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INCOME DISTRIBUTION IN THE AMERICAN AGRICULTURE: A REGIONAL ANALYSIS

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Introduction

Economics like other academic disciplines is subject to fads and fashions in terms of problems chosen for and methods of analysis. Thus it is interesting to note that the theory of factoral (or functional) income distribution has always been of concern to economists but has never been popular among them. The continuing interest in the explanation of factors share may partially be accounted for by its importance in determining the equilibrium level income and the rate of capital accumulation through the propensity to save which seems to be higher for capital owners than for wage and salary earners. In addition, for economists thinking in marxian terms, the division of output between labor and capital is of vital importance because it determines the degree of labor exploitation and the resulting intensity of the class struggle.

Among agricultural economists, traditionally preoccupied by problems of efficiency at various levels of the production process, questions of personal or factoral income distribution have been very unpopular and little time has been devoted to their study. In fact, during the post-war period there are only two published studies [8, 9] dealing with relative shares in agriculture that deserve mentioning. The obvious need for research in this area will partially be satisfied, we hope, by the present paper which contains an examination of the relative share of labor in the American agriculture at the regional level.

In particular, our objective is (a) to estimate the relative share of labor in agriculture and describe its behavior for ten U.S. regions for the period 1950-1970, and (b) to analyze the sources of change in the relative share for the same period. In the next section we present in a sketchy manner the relevant theory which will supply us with estimable equations necessary for the estimation of various key parameters. Then we proceed to the estimation of these parameters which subsequently are used to explain the changes in labor's relative share. We conclude the paper with a discussion of the implications of our findings.

Changes in Labor's Relative Share

In this section we demonstrate the proposition that changes in the relative share of a factor of production, labor in our case, depend on changes in the relative supply of factors, i.e., capital-labor ratio, the elasticity of substitution of capital for labor, and the type of technical progress [7, ch. VI.]

The production function. In its generic form the production function is given by

$$Q = F\ (C,\ L;\ t) \tag{1}$$

where F is homogeneous of degree one. The marginal product of each factor is positive but decreasing, that is, $F_C > 0$, $F_L > 0$, $F_{CC} < 0$ and $F_{LL} < 0$. The factor and product markets are assumed to be perfectly competitive, and therefore the payment to each factor for its contribution to production is equal to its marginal product; that is, $F_C = r$ and $F_L = w$, where r = return to capital and w = wage rate.

The purpose of introducing time (t) in the production function is to allow for technical change. The way t enters the production function is specified later in this section.

Technical change. We are interested in two aspects of technical change, namely, bias and rate. In the Hicksian sense, bias is defined as the proportional change in the ratio of marginal products of capital and labor, that is,

$$B = \frac{\partial [\frac{F_C}{F_L}]}{\partial t} \div \frac{F_C}{F_L} \tag{2}$$

which after some manipulations can be written as .

$$B = (\frac{\partial F_C}{\partial t} \div F_C) - (\frac{\partial F_L}{\partial t} \div F_L). \tag{3}$$

It is easily seen from (2) or (3) that when the ratio of marginal products does not change over time the bias is zero (neutral technical change). If F_C increases faster than F_L, B is positive and technical change is capital-using (labor-saving). In the opposite case B is negative and technical change is capital-saving (labor-using).

The rate of technical change, defined as $R = \frac{\partial F}{\partial t} \div F$, can be written for homogeneous production function of degree one as

$$R = \frac{\frac{\partial F_C}{\partial t} \cdot C + \frac{\partial F_L}{\partial t} \cdot L}{F} \tag{4}$$

which shows that in principle the type of technical change ($B \lesseqgtr 0$) does not affect its rate. Defining the relative share of capital and labor as $S_C = \frac{C \cdot F_C}{F}$ and $S_L = \frac{L \cdot F_L}{F} = 1 - S_C$ respectively, and multiplying the first and second terms of the numerator of expression (4) by $\frac{F_C}{F_C}$ and $\frac{F_L}{F_L}$ respectively, we can express the rate of technical change in terms of labor's relative share as below,

$$R = (1 - S_L)\frac{(\frac{\partial F_C}{\partial t})}{F_C} + S_L \frac{(\frac{\partial F_L}{\partial t})}{F_L}. \tag{5}$$

