, the other major constraint on the spread of tubewell irrigation was the indivisibility problem. The package of well and pumpset as originally introduced cost around Rs. 8,000 in 1958. The broken topography and fragmentation of holdings in this region limited the command of tubewell irrigation systems. There was no existing system of irrigation canals and channels, or a tradition of transactions in water. All these factors limited the opportunity for widespread use of tubewell irrigation, in spite of the availability of government credit.

The situation was dramatically changed by a rapid sequence of innovations, beginning with the appearance of dwarf wheat in 1965-66 (Table I). Where unirrigated yields of local varieties of wheat averaged less than half a tonne per hectare and irrigated improved varieties of Punjabi wheat less than 2 tonnes per hectare, the farmers initially obtained yields of 3 to 4 tonnes

2. For a further analysis of the economic and social structure of the region, see Biggs and Burns (3) and Wood (12). The holding size categories are only to be considered as bands which embrace different socio-economic groups.

with dwarf Mexican wheat, using far less than the recommended doses of fertilizer. In addition, a 50 per cent subsidy was introduced for credit financed tubewell investment, and with the newly established package programme, there was a more assured supply of other new inputs, seed and fertilizer, also on credit. The combination of these developments giving large windfall gains to early innovators demonstrated the potential for profitable tubewell irrigated farming; and the diffusion of tubewell technology through the region dates from this period. This demonstration of profitability also induced another remarkable sequence of private attempts to adapt tubewells to local conditions by reducing the costs of installation.

The two most important innovations were the development of lower cost wells culminating in the bamboo borings, made largely of local materials, and the emergence of a market in the services of pumpsets. This is reflected in the increasing ratio of tubewells to pumpsets in the region (Table I). The farmers were able to install several wells on small plots powered only by a single mobile diesel pumpset, or hire in a pumpset. The main impact of local innovation was to break down lumpy technology and thus to greatly reduce the minimum scale of individual operation necessary for profitable use of tubewell irrigation.

TABLE I—TRACTORS, TUBEWELLS AND PUMPSETS IN THE KOSI REGION : 1955-56—1972-73

Period	1955-56	1960-61	1965-66	1970-71	1972-73
		(Number of units)			
1. Tractors[a]	234	339	394	1,034	1,446
2. Tubewells[b]					
1. Iron	26	213	300	3,374	3,544
2. Bamboo	—	—	—	1,438	19,496
3. Total	26	213	300	4,812	23,040
3. Pumpsets[a]	80	286	399	3,009	6,589
4. HYV Wheat (thousand acres)[a]	—	—	1	425	820

Source : (*a*) Tabulation from District Office Statistics (Biggs and Burns, 3)
(*b*) Own estimate.

Tubewell irrigation, dwarf wheats and the use of fertilizer were complementary innovations for most who invested in tubewell irrigation. The separate impact of each innovation on production, other input use and income distribution is difficult to isolate. Even the form of tubewell technology, and the scale of operation were modified by innovations induced by the potential profitability of irrigated HYV wheat cultivation at prices prevailing during the late 1960s.

Lower cost wells enabled farmers with relatively smaller holdings, as defined above, to invest in tubewell technology, but ownership was still largely restricted to groups one and two (Table II). Through the sale of water, even some of those officially classified as small farmers (group three) were able to irrigate. The provision of government credit further extended well ownership amongst the small farmers (Appu, 1). However, the limited availability and investment cost of 5 H.P. diesel pumpsets have made it difficult for the smaller farmer to benefit as fully from the sinking of low cost wells as the larger farmer. Many large farmers were found to have sunk several wells on their fragmented holdings meshing together low cost wells and the high cost capacity of a single pumpset.[3] Those without pumpsets, mainly in groups two and three, were found to use less water and apply less of other inputs (Clay, 6) partly because of unavailability of hire services at critical times for water application and limited ability to finance the use of purchased inputs. The growing imbalance between the stock of wells and pumps (Table I) also forced up the rent for hiring in pump services reinforcing the tendency found in the distribution of investment goods for the larger farmers to benefit more from tubewell irrigation.[4]

TABLE II—DISTRIBUTION OF TUBEWELL INVESTMENT BETWEEN HOLDING SIZE-GROUPS IN THE KOSI REGION (UPTO MAY, 1971)

