Comparative Efficiency of Farm Tenure Classes in the Combination of Resources

By Walter G. Miller

The extent to which the tenure status of farm operators affects agricultural efficiency has interested economists for decades. Different theories dealing with the subject have evolved; but only a few empirical studies have been made to test their validity. This deficiency in agricultural economics research arises, at least partly, from the need for techniques and procedures that will deal adequately with the problems involved. One purpose of the study on which this report is based was to explore methods that might be used in analyzing the inefficiencies that are due to tenure. The study was conducted under a cooperative arrangement between the Farm Economics Research Division, Agricultural Research Service, and the Agricultural Experiment Stations of Missouri, Iowa, Nebraska, and Kansas. The author acknowledges the contributions of the members of the North Central Land Tenure Research Committee to this article.

AMERICAN FARMERS are usually broadly classified as full owners, part owners, and tenants; tenants are subclassified according to the method of rental payment. Existing theories in tenure economics suggest that these tenure classes of farmers should differ as to efficiency in the use of farm resources (*11*, *10*, *3*, *8*).[1] The objective here was to examine the usefulness of least-squares estimating equations for comparing efficiency in the combination of resources within farms operated under different farm tenure classifications. The central hypothesis in this analysis of farm tenure classes was that tenure classes are different populations, with different patterns of resource allocation and levels of efficiency.

The Methods Used

The analysis rests heavily upon estimating equations of the Cobb-Douglas type.[2] These equations were fitted to cross-sectional data for the 1954 production year obtained from a sample of farms in Iowa and northern Illinois.[3]

A separate estimating equation was fitted to the data for each tenure class considered—full owners, livestock-share renters, and crop-share-cash renters.[4] The parameters and relationships derived for each tenure class were taken to represent those for the average farm within each group.[5] The estimating equations fitted are of the form

$$\hat{Y}=aX_1^{b_1}X_2^{b_2}X_3^{b_3}, \qquad (1)$$

in which, Y refers to gross production in dollars, and the resources, (the X's), are X_1—land investment in dollars, X_2—labor in weeks, and X_3—capital services in dollars. The b's are the estimated elasticities of production; that is, a 1-percent change in resource, X_i (i=1, 2, or 3) yields a change of b_i percent in production.

The data used yielded the production elasticities and other statistics shown in table 1. Except for the production elasticities of land and labor for

[1] Underlined numbers in parentheses refer to Literature Cited, page 15.

[2] This type of equation is used frequently in resource productivity studies but to a limited extent in the analysis of tenure-resource allocation problems (*4*).

[3] Because the data used were obtained by a stratified-random sample of farms, with different sampling proportions applied to each stratum, the functions were derived through weighted least squares.

[4] In order to reduce the confounding influence of age as it relates to the quality of labor and management, and to preferences, only the younger owners—those under 45 years of age—were examined because they are more comparable to tenants, who are predominantly the younger farmers. The numbers of observations were as follows: 51 full owners (under age 45), 78 livestock-share renters, and 75 crop-share-cash renters.

[5] The estimates obtained are not the true empirical counterparts of the theoretical concepts of intrafarm relationships; they are reasonable approximations from interfarm (cross-sectional) data.

TABLE 1.—*Parameters and related statistics of the estimating equation for each tenure class*

Tenure class	Regression constant (a)	Production elasticities[1]			Sum of elasticities (Σb_i)	Correlation index (R^2)
		Land (b_1)	Labor (b_2)	Capital services (b_3)		
Full owners	4.0200	0.0919	0.1719	0.7351	0.9989	0.76
		(.06)	(.12)	(.07)		
Livestock-share renters	6.4759	.2315	.1845	.5330	.9490	.68
		(.04)	(.08)	(.07)		
Crop-share-cash renters	3.4166	.2937	.2472	.4782	1.0191	.73
		(.04)	(.11)	(.07)		

[1] The standard errors for the production elasticities are indicated, respectively, in parentheses below.

full owners, elasticities differ significantly from zero at probability levels of less than 10 percent. Estimates of elasticities of production that do not differ significantly from zero, are not, of course, plausible results. These occurrences may be accounted for by the general problem of intercorrelation that plagues regression analyses of this kind. Hence, the ensuing analysis based on these coefficients needs to be made with certain reservations.