Changes in labor's relative share. By definition the relative share of labor is given by $S_L = \frac{L \cdot F_L}{F}$ and according to our assumptions $S_L = \frac{L \cdot w}{Q}$. Taking the total time derivative of S_L results in

$$\dot{S}_L = \frac{\dot{L}w}{L} + \frac{\dot{w}L}{w} - \frac{\dot{Q}L \cdot w}{Q^2}, \tag{6}$$

and by dividing both sides of (6) by S_L we obtain

$$\frac{\dot{S}_L}{S_L} = \frac{\dot{L}}{L} + \frac{\dot{w}}{w} - \frac{\dot{Q}}{Q}. \tag{7}$$

It is shown [4, 224-227] that the rate of change of the marginal product of labor can be written as

$$\frac{\dot{F}_L}{F_L} = R - (1 - S_L)\ B + \frac{1 - S_L}{\sigma}\ (\frac{\dot{k}}{k}) \tag{8}$$

where σ = elasticity of substitution and k = capital-labor ratio, and the rate of growth of output

$$\frac{\dot{F}}{F} = R + (1 - S_L)\ \frac{\dot{k}}{k} + \frac{\dot{L}}{L}. \tag{9}$$

By our assumptions we are allowed to substitute (8) and 9) into (7) and we can thus express the rate of change in the relative share of labor by equation (10) below,

$$\frac{\dot{S}_L}{S_L} = (1 - S_L)\left[B + (\frac{\sigma - 1}{\sigma})\ \frac{\dot{k}}{k}\right]. \tag{10}$$

It is seen from equation (10) that the rate of change in the relative share of labor depends on the bias of technical change, on the size of the elasticity of substitution, and on the rate of change of the capital-labor ratio. This result is equivalent to the opening statement of this section. The relative share of labor will decline, for example, when $B \geq 0$, $\sigma > 1$ and $\frac{\dot{k}}{k} > 0$. If $\sigma = 1$, S_L will decline only when technical progress is labor-saving ($B > 0$). It follows that constancy of relative shares does not require a unitary elasticity of substitution which seems to have been the traditional view reflected in the frequent use of Cobb-Douglas production functions.

Factor augmentation in a CES production function. It is necessary for the estimation of the parameters of interest to specify the form of the production function and the type of technical progress. We adopt a constant elasticity of substitution production function where technical progress takes the form of increasing the productivity of inputs [1] which is

$$Q = \left[(\alpha_o t^{\gamma_C} C)^{-\rho} + (\beta_o t^{\gamma_L} L)^{-\rho} \right]^{-\frac{1}{\rho}} \tag{11}$$

where $\rho = \frac{1 - \sigma}{\sigma}$, and $\alpha_o t^{\gamma_C}$ and $\beta_o t^{\gamma_L}$ are the efficiency variables augmenting capital and labor respectively with γ_C, $\gamma_L > 0$. This specification implies a declining rate of factor augmentation with time since $\frac{\dot{\alpha}}{\alpha} = \frac{\gamma_C}{t}$ and $\frac{\dot{\beta}}{\beta} = \frac{\gamma_L}{t}$.

With this production function the bias of technical progress is expressed by

$$B = \left(\frac{\sigma - 1}{\sigma}\right) \left(\frac{\gamma_C - \gamma_L}{t}\right) \tag{12}$$

and consequently

$$\frac{\dot{S}_L}{S_L} = - (1 - S_L) \left(\frac{\sigma - 1}{\sigma}\right) \left[\frac{\dot{k}}{k} - (\gamma_L - \gamma_C) t^{-1} \right] \tag{13}$$

<u>Estimation of α and $(\gamma_L - \gamma_C)$.</u> There are several equivalent ways one can estimate the parameters in question. We proceed by taking the marginal product of labor of equation (11) which is

$$\frac{\partial Q}{\partial L} = \left(\frac{Q}{L}\right)^{1+\rho} \left(\beta_o t^{\gamma_L}\right)^{-\rho}. \tag{14}$$

Since by assumption $\frac{\partial Q}{\partial L} = w$ we divide both sides of (14) by w and manipulate the result to obtain

$$S_L = w^{1-\sigma} \left(\beta_o t^{\gamma_L}\right)^{\sigma-1}. \tag{15}$$

Similarly, from the marginal product of capital we achieve

$$S_C = r^{1-\sigma} \left(\alpha_o t^{\gamma_L}\right)^{\sigma-1}. \tag{16}$$

It may appear that it is possible to obtain estimates of σ, γ_L and γ_C by means of equations (15) and (16). However, a moment's reflection will show that this is impossible. First, the two equations are not independent since by definition their sum is equal to unity. Second, the elasticity of substitution of capital for labor is the same as the elasticity of substitution of labor for capital, and therefore σ must be the same for both equations. It follows that equations (15) and (16) cannot be estimated independently.[1/]