Holding size-group (acres)	1.0-2.4	2.5-5.0	5.0-19.9	20.0 and above	Total
		(per cent of row total)			
All cultivators in the Kosi Region[a] ..	20.4	29.4	41.7	8.6	100.0
All metal tubewells[b]					
4″ and 6″ diameter	—	0.6	30.3	68.9	100.0
3″ diameter	—	4.3	48.6	47.1	100.0
Bamboo 5″ diameter	—	0.4	53.5	45.7	100.0

Source: (*a*) Bihar 1961 Census modified (Biggs and Burns, 3)
(*b*) Own estimate (Clay, 6)

Whereas there was a close link between the introduction of tubewell irrigation and the spread of high-yielding wheat, restrictive lending provisions, with land mortgage requirements of the order of one acre for Rs. 1,000 borrowed, continued to restrict tractor investment to those with the largest land holdings, and there was only a partial overlap between tubewell and tractor ownership with less than 10 per cent of tubewell owners also having tractors even in the largest land owning class. Therefore, the introduction of tractors and mechanical ploughing are considered here only so far as these innovations overlap with the spread of tubewell irrigated farming, and as this produced an indirect demand for mechanized ploughing.

3. The economic problem of indivisibility is critically one of the minimum cash flow required for profitable use of lumpy investment goods, not the fact of a large work capacity in an engineering sense.

4. Rahman (11) records that in 1974-75 *rabi* season the cost of pump hire was Rs. 4-5 per hour compared with Re. 1 to Rs. 1.25 in 1971 (Clay, 6). With the increased cost of fuel per acre irrigation costs using a hired pump had risen over 200 per cent and pump owners were receiving an economic rent for the services of their equipment.

IV

THE MECHANIZATION OF PLOUGHING

The increase in the intensity of cropping and substitution of crops which require a full land preparation in place of *paira*, over sown, crops or the traditional *rabi* mixed cropping swell the demand for draught power. The change in the cropping pattern associated with tubewell irrigation increased the total annual demand for draught power by 43 per cent (Table III).

TABLE III—SEASONAL PLOUGHING REQUIREMENTS AND TRACTOR POWER SUPPLIED ON 69 SAMPLE TUBEWELL PLOTS

Seasonal draught requirements[a]	*Aus*	*Aman*	*Rabi*	Annual total
	(thousand bullock pair days)[b]			
1. Before investment	7.5	2.5	3.6	13.7
2. After investment (1970-71)	6.9	3.9	8.9	19.6
3. Supplied by tractor (1970-71)	2.3	1.8	2.9	6.9
	(percentage)			
4. Percentage change in requirements [(2)—(1) × 100]	—8	+52	+143	+43
5. Percentage of 1970-71 requirements supplied by tractor [(3) + (2) × 100]	33	46	33	35

Notes: (*a*) The farmers in the Kosi area distinguish four cropping seasons. The main *kharif*, monsoon season, is divided into *bhadai* (*aus*), harvested in the month of *Bhadra*, August and September, and *aghani* (*aman*), harvested in the months of November and December, in the months of *Agrahan* and *Pus*. *Rabi* crops are harvested not later than March-April, and *garma*, summer crops sown in the winter season are harvested before the main monsoon begins in June.

(*b*) Draught power is measured in bullock pair days (BPD). It is assumed that one bullock pair will take 5 days to double plough one acre. Total requirements are estimated as mean numbers of ploughings for each crop × 5.

However, it is not just the absolute magnitude of the increase in demand for draught power, but the timing of that demand through the agricultural year that is critical. The introduction of dwarf wheat increased pre-*rabi* land preparation by over 140 per cent and produced particularly peaked draught requirements, especially if wheat followed *aman* paddy. The local varieties of paddy are photoperiodic and are harvested from November until January. The high soil moisture levels and temperatures after the monsoon and high temperatures from March onwards restrict wheat planting to two months from late October upto late December with reduced yield to early or late sowing. Late planting also created phasing problems for any farmer wanting to follow wheat with an *aus* crop.

