# TECHNOLOGY GAP AND THE EMERGING SIZE-PRODUCTIVITY RELATIONSHIPS FOLLOWING THE ADOPTION OF NEW TECHNOLOGY: AN ANALYSIS OF EVIDENCE FROM NORTHWEST AND EASTERN INDIA

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Although the successes achieved by the adoption of new seed and fertilizer technology were impressive, especially in regions endowed with public sources of irrigation, it is often feared--on the basis of field observations and evaluation studies--that it has led to a widening of interfarm and interregional inequalities. However, the extent to which the institutional environment of a given region is responsible for such a development is not adequately appreciated in most of the evaluation studies of the Green Revolution.

The basic hypothesis to be examined in this paper is: where the institutional framework (structure of landholdings, credit, and marketing institutions) is more favourable, small and large farms realize significant productivity gains from adopting new seed and fertilizer technology. In regions where such a favourable institutional environment does not prevail, large farms realized proportionately more productivity gains than small farms. A confirmation of this hypothesis would imply that the interfarm inequity in productivity gains (widely discussed in the literature on the Green Revolution) is not as important in the institutionally well-endowed regions as in the poorly endowed regions.

The above hypothesis will be tested by contrasting the recent experience of two wheat growing regions--western Uttar Pradesh, which is geographically close to the northwestern plains (the scene of the Green Revolution), and the predominantly rainfed eastern Uttar Pradesh, which is located on the Indo-Gangetic plains in eastern India.

## Study Region and Data Sources

Eastern Uttar Pradesh comprises 15 districts located on the Indo-Gangetic plains. This region is characterized by scarce land in relation to population, very low exploitation of the existing resource potential, a slow rate of technological change in agriculture, weak and large farm biased institutional credit and input delivery systems, extreme inequality in the distribution of landholdings with a high incidence of sharecropping and a preponderance of small farms, a slow growth of the nongricultural sector, and widespread poverty and unemployment. It accounts for a large part of the groundwater of the country, but actual exploitation of its potential is probably lower than for land. This region constitutes one of the biggest problem zones of India with regard to economic development.

By contrast, the western region of Uttar Pradesh, comprising 18 districts, is endowed with a higher level and better quality of irrigation. The average size of a holding is large, and the distribution of landholdings is much more equal. The region is endowed with a well-developed institutional credit system including a growing commercial banking sector.

The western and eastern regions of Uttar Pradesh are dissimilar not only with respect to institutional characteristics but also with respect to every index of development. The eastern region lags substantially behind the western region in the adoption of HYV technology, and there is evidence to show that the technology gap has widened in the recent period (Subbarao, 1981).

This study is based on published farm management data for Muzaffarnagar (western Uttar Pradesh) and Deoria (eastern Uttar Pradesh), and on primary data for 180 sample farms located in three districts of eastern Uttar Pradesh.

## Changes in Size Productivity Relationships and Levels of Input Use

This section is concerned with changes in land productivity (total output of all crops per hectare) as measured by gross value of agricultural output (GVAO) per hectare, and the levels of input use by size class of holdings before and after the introduction of new seed and fertilizer technology in the two regions under investigation.

The implications of the spread of new HYV technology for different categories of farmers has become a critical issue resulting in a renewed interest in the so-called "inverse relationship" between farm size and land productivity (Bhalla). The contribution of HYV technology to the weakening of the inverse relationship in the Green Revolution pockets (Punjab, Haryana, and western Uttar Pradesh) is reported in some of the recent studies (Chadha). The sharpening of the inverse relationship between farm size and labour input following new technology has also been observed by some scholars (Rao; and Oberoi and Ahmed).

Thus the available evidence suggests that in institutionally well-endowed northwest India, small farmers continued to retain their productivity advantage even after the introduction of Green Revolution technology (Bhalla).

In the institutionally backward eastern region, new technology had not made any progress even by the late 1960s. However, by the mid-1970s, the area under new seed varieties increased impressively. Table 1 gives data on GVAO for the eastern region for the late 1960s and mid-1970s.

Before the advent of new technology, the GVAO per hectare declined with farm size in this region, as was the case with the western region in the late 1950s. However, by the mid-1970s, as new technology spread, the productivity advantage of small farms was practically eroded. In fact, the land productivity achieved by large farms appears to be somewhat higher than that of small farms, although no statistically significant positive relationship could be established. The disappearance of the inverse relationship implies that the output per hectare on large farms grew at a faster rate than on the small farms as a consequence of the adoption of new technology. Analysis of the changes in input use for the eastern region (table 1) shows that the increase in output was achieved by large farms by effecting significant increases in the magnitude as well as quality of irrigation and fertilizers. The data also show increasing substitution of capital for labour by large farms. The change in investment in farm implements (including irrigation equipment) as a percentage of total investment hardly rose on marginal farms, but increased by four times for medium and large farms. It is interesting that the inverse relationship between labour input and farm size has turned very sharp by the mid-1970s, although the region as a whole is characterized by low wages and surplus labour.