For the examination of the sources of change in the relative share of labor it is sufficient to have estimates of the difference of the efficiency variables, that is $(\gamma_L - \gamma_C)$, even if the individual γ's are not known. To this effect, we have combined the two equations by dividing (15) by (16) which yields

$$\frac{S_L}{S_C} = \left(\frac{\beta_o}{\alpha_o}\right)^{\sigma-1} \left(\frac{w}{r}\right)^{1-\sigma} \cdot t^{(\gamma_L - \gamma_C)(\sigma-1)}. \tag{17}$$

and in logarithms

$$\ln\left(\frac{S_L}{S_C}\right) = (\sigma-1)\ln\left(\frac{\beta_o}{\alpha_o}\right) + (1-\sigma)\ln\left(\frac{w}{r}\right) + (\gamma_L - \gamma_C)(\sigma-1)\ln t. \qquad (18)$$

Comments. Basic to the development of this section are the assumptions of (1) constant returns to scale and (2) equality between marginal product of inputs and their remuneration. Since these two assumptions have often been questioned a brief discussion may be in order. With respect to the first assumption it has been argued [3] that the notion of returns to scale has a well defined meaning when the technology of production is held constant and the nature of the inputs does not change, since in our examination of the changes of labor's relative share we are considering both types of change over time. We must caution that the degree of homogeneity should not be interpreted as measuring the scale of operation. Therefore, the criticism of restricting the production function to constant returns to scale is not applicable.

The assumptions of $w = \frac{\partial Q}{\partial L}$ and $r = \frac{\partial Q}{\partial C}$ may not be totally satisfactory, but they are not totally unsatisfactory either, particularly for the agricultural sector. Even if $w - \frac{\partial Q}{\partial L} \neq 0$ but the difference $w - \frac{\partial Q}{\partial L}$ is approximately the same in direction and amount throughout the period under examination, our results should not be seriously disturbed because although the share of labor (capital) will be, let us say, underestimated (overestimated) their rates of change will remain unaffected.[2/]

Labor's Relative Share in American Agriculture: 1950-1970

It is useful to consider the behavior of labor's relative share, briefly at least, before we present the empirical results of our investigation into the causes of its changes.

The relative share of labor is estimated for ten regions[3/] on the basis of the definitional formula, that is, $S_L = \frac{w \cdot L}{Q}$. The wage rate (w) for each region was measured by the weighted average of the composite wage rates per hour of the states included in that region. The levels of agricultural employment served as weights. The relevant data are reported in [11]. The labor input was measured by the number of man-hours of labor used for farmwork which includes hired workers as well as farmers and unpaid family workers. With this definition of labor input, estimating the wage bill by $w \cdot L$ implies that farmers and unpaid family workers are assumed to receive the market wage rate. Regional estimates of labor input are reported in [12]. Agricultural income (Q) for each region is measured by the value added (VA) of agricultural production which is estimated by VA = (cash receipts from farm marketings + government payments + value of home consumption + rental value of farm dwellings + net change in farm inventories) - (farm operating expenses - expenses for hired labor) - taxes on farm property.

The data for the estimation of value added are available in [13]. The time series used have been deflated by the index of prices paid by farmer. (1957-59=100) when it represents expenses, and by the index of prices received by farmers (1957-59=100) when it represents revenues.

The estimated relative share of labor for each region for the period 1950-1970, its mean and standard deviation are presented in Table 1. The striking characteristic, common to all regions, is the rapid decline of the relative share, which in 1970 is reduced to half (the) size of 1950. Some regions seem to have reached a plateau in the last four years, and in the appendix to this paper we pay attention to this aspect.

TABLE 1

Regional Estimates of Agricultural Labor's Relative Share,
Mean and Standard Deviation: 1950-1970

