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9. ABSTRACT

Distribution of sectoral gains between labor and nonlabor input factors attains importance in view of the growing concern about rural poverty and unemployment despite recent increases in output and total revenue in Indian agriculture. Using cross section data, this study aims at measuring changes in the relative factor shares. Changes in relative factor shares are analyzed in two regions in India: Ferozepur (Punjab) and Muzzaffernager (Uttar Pradesh). The choice of these regions is dictated by availability of comparable data relating to pre-technological and post-technological change periods. Incidentally, these two regions are the most important contributors to the green revolution in wheat. Data used in the analysis were collected by the Directorate of Economics and Statistics, Government of India. These data were derived from cost-accounting surveys conducted on a cross section sample of farmers in the two regions at two points of time: the mid-1950's and late 1960's, conforming with an a priori classification of pre-technological and post-technological change periods in Indian agriculture.

The surveys conducted in the mid-1950's (1954-57) included 200 farmers, while the surveys of the late 1960's (1966-70) included 150 farmers for each region. Farmers were selected on a stratified random sample basis. In the absence of time series data, these cross-section observations are the only source of material for studies dealing with the factor shares in Indian agriculture.

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Technological Change and Relative Factor Shares in Indian Agriculture: An Empirical Analysis*

UMA K. SRIVASTAVA AND EARL O. HEADY

Distribution of sectoral gains between labor and nonlabor input factors attains importance in view of the growing concern about rural poverty and unemployment despite recent increases in output and total revenue in Indian agriculture. Using cross section data, this study aims at measuring changes in the relative factor shares.

THE last few years have brought a perceptible technological transformation of agriculture in India and other Asian countries.[1] This transformation has become known as "the green revolution," characterized by biological-mechanical[2] innovations [21] that have rapidly increased output and total net revenue of the agricultural sector.

Despite increased income of the agricultural sector in LDC's, there has been growing concern with rural poverty and unemployment. In India, for example, recent studies show an increase in the proportion of rural population below the poverty line [2, 8, 16]. Landless agricultural laborers and small farmers constitute the bulk of the rural poor. Small farmers also derive a large portion of their income from hiring out surplus family labor. Quantitative projections of the growth of employment in the nonagricultural sector do not show any significant potential for the absorption of the growing agricultural labor force [24]. These circumstances have created a special interest in the relationship between growth in output and factor shares, particularly labor's share, within the agricultural sector in LDC's. The basic question is whether the undergoing technological change will increase employment potential in agriculture so that landless laborers will find adequate employment in agriculture.

Much research has been devoted to empirical verification of the relationship between the absolute demand for labor and growth in agricultural output [4, 5, 12, 18, 23]. This paper, however, is concerned mainly with the changes in relative factor shares. Such changes are analyzed with application of the CES production function framework. The analysis also indicates the importance of various forces affecting relative income shares.

The Data

Changes in relative factor shares are analyzed in two regions in India: Ferozepur (Punjab) and Muzzaffernager (Uttar Pradesh).[3] The choice of these regions is dictated by availability of comparable data relating to pre-technological and post-technological change periods. Incidentally, these two regions are the most important contributors to the green revolution in wheat. Data used in the analysis were collected by the Directorate of Economics and Statistics, Government of India. These data were derived from cost-accounting surveys conducted on a cross section sample of farmers in the two regions at two points of time: the mid-1950's and late 1960's, conforming with an *a priori* classification of pre-technological and post-technological change periods in Indian agriculture.

The surveys conducted in the mid-1950's (1954–57) included 200 farmers, while the surveys of the late 1960's (1966–70) included 150 farmers for each region. Farmers were selected on a stratified random sample basis. In the absence of time series data, these cross-section observations are the only source of material for studies dealing with the factor shares in Indian agriculture.

Since the published data (in the form of eight

* Journal Paper J-7360 of the Iowa Agriculture and Home Economics Experiment Station, Ames. Project number 1558. We are grateful to an inimical friend who was also one of the *Journal* referees for his extremely useful suggestions in improving this paper.

[1] There has been a temporary setback in agricultural production during the 1971–72 agricultural year because of extremely bad weather conditions, but the high yielding varieties have gained wide acceptance.