## Yield Per Hectare and Size of Holding for HYV Crops

The evidence examined in the previous section suggests that, so far as total land productivity is concerned, small farms retained their advantage over large farms in the western region but seemed to be losing ground in the institutionally less developed eastern region. In this section, we analyze the position with respect to single crop productivity; i.e., HYV wheat, which constitutes the predominant new seed variety in both regions.

In the western region, data for the recent 5 year period (table 2) suggest that farmers of all size categories increased the use of nutrients, although the small and medium farmers used them more intensively than others. Yields per hectare realized by different categories of farms suggest no firm evidence of a positive relationship with size of holding.

**Table 1. Changes in Gross Value of Agricultural Output per Hectare (GVAO) and Input Use by Size Class in Eastern Uttar Pradesh**

| Size class and years (hectares) | GVAO per hectare (100 rupees) | Total labour (man-days) | Gross irrigated area as a percentage of gross cropped area | Area under tubewells as a percentage of total irrigated area | Fertilizer consumption (kilograms) | Investment in farm implements as a percentage of total investment |
|---|---|---|---|---|---|---|
| Less than 1.00 | | | | | | |
| 1966-1969 | 24.1 | 183.5 | 22.1 | 0.0 | 20.5 | 1.9 |
| 1975-1976 | 31.9 | 647.0 | 62.2 | 51.0 | 41.3 | 0.7 |
| 1.00-2.50 | | | | | | |
| 1966-1969 | 20.9 | 158.4 | 28.2 | 3.3 | 22.5 | 2.7 |
| 1975-1976 | 33.1 | 420.2 | 62.2 | 72.0 | 59.4 | 5.9 |
| 2.51-5.00 | | | | | | |
| 1966-1969 | 21.7 | 136.8 | 29.3 | 3.2 | 30.0 | 2.9 |
| 1975-1976 | 31.7 | 330.0 | 64.8 | 71.0 | 56.7 | 8.8 |
| 5.01 and above | | | | | | |
| 1966-1969 | 19.1 | 122.7 | 32.4 | 10.2 | 31.5 | 4.4 |
| 1975-1976 | 34.6 | 239.8 | 79.5 | 82.7 | 78.7 | 14.8 |

Sources: Ministry of Agriculture for 1966-1969, and unpublished data from the Agro-Economic Research Centre, Allahabad, for 1975-1976.

In the eastern region, on the other hand, we expect firm evidence of a positive relationship between yields of HYV wheat and size of holding because, as stressed at the beginning, the institutional credit and input delivery system in this region is extremely inefficient and biased against small farms. Subbarao (1980) brings out this bias of the predominant institutional credit agency (cooperatives) in the distribution of credit against the small farmers: the amount per hectare made available to small farmers in the eastern region is about one quarter of the amount disbursed in the western region, whereas the difference for the medium and large farm size groups is much less pronounced.

**Table 2. Changes in Input Use and Yield Per Hectare of HYV Wheat by Farm Size in Muzaffarnagar, Western Uttar Pradesh**

| Size class (hectares) | Fertilizer and manure (rupees) | | Hired labour (rupees) | | Draught power (rupees) | | Total production expenses (rupees) | | Yield per hectare (quintals) | |
|---|---|---|---|---|---|---|---|---|---|---|
| | 1966-1967 | 1971-1972 | 1966-1967 | 1971-1972 | 1966-1967 | 1971-1972 | 1966-1967 | 1971-1972 | 1966-1967 | 1971-1972 |
| Under 2.88 | 95 | 307 | 0 | 40 | 450 | 171 | 1,509 | 1,552 | 16.80 | 30.72 |
| 2.88-4.71 | 16 | 204 | 42 | 111 | 358 | 170 | 1,304 | 1,467 | 20.59 | 35.85 |
| 4.72-6.96 | 14 | 231 | 56 | 98 | 280 | 164 | 1,087 | 1,423 | 13.36 | 35.67 |
| 6.97-10.65 | -- | 307 | 86 | 124 | 263 | 135 | 1,054 | 1,693 | 16.52 | 37.08 |
| Over 10.65 | 14 | 250 | 58 | 111 | 239 | 124 | 1,019 | 1,739 | 10.76 | 32.69 |

Source: Dasgupta, pp. 193-206.