The changes in the use of draught power and the farmers' explanations of their decisions reflect the pressure that the intensification of cropping rotations and the introduction of dwarf wheat placed on draught power resources. The farmers responded to this draught problem through the choice of crop rotation and the introduction of mechanized ploughing. Most farmers did not increase cropping intensity, 65 per cent retaining pre-investment seasonal rotations. The main change was the introduction of dwarf wheat in place of traditional unirrigated *rabi* crops, local varieties of wheat, cereal and pulse mixtures and mustard. The cropping intensity index only increased from 1.56 to 1.72. In the surveyed village no less than 8 tubewell investors continued to follow a two-year three-crop rotation, using tubewell water to irrigate wheat every second year and otherwise to provide supplementary water for *kharif* crops if rainfall was inadequate. The limited change in crop rotations is not to be entirely explained in terms of draught power constraints, because where holdings were highly fragmented the common practice of sowing over large areas of village land, especially jute and paddy, restricted the individual farmers freedom of action (Clay, 6).

The farmers were found to be increasing their use of mechanized ploughing and some were even reducing their use of draught animals in the face of their increased ploughing requirments. The majority of the sample were reducing their stock of draught animals. The number of work animals and their work/animal/land ratios were both below the regional average and too low to permit them to meet their ploughing requirements without hiring in bullocks or tractors. The hiring in of bullock services was also relatively unimportant amongst tubewell owners. It was found that only 30 per cent hired in bullock services at all, 25 per cent doing so for ploughing, but only 16 per cent for ploughing on tubewell plots.

In contrast, the farmers were introducing tractor ploughing with the spread of tractor ownership and the development of a market in tractor services. Two-thirds of tubewell owners, who did not have tractors, hired in tractor services, and the seasonal pattern of hiring closely followed the seasonal pattern of draught requirments. Those with tractors used them for almost all their ploughing, leaving only puddling and inter-cultivation to bullock teams. On the plots of non-owners one double ploughing by the tractor was the most common. The total ploughing done by the tractor was more than one-third of annual requirments. Those who regularly hired tractor services also had a lower ratio of bullocks to cultivated area than others without tractors.

Thus, the transition to tubewell irrigated farming was associated with the development of a market in tractor services. In all cases, except that of a farmer who was using the tractor of a relative, this involved a cash transaction with a most common hiring charge of Rs. 20 per acre, roughly equivalent to the cost of double ploughing an acre with hired bullocks.

As tractor and bullock ploughing are substitutes, it is necessary to explain not merely why a market for tractor services developed but why the use of bullocks did not expand at the same time. The hiring in of draught services would seem to be explained by the peaked demand for draught power, which was accentuated by the introduction of dwarf wheat, in particular by land preparation between an *aman* and a *rabi* crop and between a *rabi* and *bhadai* crop. The hiring in of draught services also enabled the farmers to reduce their own draught capacity. This in turn reduced the fodder requirements, when the possibility of intensive rotations involving the substitution of a cash crop, wheat, for the main fodder crop, cereal and pulse mixtures, was increasing the opportunity cost of assigning land to fodder crops and pasture. The farmer also saves on the wages of an additional farm servant, a ploughman, and keeps in his own cultivation land often given out under share crop to a ploughman. The increase in potential returns of own cultivation had also raised the opportunity costs of share cropping out land.[5]

From a managerial standpoint the hiring in of a tractor has another advantage. A single transaction can rapidly secure sufficient capacity to plough a tubewell plot, whereas this would have required the hiring in of many bullock pair day equivalents. As few of those who hire out bullocks have more than one pair for hire and these may not be continuously available, such a transaction would involve a formidable organizational problem, especially for those without a large number of dependent small farmers and share croppers.

The farmers claimed that tractor ploughing was better than bullock ploughing because it was deeper, and this is supported by agronomic evidence on the effect of breaking up the plough pan in preparing land for wheat and jute (Nezamuddin and Sinha, 10; Brammer, 4). The size of tubewell plots, mean size 6 acres, made them more suitable for tractor ploughing as there was less likelihood of breaking down bunds than on small plots. The farmers also seemed to display a preference for tractor ploughing, perhaps because it was a recent innovation. The sight of a tractor going up and down one's field is a conspicuous demonstration of modernity; another reason why tractors and bullocks are not perfect substitutes.