Although the elasticities of production for land and labor for owners were nonsignificant at the more frequently acceptable levels of probability, the differences between tenure classes in the elasticities were tested. These tests were made in pairs. As shown in table 2, only 3 of the 9 pairs of differences tested differed significantly from zero at the 10 percent level of probability. The significant ones are (1) between full owners and the two tenant groups with respect to land and (2) between full owners and crop-share-cash renters with respect to capital services. None of the differences between the two tenant groups are significant. One might have expected to find more of the differences significant because of possible differences between tenure classes in scale of operation and combination of products.[6]

On the premise that the individual estimating equations represent the production functions which, along with the prices of productive factors, should guide decisions as to resource combinations, the analysis that follows seeks to estimate

[6] The differential effects of intercorrelation of the input categories and aggregation may also have affected the results obtained.

TABLE 2.—*Values of t for differences between tenure classes in production elasticities*

Tenure classes compared	Value of *t* for differences		
	Land	Labor	Capital services
Full owners vs. livestock-share renters	[1] 1.99	[2] 0.12	[2] 1.50
Full owners vs. crop-share-cash renters	[3] 2.68	[2] 0.59	[4] 1.86
Livestock-share vs. crop-share-cash renters	[2] 1.08	[2] 0.47	[2] 0.57

[1] Significant at a probability level of 1 to 5 percent.
[2] Nonsignificant at probability levels of 10 percent and less.
[3] Significant at a probability level of 0.1 to 1 percent.
[4] Significant at a probability level of 5 to 10 percent.

the extent to which the optimum in the combination of resources is achieved under each tenure situation. Holding production fixed, the optimum (or the least-cost) combination of resources is determined by obtaining an equality of the ratios of the marginal return for each resource with the respective resource price.[7]

Using the basic estimating equation (1) for each tenure class, the equality to be achieved is

$$\frac{\partial \hat{Y}/\partial X_1}{P_1}=\frac{\partial \hat{Y}/\partial X_2}{P_2}=\frac{\partial \hat{Y}/\partial X_3}{P_3}, \qquad (2)$$

[7] Actually, opportunity costs are estimated and used instead of market factor prices. The solution used is analogous, however, to equating the marginal rates of substitution of resources with the inverse of the respective price ratios. The exceptions are that the value of production is used instead of physical production, and opportunity costs are used instead of actual factor prices.

in which production is held fixed at the geometric mean[8] for the respective tenure class.[9] That is, the marginal return-opportunity cost ratios are made equal for the resources—land, labor, and capital services. The values used for the opportunity costs are P_1 (land) = \$0.06 per dollar of land investment; P_2 (labor) = \$40 per week; and P_3 (capital) = \$1.10 per dollar, in which the extra dollar represents resources used up in the production process.

The solution yields the lowest possible costs for the given levels of production, granting the basic estimating equations and the price assumptions.[10] The calculated resource inputs associated with the optima are, more accurately, what the mean resource inputs, X_i, should have been to achieve the most efficient allocation of resources. The optimum quantities of each resource and the deviations of actual resource inputs from the optimum are shown in table 3.

Levels of Inefficiencies in Resource Combinations

According to table 3, livestock-share renters are the most efficient producers with total resource inputs used up of \$184, or 1.2 percent, more than the optimum. Full owners are the most inefficient when compared with tenant operators; their average excess of resource inputs over the minimum cost attainable is \$394, or 2.9 percent. Crop-share-cash renters are more like livestock-share renters. It is shown later that the small differences in average deviations, or levels of inefficiency, are not significant in a probability sense.[11] The expected differences could be reduced by possible errors in measurement.[12] Greater contrasts and variations in resource excesses and deficits are observed, however, through examination of the deviations with respect to each of the resource categories.

Full owners should have used less of both land and labor with more capital to achieve the optimum combinations. They show an excess (\$5,033, or 22.4 percent) in the amount of land needed to achieve their optimum and a deficit (\$1,031, or 10.4 percent) in capital services. Their greatest inefficiency was in the use of labor, which was 44 percent in excess of the optimum.[13] These results are in accord with economic reasoning: On the average, full owners should be limited in land, or capital services, or both, as compared with labor, because of capital rationing. Prior com-

---

[8] The geometric mean was used because the estimating equations were derived after logarithmic transformation of the variables. The arithmetic mean could have been used as well but would, of course, be subject to larger errors of the estimate.