Year	Relative Share of Labor									
	Northeast	Lake States	Corn Belt	Northern Plains	Appalachian	Southeast	Delta States	Southern Plains	Mountain	Pacific
1950	.558	.618	.411	.453	.599	.521	.576	.541	.468	.571
1	.556	.586	.428	.486	.605	.522	.633	.592	.438	.582
2	.525	.585	.420	.500	.624	.540	.592	.597	.443	.559
3	.505	.586	.428	.533	.573	.460	.555	.610	.448	.494
4	.530	.580	.361	.428	.542	.504	.545	.546	.472	.480
5	.503	.595	.414	.543	.496	.380	.430	.533	.457	.448
6	.481	.530	.380	.481	.477	.414	.493	.546	.424	.442
7	.481	.536	.350	.376	.502	.372	.476	.446	.377	.444
8	.431	.471	.332	.310	.421	.320	.428	.368	.358	.468
9	.441	.475	.363	.361	.445	.306	.355	.372	.349	.415
1960	.399	.445	.339	.297	.405	.312	.370	.351	.369	.419
1	.398	.403	.303	.319	.365	.279	.316	.309	.345	.422
2	.425	.416	.259	.255	.362	.282	.304	.314	.307	.400
3	.390	.368	.250	.269	.368	.251	.262	.316	.312	.394
4	.356	.386	.259	.283	.344	.239	.250	.309	.320	.358
5	.325	.324	.198	.217	.331	.240	.263	.272	.275	.358
6	.326	.300	.200	.210	.346	.251	.232	.251	.279	.368
7	.317	.313	.204	.226	.333	.263	.236	.274	.272	.355
8	.324	.308	.210	.233	.359	.265	.246	.274	.267	.353
9	.291	.285	.207	.202	.334	.259	.261	.273	.230	.347
1970	.287	.269	.208	.230	.337	.276	.245	.243	.217	.352
Mean	.421	.447	.311	.343	.437	.346	.384	.397	.354	.430
S.D.	.0896	.12	.0865	.1169	.1026	.1054	.1378	.1320	.0813	.0742

The behavior of labor's relative share per time is also described in Table 2, where we report the results of regressing S_L on t (time) and t^2. For each region we report the regression that better describes the trend of the relative share.

Empirical Results

We now turn to the estimation of the variables that will allow us to explain the changes in the proportion of income allocated to labor. The variables to be estimated are: the rate of change of labor's relative share $(\frac{\dot{S}_L}{S_L})$ and capital-labor ratio $(\frac{\dot{k}}{k})$, the elasticity of substitution (σ), and the difference of the efficiency of inputs indices $(\gamma_L - \gamma_C)$. Before we present our estimates we briefly discuss the statistical data on which the estimation is based.

Data. For the estimation of the relevant variables and parameters we need data on: (1) wage rates, (2) labor input, (3) value added, (4) capital input, and (5) interest rates. We have already described the available data for the measurement of wage rates, labor input and value added. The capital input consists of the following items: depreciation and other consumption of farm capital, expenses for repairs and operation of capital items, interest on farm mortgage debt, and expenses for feed, livestock, seed and fertilizers. The resulting series of capital output is deflated by the index of prices paid by farmers (1957-59=100). The statistical series of the items included in the estimate of capital input are available in [13]. Finally, the rate of return to capital is measured by the interest rate of the Production Credit Association which in addition to pure interst rate it includes various costs associated with the loan transactions. The Production Credit Association interest rate is available for eleven regions which

TABLE 2

Results of Regressions of S_L on t and t^2: All Regions 1950-1970

Region	Constant term	t	t^2	R^2	d.f.	D-W
1. Northeast	.5779 (.016)	-.0142* (.0006)		.97	19	1.97
2. Lake States	.6555 (.0227)	-.0190* (.0008)		.96	19	1.49
3. Corn Belt	.4579 (.0252)	-.0134* (.0009)		.92	19	1.40
4. Northern Plains	.533 (.0485)	-.0172* (.0017)		.83	19	1.39
5. Appalachian	.6767 (.0225)	-.0336* (.0034)	.00082* (.00015)	.95	18	1.79
6. Southeast	.6102 (.0268)	-.0405* (.0041)	.0011* (.00017)	.94	18	2.18
7. Delta States	.6865 (.0337)	-.0394* (.0051)	.0008* (.0002)	.94	18	1.62
8. Southern Plains	.6713 (.0421)	-.0343* (.0060)	.0006* (.0002)	.90	18	.83
9. Mountain	.4936 (.0202)	-.0127* (.0007)		.94	19	1.10
10. Pacific	.5983 (.0184)	-.0228* (.0027)	.00053* (.0001)	.94	18	1.43

NOTE: One asterisk indicates significant coefficient at the 5 percent level of significance.

we were unable to identify with the regions for which the other data are available. Thus we have used the same series, a weighted average of all regions, for all of our ten regions. This is equivalent to assuming that the rate of return to capital is the same in all regions. A feeling of uneasiness resulting from this assumption forced upon us by data limitations is reduced by the fact that the available data indicate that interest rates are changing at approximately the same rate across regions. The data on interest rate which are available in [14] were deflated by the index of prices paid by farmers.