Finally, and perhaps most important, the tractor has the further advantage of being outside the traditional set of economic transactions. Ploughing services used to be provided by tenants for their landlords. Since the settlement reform these continue to be provided by the small farmers with security of tenure for those to whom they are obligated by ties or indebtedness. There is also the ritual link between following the plough and low caste status. This is a factor which restricts the supply of services for hire, even when some small farmers have spare capacity. In such an imperfect market, an uninfluential farmer could find it difficult to obtain extra draught power.

5. There is some evidence that the expansion of tractor ownership *per se* is enabling the farmers in category one to switch to direct cultivation reducing land holdings of group three or forcing the small farmers into the landless category (Ladejinsky, 9).

Apart from the short-term inelasticity of supply of bullock draught services, because of the status connotations of providing these for others, there is evidence of a continuing secular reduction in the bullock-cultivated area ratio for the region, implying a reduction in the potential supply of services for hire (Biggs and Burns, 3). In contrast, the supply of tractor powers in the region was rapidly increasing (Table I). The 25 to 45 horse power tractors which were supplied in the majority of cases also left many new owners with spare capacity to hire out.

Thus, the increase in draught power requirements was satisfied largely through an important innovation in economic relationships. The peaked draught requirements of irrigated cultivation provided sufficient incentive to induce the farmers to engage in the marketing of tractor services but not sufficient to increase the scale of traditional bullock hire transactions. In part, this is because of the advantages of tractor hire but also it is because the hiring out of tractor services is a novel transaction considered to be outside the set of traditional ritual and status relationships. For, on the evidence of the survey, the tractor owners are willing to hire out their tractors to the farmers through the entire range of ritual and economic status found within the investing group. Those who hired tractors in or out included Brahmins, Rajputs, Bhumiars, merchant and cultivator castes and Muslims. This included cultivators with holdings from five to several hundred acres excluding those small farmers who had previously provided bullock services.

V

EMPLOYMENT AND INCOMES OF AGRICULTURAL LABOUR

Our purpose here is only to provide a broad quantitative measure of the direct impact of innovation on employment and incomes of agricultural labour as compared with land holders. As labour augmenting innovation is controversial there is also a separate estimate of the direct impact of mechanization on employment. The approach adopted is partial budgetting analysis using sample data for 1970-71 and recall evidence for pre-innovation cropping patterns.[6]

Agricultural labour is not a single homogeneous input; not only is it time-specific but there are also several distinct labour markets requiring different levels of skill. Wage differentials are found which are based on quasi-feudal links between farmer and labourer, skill and sex and intra-regional

6. The precise measurement of the impact of all these innovations on employment and labourers' income would require time-series analysis and have to take into account the interdependence of the different sectors of the regional economy, an issue which Biggs (2) tackled with a regional programming model. Even to measure the impact on individual farms it is preferable to have reliable time-series information which cannot be obtained from a sample survey based on recall information. There were also difficulties in the way of collecting accurate whole farm budgets from large land holders who are concealing the full size of their holdings and the existence of share croppers. However, one could inspect tubewell plots, and the farmers would discuss fairly freely the use of tubewells, evidence of modernity about which they were proud.

variations based on local supply and demand conditions. The situation is again complicated by further variations in the degree to which wage payments have been commuted to cash, or are still paid in kind. In view of our limited purpose many of these complexities have been ignored. One simplification is to disaggregate into two categories, "permanent" farm servants and "casual" labour. This distinction corresponds to a real division of labour, because ploughmen and other farm servants are a separate category of employees with a separate range of established conditions of employment, and only the employment of the first group is directly affected by tractor ploughing.

The post-investment cropping rotation, it is estimated, involved 13,700 man-days of ploughing work compared with 14,000 for the pre-investment rotation if all ploughing had been done with draught animals, implying that the introduction of tubewell irrigation compensated for the reduction in ploughing employment resulting from mechanization alone. The change in the cropping pattern brought an unambiguous increase in other work for farm servants in operating pumping sets, applying fertilizer and acting as watchmen. In this way, extra work associated with irrigated cultivation more than compensated for the reduction in ploughing employment with partial mechanization (Table IV).