We therefore hypothesize that, in the eastern region, yield per hectare of HYV is positively related to size of holding (which we use as a proxy for the farmers' ability to raise working capital), apart from fertilizer input and irrigation. The estimated equations are as follows:

$$(1)\quad Y = \underset{(3.50)}{0.06^*}\, X_1 + \underset{(6.76)}{0.0003^*}\, X_2 + \underset{(1.87)}{0.059^*}\, X_3$$

$$\bar{R}^2 = 0.79 \quad FV = 219.6^* \quad (n = 180)$$

$$(2)\quad Y = \underset{(3.08)}{0.06^*}\, X_1 + \underset{(7.72)}{0.0004^*}\, X_2 + \underset{(2.58)}{0.009^*}\, X_4$$

$$\bar{R}^2 = 0.79 \quad FV = 227.2^* \quad (n = 180)$$

where $Y$ = yield per hectare of HYV wheat,

$X_1$ = total fertilizer input (NPK) per hectare,

$X_2$ = quadratic term for fertilizer (NPK) input,

$X_3$ = size of operated holding, and

$X_4$ = irrigated area as a percentage of operated area during the wheat-growing (rabi) season.

Figures in brackets denote t values. Asterisks denote that the coefficient is significant at a 5 percent or lower level of significance.

The results suggest that differences in fertilizer use is the dominant explanatory variable. Normally, a quadratic term is also fitted since it allows for diminishing returns. We tried both linear and quadratic fits but, as can be seen from the results, the addition of a quadratic term did not improve the overall explanatory power ($\bar{R}^2$). This is understandable because this region is characterized by relatively low levels of fertilizer applications, so that diminishing returns may not have set in.

Of the other explanatory variables, it is interesting to note that the size of operated holdings is significant with a positive sign implying that the higher yields of large farms under new technology may be due to their wealth and resource position reinforced by factor price distortions (Berry and Cline) rather than due to their inherent technical superiority over small farms.

Since fertilizer consumption emerged as the dominant explanatory variable, we examined the actual use of NPK as a percentage of recommended doses of farm size in two sets of villages falling under distinctive categories: (1) villages with an active target group oriented (small farm) credit cooperative and multiple agencies for fertilizer distribution; and (2) villages where noninstitutional credit agencies were predominant with practically no institutional agencies for fertilizer distribution. Table 3 shows that, in villages falling under the first category, differences between size groups in fertilizer dosage are much less pronounced in sharp contrast to the second category where small farmers applied fertilizer doses substantially lower than the recommended levels. While this is indicative of the role of institutions in serving small farmers, we recognize that more micro level data are needed to understand why institutions in most of the villages in the eastern regions failed to serve the weaker sections.

**Table 3. Actual Use of NPK as a Percent of Recommended Doses by Size Class—HYV Wheat in Eastern Uttar Pradesh**

| Size Class (hectares) | Category (1) Villages | Category (2) Villages |
|---|---|---|
| | Percent | |
| Less than 1.0 | 78.40 | 25.85 |
| 1.0-2.5 | 60.88 | 34.54 |
| 2.6-5.0 | 60.98 | 43.25 |
| Over 5.0 | 75.29 | 52.70 |
| Holdings in sample | 28.00 | 72.00 |

Source: Unpublished data from the Agro-Economic Research Centre, Allahabad.

## Conclusions

The above analysis suggests that, in institutionally well-endowed northwest India, small farms retained the productivity advantage under both traditional and new technologies. In institutionally weaker eastern India, small farms responded to new technology by substantially increasing the use of the country's abundant factor, labour input, without sacrificing the overall (crop year) productivity, and they made only modest use of scarce inputs such as fertilizer. By contrast, large farms invested substantial amounts in fixed capital (pumpsets, tubewells, etc.) as well as working capital (fertilizer) and realized yields comparable to, if not higher than, those of small farms for HYV wheat. Even with respect to crop yield productivity, large farms attained levels close to those of small farms. In order that small farms retain their superiority with respect to crop year productivity, it is imperative that these farms attain much higher yields for the HYV crops (wheat and rice). Our results show that the yields of these crops are a positive function of controlled irrigation and access to borrowed resources (working capital). The prevailing institutional credit and input delivery system is weak and inefficient in eastern Uttar Pradesh, with a pronounced bias against the small farms. Where an active target group oriented credit and input delivery system existed, small farms used fertilizer doses equal to, if not higher than, those of large farms. If small farms are to be aided to retain their productivity advantage under the new technology, urgent corrective action is needed for the toning up of the institutional credit and input delivery systems in eastern India, apart from the provision of controlled irrigation through public sources.

## Note

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