[2] For a classification of innovation in agriculture and impact on factor demand, see Heady [9].

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[3] The Farm Management Surveys of 1955–56 included two districts: Amritsar (besides Ferozepur) in Punjab, and Meerut (besides Muzzaffernagar) in Uttar Pradesh Survey. To have a large cross section sample of the area, this analysis uses the data of both the districts in the pre-technological change period.

Table 1. Percentage share of selected Indian states in sown area and in holdings of agricultural machinery

State	Net sown area (1964–65)	Holdings of agricultural machinery (1966)		
		Diesel engines	Electric pumps	Tractors
Andhra Pradesh	8.4	10.4	9.5	5.4
Gujarat	6.9	25.0	3.8	6.0
Maharashtra	13.2	32.5	9.7	6.0
Punjab (including Haryana)	5.6	1.8	2.3	28.7
Tamil Nadu	4.4	9.5	53.4	6.1
Uttar Pradesh	12.6	6.3	2.6	18.8
Other states and centrally administered territories	48.9	14.5	18.7	29.0
	100.0	100.0	100.0	100.0

Source: K. N. Raj [17].

class means) from the studies [11] have been found to contain aggregation bias, this analysis uses the actual farm-level data. Farm level data were available to the authors only for one year (Uttar Pradesh, 1956–57, and Punjab, 1955–56) of the pre-technological change period and two years (1967–69) of the post-technological change period. The two data sets of each of the regions have been used for the following analysis. Changes in relative factor shares, particularly in labor's share, in Uttar Pradesh and Punjab should also reflect the impact of tractor use. Uttar Pradesh and Punjab account for a sizeable percentage share of the tractors in use in Indian agriculture (Table 1).

Limitations of Earlier Studies With Cobb-Douglas Framework

Production function studies for agriculture in developing economies have assumed the Cobb-Douglas form to be logically appropriate to the data. Very little effort has been made to verify the actual value of the elasticity of substitution,[4] with the exception of a study by Yotopoulos *et al.* [25]. In the Cobb-Douglas form, the relative factor shares remain unchanged, even with a change in relative factor prices and factor ratios (substitution between factors), because the elasticity of substitution between inputs is forced to unity. Technological change is expressed in the Cobb-Douglas function by a change in the partial elasticities of production, and/or a change in the intercept term in the function (A). Technological change alters relative factor shares only when it changes the ratios of the partial elasticities of production. Bardhan [3] has recently tried to verify the elasticity of substitution between land and labor by means of a "Kmenta approximation" for some of the post-technological change data used in the present study (data sets relating to 1967–69). The elasticity of substitution between land and labor inputs was found to be significantly different from unity. This pioneering study throws some doubt on the elasticity of substitution assumption underlying the studies with Cobb-Douglas production functions.

Furthermore, the prices of both labor and capital inputs have increased in recent years for both regions studied. Contrary to the expectation of "surplus labor theorists," wage rates in the two regions have increased much faster than the prices of major capital goods such as tractors and implements. Some indications of changes in relative factor prices are available in the fragmentary evidence in Table 2. Average daily wage rates of adult laborers nearly doubled in Uttar Pradesh and tripled in Punjab between 1961–62 and 1968–69. During the same period prices of two brands of tractors (Eicher and Tafe, the only ones being produced in 1961–62) increased by only 50 percent. Prices of other brands of tractors (production of these started in later years) have risen very little since the first year of production as compared with wage rates during the same period. Interest rates on long term capital also have been very low [19]. Two explanations have been offered recently for such a rapid rise in wage rates: Rao [19] offers a Ricardian explanation that prices of wage goods have increased because cultivation has been extended

Table 2. Some indicators of relative factor prices

Indicator	Unit	1961–62	1964–65	1968–69
Wage Rates (per day):				
Uttar Pradesh	Rs.	1.33	1.74	2.61
Punjab	Rs.	2.39	3.02	6.23
Tractor Prices (different brands)				
Eicher (27 H.P.)	Rs.	11,900	—	17,460
TAFE (35 H.P.)	Rs.	14,450	—	21,141
Hindustan (50 H.P.)	Rs.	—	17,500	22,350
Escorts (27 H.P.)	Rs.	—	13,100	13,810
Escorts (37 H.P.)	Rs.	—	15,400	17,910
Hindustan (35 H.P.)	Rs.	—	12,500	15,710
International (35 H.P.)	Rs.	—	16,380	19,570
Percentage Ratios of Indices of Fertilizer Prices to Cereal Prices Indices (1961–62 = 100)		100.0	79.9	71.0