Estimates of $\frac{\dot{S}_L}{S_L}$ and $\frac{\dot{k}}{k}$. The estimated annual rates of change of labor's relative share $(\frac{\dot{S}_L}{S_L})$ and capital-labor ratio $(\frac{\dot{k}}{k})$ were obtained directly from the available data. In Table 3 we present for each region the average annual rate of change of S_L and k, and their standard errors. It may be seen that the regional differences in both rates are not substantial. The relative share of labor declines on the average at 2.3 to 3.9 percent per year, while the capital-labor ratio increases at 4.3 to 9.1 percent per year. These estimates will be used later in the paper in connection with equation (13).

Estimates of σ and $(\gamma_L - \gamma_C)$. Regional estimates of the elasticity of substitution and the difference of the efficiency of inputs indices were obtained from the estimation of equation (18a) below,

$$\ln \left(\frac{S_L}{S_C}\right)_{t,i} = b_0 + b_1 \ln \left(\frac{w}{r}\right)_{t,i} + b_2 \ln t + u_t \qquad (18a)$$

for t = 1950, . . ., 1970 and i = 1, . . ., 10 and where

TABLE 3

Annual Average Rates of Change of S_L and $\frac{C}{L}$, by Region, 1950-1970

Region	$\frac{\dot{S}_L}{S_L}$	$\frac{\dot{k}}{k}$
1. Northeast	-.031	.048
	(.012)	(.007)
2. Lake States	-.039	.061
	(.014)	(.005)
3. Corn Belt	-.029	.062
	(.020)	(.008)
4. Northern Plains	-.023	.062
	(.010)	(.004)
5. Appalachian	-.026	.067
	(.014)	(.007)
6. Southeast	-.027	.075
	(.020)	(.011)
7. Delta States	-.037	.091
	(.022)	(.012)
8. Southern Plains	-.036	.071
	(.018)	(.013)
9. Mountain	-.035	.066
	(.014)	(.015)
10. Pacific	-.023	.043
	(.011)	(.011)

NOTE: The standard errors are in parentheses.

$b_0 = (\sigma-1)\ (\frac{\beta_0}{\alpha_0})$, $b_1 = 1-\sigma$, $b_2 = (\gamma_L - \gamma_C)\ (\sigma-1)$ and, $u_t \sim NID\ (0, \sigma_u^2)$.

The assumed distribution of the error term (u_t) implies that the right-hand side of equation (18) is multiplied by e^u which follows a lognormal distribution. If $\hat{b}_1$ and $\hat{b}_2$ are the estimates of b_1 and b_2, respectively, estimates of σ and $(\gamma_L - \gamma_C)$ can be obtained from $\hat{\sigma} = 1 - \hat{b}_1$ and $\widehat{(\gamma_L - \gamma_C)} = \frac{\hat{b}_2}{\hat{b}_1}$.

The variances of these estimates are obtained by $var(\hat{\sigma}) = var(\hat{b}_1)$ and

$$var\ \widehat{(\gamma_L - \gamma_C)} = \left(\frac{1}{-\hat{b}_1}\right)^2 var\ (\hat{b}_2) + \left[\frac{\hat{b}_2}{(-\hat{b}_1)^2}\right]^2 \quad var(\hat{b}_1) + \left(\frac{1}{-\hat{b}_1}\right)\left[\frac{\hat{b}_2}{(-\hat{b}_1)^2}\right]$$

$cov(\hat{b}_1, \hat{b}_2)$.

The results of applying direct least squares to the data of each of the ten regions are presented in Table 4. The expected value of the estimated elasticity of substitution is positive and significantly different from zero in all ten regions. However, the critical value of $\hat{\sigma}$ in our context is unity, and although its expected value is greater than one in all regions, it is significantly so in six. The expected value of the estimated $(\gamma_L - \gamma_C)$ is negative in all regions indicating that the efficiency of capital rises faster than that of labor. There exists a difficulty in testing the significance of $\widehat{(\gamma_L - \gamma_C)}$. The difficulty arises from the fact that the distribution of $\widehat{(\gamma_L - \gamma_C)}$, which is the ratio of two variables each following a t-distribution, is not known. Given this difficulty, we shall use all estimates of $(\gamma_L - \gamma_C)$ in the subsequent analysis but with a decreasing degree of confidence in the results as the standard error of the estimate increases.