[9] As $\partial\hat{Y}/\partial X_i = b_i\hat{Y}/X_i$, the equality to be achieved, in other terms, is

$$\frac{b_1\overline{Y}/X_1}{P_1} = \frac{b_2\overline{Y}/X_2}{P_2} = \frac{b_3\overline{Y}/X_3}{P_3} \qquad (1)$$

the unknowns being the values for X_i that represent the optimum quantities called X_i^*. The algebraic solution used was as follows. From equation (1) it follows that

$$X_1P_1b_2/P_2b_1 = X_2 = X_1', \text{ and} \qquad (2a)$$

$$X_1P_1b_3/P_3b_1 = X_3 = X_1'' \qquad (2b)$$

Substituting the left sides of equations (2a) and (2b), respectively, for X_2 and X_3 into the basic estimating equation expresses that equation in terms of X_1. Thus, with $\hat{Y} = \overline{Y}$, the estimating equation becomes

$$\overline{Y} = aX_1^{b_1}X_1'^{b_2}X_1''^{b_3}. \qquad (3)$$

Solve for X_1^* (the optimum quantity of X_1) in logarithms:

$$\log X_1^* = 1/\sum_{i=1}^{3} b_i \Big[\log \overline{Y} - \log a - \sum_{i=2}^{3} b_i(\log P_1/P_i + \log b_i/b_1)\Big]. \qquad (4)$$

The optimum quantities of X_2 and X_3 are obtained by substituting X_1^* into equations (2a) and (2b), respectively. That is

$$X_j^* = X_1^*P_1b_j/P_jb_1. \quad (j=2,3) \qquad (5)$$

[10] Logically, different prices will yield different optima.

[11] Interpreted in a different way: full owners are 97.1 percent, livestock-share renters 98.8 percent, and crop-share-cash renters 98.2 percent efficient. The differences between these "efficiency indices" are probably nonsignificant.

[12] For example, as the market values used for land inputs were obtained from tenants as well as owners, one can suspect subjective underestimation by tenants on the average.

[13] The excess labor for full owners can be identified, perhaps, with the general belief that "there is too much labor in agriculture." But it should be noted that, on the average, about 20 percent of the total labor reported is from the operator's family.

TABLE 3.—*Optimum resource combination, and deviations of actual resource combination from the optimum at the geometric mean of production for each tenure class*

Item	Resource combinations		Average deviation of actual from optimum combination	
	Actual	Optimum	Amount [1]	Percent
Full owners with production at $17,714:				
Land ... dollars	27,551	22,518	+5,033	+22.4
Labor ... weeks	91	63	+28	+44.4
Capital services ... dollars	8,794	9,825	−1,031	−10.4
Total value of productive services [2] ... dollars	14,087	13,696	391	2.9
Livestock-share renters with production at $22,936:				
Land ... dollars	45,884	65,238	−19,354	−29.7
Labor ... weeks	77	78	−1	−1.3
Capital services ... dollars	9,566	8,181	+1,385	+12.0
Total value of productive services [2] ... dollars	15,399	15,215	184	1.2
Crop-share-cash renters with production at $15,105:				
Land ... dollars	41,506	59,389	−17,883	−30.1
Labor ... weeks	76	75	+1	+1.3
Capital services ... dollars	6,517	5,274	+1,243	+23.6
Total value of productive services [2] ... dollars	12,047	11,837	210	1.8

[1] (+) indicates an excess (or greater than the optimum), and (—) indicates a deficit (or less than the optimum).
[2] Land services are valued at 6 percent of the total market value of land, and labor services at $40 per week.

mitments in land purchases may cause a restriction in the amount of other capital needed to operate most efficiently with a given quantity of labor.