Sources: (1) Tractor prices and wage rates for 1961–62 and 1968–69 in Uttar Pradesh [19]; (2) wage rates in Punjab [10]; (3) wage rates for 1964–65 in Uttar Pradesh [13]; (4) the ratios of indices of fertilizer to cereal prices are worked out from Economic Survey of Agriculture Ministry of Food and Agriculture 1968–69.

[4] There have been a large number of studies with Cobb-Douglas production function. For studies relating to Indian agriculture, see Srivastava *et al.* [22].

to the marginal lands; Herdt and Baker [10] argue that the supply curve of labor is no longer perfectly elastic in these areas.

Empirical Estimates of the Parameters Affecting Relative Income Shares

Arrow *et al.* [1] formulated the CES production function which eliminates the assumption of an elasticity of factor substitution equal to unity. The CES function is

$$(1) \qquad Q = \gamma\{\delta K^{-\rho} + (1-\delta)L^{-\rho}\}^{-1/\rho}$$

where Q, K, and L denote output, capital, and labor, respectively; γ is a technological parameter, δ is a distribution parameter, and ρ is the factor substitution parameter. Brown [6, 7] has shown that the relative shares of capital and incomes, in terms of the CES function, depend on the ratio of labor to capital, on capital intensity, and elasticity of substitution parameters. The share of labor relative to capital under marginal productivity equilibrium can be expressed as:

$$(2) \qquad S = \frac{wL}{qK} = \frac{1-\delta}{\delta}\left(\frac{q}{w}\right)^{\sigma-1}$$

where

S = the ratio of labor income to capital income,
w = wage rate per unit of labor,
q = rental per unit of capital,
$1-\delta/\delta$ = labor intensity,

and

σ = elasticity of substitution $(1/1+\rho)$.

The parameters affecting relative income shares were empirically estimated. Brown [7] has derived the estimating form of the equation using time series data. In the absence of time series data, the estimating equation becomes as follows:

$$(3) \qquad \log\left(\frac{L}{K}\right) = \sigma \log\left(\frac{1-\delta}{\delta}\right) + \sigma \log\left(\frac{q}{w}\right) + \epsilon$$

where

L = human labor (adult man days),[6]
K = value of fixed assets on the farm in rupees (includes value of land, machinery, and implements),
w = wage rate per day in rupees (derived by dividing total wage bill by total number of days),
q = rental of capital per unit in rupees (derived by dividing the share of capital in value added on each farm by the total amount of capital on the farm; share of capital in value added has been calculated by subtracting the wage bill and expenditures on seed, fertilizers, and irrigation from the total output; expenditures on seed, fertilizers, and irrigation are the measures for intermediate inputs),

and

ϵ = error term.

The logarithm of the share of labor relative to capital in value added can be obtained by subtracting $\log(q/w)$ from the estimated equation (3). It gives all the components of the relative factor shares. The logarithm of the labor intensity parameter $(1-\delta/\delta)$ is derived from the estimated intercept term. The logarithm of S can be expressed as [7]:

$$(4) \qquad \log S = \sigma \log\left(\frac{1-\delta}{\delta}\right) + (\sigma - 1)\log\left(\frac{q}{w}\right) + \epsilon$$

where all the terms are as defined previously.

It is, however, well known that there are imperfections in the labor market in a dual agrarian economy such as India's [20]. Although the proportion of hired labor to total labor is very low on the small farms, it is relatively high on the large farms. Family labor usually is willing to work on the family farm at less than the going market wage rate, yet the surveys impute the value of family labor at the going market wage rate. This is one of the main imperfections in the labor market for a dual agrarian economy. To take out the effect of this imperfection in the labor market, a farm size dummy variable was added in equation (3). Also, since two years of post-technical change data were used, a dummy variable was added to account for the time differences. The final estimating form of equation (3) is as follows:

[6] Female and child labor days have been converted into adult man days by using the conversion factors applied in the studies [11].