<u>Sources of change in $\frac{\dot{S}_L}{S_L}$.</u> We know from equation (13) that the rate of change in the relative share of labor depends on the elasticity of substitution

TABLE 4

Regression Results of Equation (18a): Ten Regions, 1950-1970

Region	$(\sigma-1)\ \ln\ (\frac{\beta_o}{\alpha_o})$	$1-\sigma$	$(\sigma-1)\ (\gamma_L-\gamma_C)$	$\bar{R}^2$	d.f.	D-W	σ	$\gamma_L-\gamma_C$
1. Northeast	-3.226	-1.641* (.563)	-.1527 (.097)	.86	18	1.19	2.641* (.563)	-.093 (.069)
2. Lake States	-4.003	-2.172* (.703)	-.2561** (.107)	.85	18	.95	3.172* (.703)	-.118 (.18)
3. Corn Belt	-4.146	-1.813* (.585)	-.1637 (.1011)	.80	18	1.32	2.813* (.585)	-.090 (.119)
4. Northern Plains	-2.763	-1.481 (.985)	-.3808* (.1296)	.70	18	1.22	2.481 (.985)	-.271 (.254)
5. Appalachian	-.412	-.437 (.347)	-.4005* (.077)	.88	18	1.09	1.437 (.347)	-.916 (1.885)
6. Southeast	.167	-.099 (.347)	-.4982* (.093)	.84	18	1.06	1.099 (.347)	-5.05 (18.46)
7. Delta States	-1.350	-.801** (.383)	-.4881* (.106)	.86	18	.99	1.801* (.383)	-.609 (.467)
8. Southern Plains	-1.953	-1.149 (.695)	-.4153* (.135)	.79	18	.91	2.149 (.695)	-.361 (.325)
9. Mountain	-3.464	-1.643* (.628)	-.1798** (.091)	.80	18	.63	2.643* (.628)	-.109 (.090)
10. Pacific	-.845	-.679** (.296)	-.2685* (.044)	.94	18	1.91	1.679* (.296)	-.394 (.398)

Note: Standard errors are shown in parentheses. One and two asterisks indicate significance at one and five percent levels, respectively.

the rate of change in the capital-labor ratio and the difference in the efficiency of inputs. We have gathered information on all three variables which now can be used to explain the decline in the proportion of agricultural income allocated to labor. The necessary information for obtaining $\frac{\dot{S}_L}{S_L}$ from equation (13) are given in Table 5 (columns 2-5). To obtain the values of $(1 - S_L)$ we have used the mean values of S_L which is given in Table 1. The values of $\frac{\sigma-1}{\sigma}$ are derived from Table 4 which gives estimates of σ. The estimates of $\frac{\dot{k}}{k}$ are taken from Table 3. Finally the estimates of $(\gamma_L - \gamma_C)t^{-1}$ were obtained by using the values of $(\gamma_L - \gamma_C)$ from Table 4 and taking the mean value of t (t = 11). By means of equation (13) we have obtained estimates of $\frac{\dot{S}_L}{S_L}$ which are presented in column (6) of Table 5. It may be noted that the regional estimates of the average annual rate of decline in labor's relative share obtained from equation (13) are very close to the estimates of Table 3 obtained directly from the available statistical data.

We postpone the discussion of the results to present the regional estimates of the bias of technical progress.

Estimates of bias of technical progress. We have shown earlier that the bias of technical progress is given by

$$B = \left(\frac{\sigma-1}{\sigma}\right) (\gamma_C - \gamma_L)t^{-1}. \tag{12}$$

Thus regional estimates of the bias can easily be obtained from Table 5 by multiplying the product of columns (3) and (5) by minus one. The estimated bias is given in column (7) of Table 5. It is seen that the estimates of B are positive in all regions indicating that the marginal product of capital has increased relative to that of labor as a result of technical change.

TABLE 5

Average Values of the Variables in Equation (13)

	Region	$1-S_L$	$\frac{\sigma-1}{\sigma}$	$\frac{\dot{k}}{k}$	$(\gamma_L - \gamma_C)^{-t}$	$\frac{\dot{S}_L}{S_L}$	B
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
1.	Northeast	.579	.621	.048	-.0084	-.0202	.005
2.	Lake States	.553	.685	.061	-.0107	-.0271	.0073
3.	Corn Belt	.689	.645	.062	-.0081	-.0311	.0052
4.	Northern Plains	.657	.597	.062	-.0246	-.0339	.0146
5.	Appalachian	.563	.304	.067	-.0832	-.0256	.0252
6.	Southeast	.654	.090	.075	-.4590	-.0313	.0413
7.	Delta States	.616	.445	.091	-.0553	-.0401	.0246
8.	Southern Plains	.603	.535	.071	-.0328	-.0334	.0175
9.	Mountain	.646	.622	.066	-.0099	-.0304	.0061
10.	Pacific	.570	.404	.043	-.0358	-.0181	.0144