TABLE IV—IMPACT OF INNOVATION ON EMPLOYMENT AND INCOMES OF PERMANENT AND CASUAL LABOUR ON 69 TUBEWELL PLOTS

	Before investment	After investment	Change	Per cent change
(*i*) Employment[a]		(thousand man-days)		
1. Farm servants	14.2	20.1	+5.9	+42
2. Casual labour	31.9	42.6	+10.7	+34
3. Total	46.1	62.7	+16.6	+36
(*ii*) Wages[b]		(thousand Rs.)		
1. Farm servants	29.0	40.3	+11.3	+39
2. Casual labour	70.7	105.2	+34.5	+49
3. Total	99.7	145.5	+45.8	+46

Notes : (*a*) Assumes 1970-71 level of mechanization.
(*b*) Kind component computed at Rs. 20 a maund for daily labour wages as coarse grains were often given and Rs. 25 for harvest share, largely paddy and wheat.

The employment of casual labour has been separated into two categories according to mode of payment. First, there are those types of work for which daily rates apply. These include transplanting, and inter-cultivation operations such as weeding, hoeing and digging. Second, there are operations for which the labourers receive a conventionally fixed proportion of the crop, harvesting and threshing of all foodgrains, usually 1/12th and 1/24th respectively, and stripping jute, 1/8th. The income received by labour for the first group of operations varies with the number of persons employed, and for the second group with the quantity of output. This second mode of payment enables labour to maintain its overall share of benefits from all increases in productivity, so long as the shares remain unchanged and labour is not replaced by mechanization of a process such as threshing.

The total area of tubewell plots generated over 30 thousand man-days of daily wage employment during 1970-71, as compared with 21 thousand with the pre-investment cropping pattern, an increase of over 47 per cent. This produced increases in cash income and kind income of 26 per cent and only 6 per cent. The relatively smaller increase in wage payments is explained by the propotionately greater increase in demand for lower wage weeding labour as compared with higher wage employment such as hoeing and transplanting.

Employment estimates for harvest operations are notoriously unreliable, because the farmers pay a share and not wages and so have little interest in the number of labourers employed. However, according to the standardised comparison the income from these operations increased by 181 per cent. This overall large increase resulted from the higher yields of paddy and the introduction of wheat in place of low yield cereals and pulses. If one calculates a single measure of the income of casual labour, converting wages in kind into rupees at 1970-71 post-harvest village prices for low grade paddy and coarse grains, then the total income increased by 49 per cent (Table IV), largely because of the increased income from harvest shares. The share of wages in kind rose from 60 per cent to 67 per cent of total casual labour income. Whatever the limitations of this exercise, it does demonstrate, that because of the difference in magnitude of the changes involved, the income of landless labourers increased substantially as a result of the changes in the cropping practice and increase in yields.

VI

OUTPUT AND INCOME SHARES

Next, we turn to measure the direct impact of innovation on aggregate output and income shares of labour and landowners based on the same assumptions as the previous analysis of changes in demand for labour. The value of gross output is estimated on a per cultivated acre basis to have risen by 86 per cent. The value of output and increase in the value of output per net cultivated acre, 104 per cent, are higher because the cropping intensity index is greater than one and increased with the introduction of tubewell irrigation.

Variable costs of production were found to have also more than doubled with the change in rotation and introduction of tubewell irrigation, and the composition of costs changed significantly. The value of purchased physical inputs, seed, fertilizer and fuel, increased from only 9 per cent of total costs with the pre-investment rotation to 36 per cent of actual costs of cultivation in 1970-71. Only 32 per cent of the increased costs of cultivation were daily labour hire costs, and the greater part of this was through the proportional increase in harvesting cost with higher total output. The overall share of labour costs in total variable costs fell from 77 per cent to 54 per cent. Three quarters of the increase in costs represented services and inputs which had to be paid for in cash or obtained on credit, and the cash cost of production rose to an average of Rs. 126 per cultivated acre.

The overall direction of the change in costs is clear, there were increases in the use of purchased inputs and variable capital costs of production. This change, whilst it brought an increase in the demand for labour and in labour costs, implied a relative reduction in the direct costs of agricultural labour through a substitution of purchased intermediate goods for labour in the production process.