Table 3. Estimated parameters of equation (5)

Region	Year	$\log\left(\frac{1-\delta}{\delta}\right)$	σ	ξ_1	ξ_2	d.f.	R^2	$\log\left(\frac{q}{w}\right)$	Actual log S	Computed log S
Uttar Pradesh	1956–57	−1.8002* (0.0366)	0.2453* (0.0308)	—	−0.0077 (0.0292)	191	0.4582	−1.0857* (0.4597)	−0.9730	−0.9809
	1967–69	−1.8259* (0.0767)	0.4855* (0.0506)	0.0469* (0.0144)	−0.0918* (0.0142)	295	0.6511	−1.5115* (0.1473)	−1.0862	−1.0481
Punjab	1955–56	−1.9513* (0.0674)	0.1744* (0.0355)	—	−0.0277 (0.0240)	192	0.4204	−1.7690* (0.3247)	−0.3013	−0.3141
	1967–69	−2.1155* (0.1171)	0.2755* (0.0472)	0.0672* (0.0243)	−0.1347* (0.0457)	292	0.6052	−2.1691* (0.2681)	−0.5338	−0.5440

* Significantly different from zero and one at 1 percent probability level.

$$\log\left(\frac{L}{K}\right) = \sigma \log\left(\frac{1-\delta}{\delta}\right) + \sigma \log\left(\frac{q}{w}\right) + \xi_1 d_1 + \xi_2 d_2 + \epsilon \tag{5}$$

where

d_1 = year dummy variable. It takes the value zero for the observations of 1967–68 and value one for the observations of 1968–69 for each of the two regions. This variable has been included only in the case of post-technological change data.

d_2 = farm size dummy variable. It takes the value zero for the observations relating to the farmers having below 10 acres of land area, and value one for the farmers having 10 acres or more.[6]

Estimated parameters of equation (5) are presented in Table 3. All the parameters, except for the farm size dummy variable in the mid-1950's, are significantly different from zero and one at the 1 percent probability level. However, before the changes in share of labor relative to capital were computed on the basis of estimated parameters at different points of time, it was necessary to test the null hypotheses:[7] $\log(1-\delta/\delta)_{1955-56} = \log(1-\delta/\delta)_{1967-69}$, $\sigma_{1955-56} = \sigma_{1967-69}$, and $\log(q/w)_{1955-56} = \log(q/w)_{1967-69}$. All the parameters in 1967–69, except $\log(1-\delta/\delta)$ in Uttar Pradesh, are significantly different from the parameters in 1955–56 at the 1 percent probability level. The parameter $\log(1-\delta/\delta)$ for Uttar Pradesh in 1967–69 is significantly different from the 1956–57 estimates at the 10 percent probability level. Thus there has been a significant change in all the relevant parameters.

It can be seen that there has been a decline in the labor intensity and factor price ratio (q/w). But there has been an increase in the elasticity of substitution between capital and labor in both regions included in this study. A decline in the parameter of labor intensity and factor price ratio causes a decline in the share of labor relative to capital [6, 7]. Similarly an increase in the elasticity of substitution also causes a decline in the share of labor relative to capital (when labor intensity and factor price ratios are less than unity). Expected changes in the share of labor relative to capital (S) have actually taken place (Table 3). It can also be noted that the computed relative share of labor (computed on the basis of estimated parameters) is very close to the actual share. The error in the computed estimates of S is less than 1 percent of the actual estimates in all cases. It is interesting to note that as compared to Uttar Pradesh, there has been a marked decline in S in the case of Punjab. As shown in Table 1, Punjab has undergone a rapid mechanization as compared to the rest of the regions in India.

[6] The division of less than 10 acres and 10 acres and above is also suggested by a study on the relative efficiency of farm size groups [14].

[7] In testing the null hypothesis, the pooled standard errors are computed by not assuming that variances of two populations are equal. It can be expressed as:

$$SE = \sqrt{s_1^2/n_1 + s_2^2/n_2}$$

where

SE = pooled standard errors,

s_1 = computed standard error for the parameter in the mid-1950's,

s_2 = computed standard error for 1967–69,

n_1 = number of observations in the mid-1950's sample and

n_2 = number of observations in the 1967–69 combined sample.