Interpretation of the results. We have already indicated that there are several combinations of values of the relevant parameters that may cause the relative share of labor to decline. The results obtained from our empirical investigation specify the combination of forces that has led to the decline of labor's relative share in agriculture. We have found a capital-using technical progress (positive B) in all regions, positive rates of growth in the capital-labor ratio and elasticities of substitution that exceed unity. It is apparent from equation (10) [or equation (13)] that the result is negative $\frac{\dot{S}_L}{S_L}$ and, therefore, a decline in S_L.

Equivalently, our empirical results may be interpreted as follows: With given factor prices, technical progress that increases relatively the marginal product of capital provides producers with an incentive to substitute capital for labor. As a result the marginal product of labor would increase, and under perfectly competitive conditions in the labor market the wage rate would also increase. Although this may have a positive effect on the share of labor, with an elasticity of substitution greater than unity the relative share of labor would decrease.

Since capital-using technical change is equivalent to a relative increase in the supply of labor two additional comments may be in order. First, given the limited capacity of the economy to absorb agricultural products, capital-using technical change would tend to decrease, in absolute terms, the level of employment, thus creating a dumpening effect on the level of wages which in turn would tend to reduce the rate of capital substitution. Second, simultaneously with the introduction of capital-using technology which has served as a device to keep labor in abundant supplies, the massive movement of agricultural labor to the non-agricultural sector generated by increasing wage differentials has shifted the supply of labor curve to the left thus creating a positive effect on wages. The available data show that the net effect of these changes has been an increasing wage rate but a decreasing relative share of labor.

Comments: It is interesting to observe that our estimates reveal close similarities between the regions. For example, the average annual rates of change of the relative share of labor and the capital labor rates tend to cluster around -.03 and .06, respectively. In addition, the elasticity of substitution is found to be around 2 and many of the regional estimates are statistically equal. The examination of these similarities is not our concern in this paper. However, we are tempted to speculate that part oof the explanation may be related to the high degree of labor mobility within (from farm to nonfarm employment) and among regions as well as to the synchronous regional adoption of technological advancements.

Another feature of our results is that the estimate of $(\gamma_L - \gamma_C)$ is negative (in all regions) which means that the efficiency of capital is higher than that of labor.

It may be noted that we have not discussed the causes of factor-augmentation, as this topic belongs to the area of investigation of the sources of inputs productivity growth.[4/] However, we may simply mention that, as far as labor is concerned, the increasing volume of past and current research attributes labor productivity increases to the improving quality of labor due primarily to the educational attainments of the labor force.

The definition of labor (measured in man-hours), as we stated earlier, includes farm work performed by farm operators, unpaid family workers, and hired workers. To arrive at an estimate of the wage bill, the wage rate for hired labor was applied to the other two categories of labor. If, however, farm operators have higher productivity due to larger amounts of investment in human capital, the above procedure leads to an underestimate of labor's share with unknown effects on the estimated regression coefficients, unless the effect of the underestimation on the share's ratio is uniform throughout the period in which case the estimated elasticity of substitution will be unaffected. The nature of our data does not allow the estimation of the amount of capital's share that belongs to human capital of farm operators.

We indicated earlier in the paper that in some regions the share of labor shows a tendency to stabilize in the last four years. These regions have been examined further and the results are reported in the appendix.

Summary

In this paper we have attempted an empirical investigation of the sources of change in the relative share of labor in the American agricultural sector. We have examined ten regions comprising 48 states for a period of 21 years (1950-1970). We have conducted our study within the neoclassical framework of production and distribution by adopting a CES production function allowing for factor augmentation and assuming competitive markets for factors of production and output.

The results of this study may be summarized as follows:

1. The relative share of labor is declining in all regions at an average annual rate in the neighborhood of 3 percent.
2. The capital labor ratio is increasing in all regions. The average annual rate varies from about 4 to 9 percent.
3. The elasticity of substitution is found to be greater than unity in all regions, and it varies regionally from approximately 1.1 to

3.2. It follows that the Cobb-Douglas production, so often used in studies of the agricultural sector, by imposing the restriction that $\sigma=1$ biases the estimates of the remaining parameters.