Estimates of income shares derived from comparative static analysis should be considered as only tentative measures of the order of magnitude (Table V). The farmers' income is defined as the net revenue or surplus left after the payment of all variable costs and overhead costs necessary to maintain the production process, but without any allowance for depreciation. The share of agricultural labour is income of daily labour plus a share of farm servants' wages imputed to the tubewell plots. The repayment of institutional loans has to be deducted from net revenue to find the disposable income that actually accrued to the farmers; and this is then compared with labour income. The share of labour in net income decreased from 48 per cent of the pre-investment income to 40 per cent of post-investment income whilst the share of labour in the increase in net income was only 31 per cent. This is what would be expected; the use of daily labour failed to increase proportionately to the growth in output, so that at constant wage rates, assumed in this comparative static analysis, the share of labour must fall. The conventional share of harvested output cannot maintain the overall share of labour in

TABLE V—INCOME SHARES FROM PRODUCT OF 69 TUBEWELL PLOTS

	Pre-investment rotation		Post-investment rotation		Change	
	Thousand Rs.	Per cent	Thousand Rs.	Per cent	Thousand Rs.	Per cent
1. Farmer income	109	52	210	59	101	+69
2. Agricultural labour income	100	48	145	41	45	+31
3. Net income	209	100	355	100	146	100

total income. This would require an unlikely compensating increase in the relative price of labour.

There were other changes in the wind, comparable to the break with traditional modes of transaction brought about by mechanized ploughing, that could wipe out the benefits achieved through harvest shares tied to the volume of output. Commutation of customary payments in kind into cash would make labourers more vulnerable in periods of price inflation and dearth, as they are forced to purchase a greater proportion of their food requirements or take loans in kind from the farmers that weaken their bargaining position in the labour market. Only one of the sample had commuted a customary harvest share, the share of labour from stripping jute, but the economic incentive for the farmer to break the link, costly for him, between wages and output would suggest that there will be a movement in this direction which "tied labour" and the under-employed could find hard to resist if employers act in unison.

VII

CONCLUSIONS

The process of innovation through the introduction of new technologies and purchased inputs brought a substantial increase in output, doubling the value of production but increasing income inequalities. The reduction in investment costs through tubewell innovation, the development of more appropriate forms of technology and novel forms of transaction enabled a wider size distribution of farmers to participate in the benefits of tubewell irrigation. Official choice of technique, initially in the case of tubewells, the introduction of tractors rather than power tillers and the restrictive collateral requirements of credit agencies probably impeded this process. In so doing it ensured that a higher proportion of the benefits accrued to larger land holders through own use of equipment and earning economic rents on the supply of scarce machine services. The introduction of farm machinery financed with subsidised credit and controlled by the large farmers was reversing the traditional pattern of transactions, making smaller farmers depend on large farmers for service of agricultural equipment.

The participation of labour in the benefits of innovation was found to depend disproportionately on the maintenance of customary modes of payment for labour services, which are giving way elsewhere in the face of similar shifts towards higher productivity commercialised agriculture, for example, in Java (Collier, *et al.*, 7, 8) and Bangladesh.[7] So far, the impact of labour augmenting innovations on employment and labour incomes has been ambi-

7. The author is currently engaged in a study of the relationship between the introduction of new varieties of rice and purchased inputs and changes in the scale and modes of payment for harvesting in Bangladesh. Preliminary unpublished findings suggest that a reduction in labour share and shift to cash contract payments are associated with the spread of new varieties and purchased inputs.

guous. More intensive cultivation and employment for casual labour would have been restricted by the absence of a market for tractor services. The willingness of tubewell investors, generally cautious with their cash outlay on inputs such as fertilizer or seed, to pay Rs. 20 an acre for ploughing would imply that there was a serious draught constraint. Some farmers were also introducing mechanized threshing. Events such as the substantial grain losses incurred by farmers in 1971, unable to thresh their wheat before it was ruined by rain and subsequent germination, provided an incentive for further investment in mechanical threshing. The traditional labour intensive methods are inefficient for threshing wheat. The mechanization of this operation is a genuine example of a conflict between increased output and employment objectives. Other innovations, especially herbicides and combine harvesters, could have an even more disastrous effect on the income of the poor, but these were not in use at the time of the survey.

The impact of technical innovation is a highly complex affair and technology policy a difficult business with many traps for the crop production, engineering and other specialist promoting simple solutions. The currently fashionable emphasis on maximization of employment creation could become one such trap unless one appreciates that it is the overall impact of technical change that is critical, and that without appropriate institutional structures, employment creation may guarantee labour a share of the work but not of the benefits.

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