Importance of Various Forces Affecting Relative Income Shares

To determine the importance of forces affecting the relative income shares, the effect of a unit change in each of the three parameters—elasticity of substitution (σ), factor price ratio (log $[q/w]$), and labor intensity $(1-\delta/\delta)$—on log S (ratio of labor share to capital share) was evaluated (Table 4). It was determined that a unit change in σ is the most important contributor to the change in the relative share of labor (log S) at both points of time in Uttar Pradesh as well as Punjab. The other two forces are, according to importance, log (q/w) and log $(1-\delta/\delta)$. Absolute importance of parameters σ and log $(1-\delta/\delta)$ has increased in 1967–69 as compared to the mid-1950's (Table 4). But the absolute importance of log (q/w) has declined in the 1967–69 period as compared to the mid-1950's. Since capital has been the expanding factor, the rise in σ has contributed to a decline in the relative share of labor. An expanding use of capital has been encouraged by the decline in the factor price ratio (q/w) in addition to noneconomic factors [17]. Expansion in capital use is reflected by a strong demand for tractors, particularly in the Punjab.

Implications of the Decline in Relative Share of Labor in Indian Agriculture

The evidence presented above indicates that there has been a decline in the relative factor share of labor in value added. This decline has occurred despite a marked increase in the wage rate, particularly in peak season. It seems to indicate that technological change has been labor-saving in nature. What are the implications of this change for the landless laborers who primarily depend on wage employment in agriculture for subsistence? This question should be examined in relation to the increase in labor force in the category of landless laborers.

Agricultural labor force has been divided between the cultivators and agricultural laborers in Indian Census publications.[8] Census data indicate that the labor force in the category of cultivators and nonagriculture marginally declined or at best remained constant between 1961 and 1971.[9] There was an increase, however, in the labor force in the agricultural laborers category in all the states in India. How can one explain the increases in agricultural laborers and marked increases in wage rates in recent years? The answer is that high yielding varieties of crops require planting and harvesting operations to be completed in a very short period of time. This sharpened the peaks in labor demand and thereby created a shortage of labor during that period. The seasonal shortage of labor pushed the wage rates upward. But there was not much improvement in the demand for labor in the nonpeak season. Overall demand for labor did not increase in direct proportion to the increases in output because of a decline in the labor intensity of the new technology. Therefore, despite the peak season wage increases, the relative share of labor declined.

Technological change in agriculture has, left to itself, failed to improve relative income shares of agricultural laborers. Under these circumstances, apprehensions have been expressed over government policies to permit and aid mechanization in Indian agriculture [17, 19, 21]. Rao [19] has supported a policy of selective mechanization in the states like Punjab on the grounds that the prohibitive cost of biological energy and acute shortage of labor during peak season form serious constraints in increasing output in these areas. Also, use of tractors increases crop intensity and thereby increases output. But at the same time it is necessary to provide work to the landless laborers during the off-season to guarantee them a basic minimum income. To accomplish this task, a wide range of rural works programs has been suggested [8, 15]. These programs can lead to further increases in output and labor demands. Domestic food surpluses can be used to sustain the rural works programs. The State of Maharashtra in India has already taken the lead in this direction.

Table 4. Computed partial derivatives of log S

Region	Year	$\frac{\partial \log S}{\partial \sigma}$	$\frac{\partial \log S}{\partial \log (1-\delta/\delta)}$	$\frac{\partial \log S}{\partial \log (q/w)}$
Uttar Pradesh				
	1956–57	−2.8859	−0.2453	−0.7546
	1967–69	−3.3374	+0.4855	−0.5146
Punjab				
	1955–56	−3.7103	+0.1744	−0.8255
	1967–69	−4.2840	+0.2755	−0.7245

[8] Only about 39 percent of landless laborers owned some land in 1961.

[9] A decline or constancy of labor force among the categories of cultivators and nonagricultural sector shows up primarily because of a sharp decline in female labor participation and a slight change in definition of female labor in the 1971 census.

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