4. The difference between labor and capital efficiency $(\gamma_L - \gamma_C)$ is negative in all regions. Since the standard errors of $(\gamma_L - \gamma_C)$ are high for most regions the question of their reliability remains.

5. Technical progress is nonneutral. Its bias is estimated and is found to be positive in all regions indicating labor-saving technical progress.

6. The combination of a greater than unity elasticity of substitution and a negative $(\gamma_L - \gamma_C)$ results in a declining relative share of labor.

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APPENDIX

In an attempt to improve some of the estimates presented in Table 4 we have experimented with the regions that have shown a tendency of stability in relative shares. For these regions we have repeated our statistical analysis with the observations of the period 1950-1966. The results are reported in Table 6. Despite the loss of four degrees of freedom the equations of Table 6 are a clear improvement over the corresponding equations of Table 4. In two cases (Appalachian and Southeast regions) the elasticity of substitution is significantly greater than one with no loss in the other four regions. More impressive is the improvement in the estimates of $(\gamma_L - \gamma_C)$. For the Appalachian, Southeast and Delta States regions the estimate of $(\gamma_L - \gamma_C)$ is reduced in absolute value to more satisfactory levels. No substantial changes have occurred in the adjusted coefficient of determination.

As we have already mentioned in the remaining four years (1967-1970) the relative share of labor seems to have reached a floor in the six regions of Table 6. On the basis of equation (13) we may infer either that the elasticity of substitution has decreased to a value of one which is rather unlikely, or that $(\gamma_L - \gamma_C)t^{-1}$ is positive and equal to $\frac{\dot{k}}{k}$. Given the limited number of observations we have not subjected our data to further tests. A period of four years is much too short to supply any reliable information of the sort we need in our investigation.

TABLE 6

Regression Results of Equation (18a): Six Regions, 1950-1966

Region	$(\sigma-1)\ \ln\ (\frac{\beta_o}{\alpha_o})$	$1-\sigma$	$(\sigma-1\ (\gamma_L-\gamma_c)$	$\bar{R}^2$	d.f	D-W	σ	$\gamma_L-\gamma_c$
3. Corn Belt	-5.37	-2.34*	-.093	.73	14	1.55	3 34**	-.04
		(.90)	(.123)				(.90	(.052)
4. Northern Plains	-2.17	-1.19	-.387*	.57	14	1.13	2.19	-.33
		(1.34)	(.149)				(1.34)	(.29)
5. Appalachian	-1.74	-.94	-.346*	.86	14	.94	1.94*	-.37
		(.54)	(.092)				(.54)	(.14)
6. Southeast	-2.95	-1.21**	-.358*	.86	14	1.24	2.21**	-.21
		(.60)	(.109)				(.60)	(.24)
7. Delta States	-4.76	-2.05*	-.333*	.86	14	1.29	3.05*	-.16
		(.70)	(.126)				(.70)	(.004)
8. Southern Plains	-2.78	-1.50	-.378**	.72	14	.75	2.50	-.25
		(1.03)					(1.03)	(.19)

NOTE: Standard errors are shown in parentheses. One and two asterisks indicate significance at one and five percent levels, respectively.

FOOTNOTES

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1/ The problem we are alluding to is essentially that associated with the well-known "impossibility theorem" [2]. In this connection a recent paper by Sato [10] is of interest.

2/ It is fair at this point to mention the much more damaging criticism of the inappropriateness of the neoclassical production theory in dealing with problems of income distribution. However, given the present state of the debate between neoclassists and Cambridge economists, and the fact that those involved in the controversy are still using aggregate production functions, we do not feel too uncomfortable in examining the share of labor within the neoclassical framework.

3/ The states contained in each region are as follows:

Northeast: Maine, Vt., N.H., Mass., R.I., Conn., N.Y., N.J., Pa., Md., and Del.

Lake States: Mich., Wisc., and Minn.

Corn Belt: Iowa, Mo., Ill., Ind., and Ohio.

Northern Plains: N. Dak., S. Dak., Nebr., and Kans.

Appalachian: W. Va., Va., Ky., Tenn., and N.C.

Southeast: Ala., Ga., S.C., and Fla.

Delta States: Ark., Miss., and La.

Southern Plains: Okla. and Texas.

Mountain: Mont., Idaho, Wyo., Nev., Utah, Colo., Ariz., and N. Mex.

Pacific: Wash., Oregon and Calif.

FOOTNOTES (continued)

4/ For studies devoted to the U.S. agricultural sector the reader is referred to Griliches [5, 6] and Welch [15].

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