The deviations from optimum resource combinations are similar for the tenant groups, with a minor exception: Crop-share-cash renters would require an additional week (or 1.3 percent) of labor while livestock share renters should have used a week less. This difference may be ignored. Hence the needed reorganization of resources for the tenants is predominantly the substitution of land for capital services. The less-than-optimum use of land may be associated partly with possible "undervaluation" of land input as noted earlier.[14]

[14] If the malallocations had been in terms of land-labor or labor-capital ratios, more plausible explanations could be advanced. For example, if the reorganization needed were the substitution of land for labor services, the inference could be drawn that landlords are in a better bargaining position than tenants. That is, landlords would be maximizing the marginal returns to land and minimizing the marginal returns to the tenants' contributions in labor. Or, if the malallocations were in terms of excess capital and deficit labor, the conclusion could be that a premium is placed on minimizing irksome farm operations or on leisure time. But, these ideas are not relevant in this instance.

However, there may still be a tendency under livestock-share leasing for landlords to "ration" land, choosing instead to furnish additional capital that is matched directly by tenants' capital under the terms of the usual livestock-share arrangements. If landlords provided more land, they would also need to provide more capital.

In the case of crop-share-cash leases, one might have supposed capital services to be limited in relation to land because of "imperfections" in cost-sharing arrangements. The improvements required in resource use would then be in favor of capital services instead of land. The results do not support these hypotheses. It is likely that restrictions in specific kinds of capital items are concealed by the aggregation of capital services. It may also be true that under conditions of a landlord rental market, landlords tend to allocate their land to tenants who have the largest amounts of capital available for the farm business.

Inasmuch as the directions of the resource malallocations observed do not differ between the tenant groups, the total value of productive services required at the optima for a similar level of production would vary between them (table 4). With the same production of $17,714, the average

490700—59——2

TABLE 4.—*Resource quantities and total value of productive services required at the optima by each tenure class for a similar production level*

Tenure class	Production [1]	Resource requirements			Total value of services [2]
		Land	Labor	Capital services	
	Dollars	*Dollars*	*Weeks*	*Dollars*	*Dollars*
Full owners	17, 714	22, 518	63	9, 825	13, 696
Livestock-share renters	17, 714	49, 694	59	6, 233	11, 575
Crop-share-cash renters	17, 714	69, 423	88	6, 168	13, 853

[1] This level of production is that for the full owners.
[2] Productive services are valued as before.

livestock-share farm would use resources in the amount of \$11,575. This is considerably less than the \$13,853, required by the average crop-share-cash farm.

The total value of productive services required by the average crop-share-cash farm would be 19.7 percent greater than the amount required by the average livestock-share farm. Also, the amount required by the average owner-operator farm would be higher by 18.3 percent. When owner-operator farms are compared with crop-share-cash farms, the value of productive services is only 1.2 percent higher than that for the latter tenure class, a negligible difference.

The foregoing differences between the tenure classes in the total value of productive services required as well as the associated resource inputs are uniquely a function of the basic estimating equations representing each tenure class. The different estimating equations, in turn, cause differences in optimum resource requirements. To the extent that these differences are tenure-oriented and significant, it is presumed that the livestock-share lease encourages superior selection of enterprises or management.

Significance Tests for Inefficiencies in Resource Combinations

The significance of the deviations of actual resource inputs from the optimum inputs were first tested by comparing, statistically, the marginal rates of substitution of the resources at the geometric means with the inverses of the respective price ratios for the resources. Second, the differences in the absolute deviations (signs ignored) between these substitution rates and the respective price ratios were examined.[15]

From the basic estimating equation (1), the marginal rate at which resource X_j substitutes for X_i is defined as

$$\partial X_j/\partial X_i = b_i X_j / b_j X_i. \quad (3)$$

The well-known condition for the optimum combination of resources is that the marginal rate at which one resource substitutes for another must be equal to the inverse of the ratio of prices for the respective resources. It follows from equation (2) that this condition can be expressed as

$$b_i X_j / b_j X_i = P_i / P_j \quad (4)$$

for all possible pairs of resources. P_i and P_j are, respectively, the prices of the resources X_i and X_j. It can be shown that at the optimum values (X_i^*) determined for each resource, the marginal rates of substitution of the resources are identical to the inverses of the price ratios. That is,

$$b_i X_j^* / b_j X_i^* = P_i / P_j. \quad (5)$$

Thus the deviations of the marginal rates of substitution of resources at the geometric means from the inverse of the respective price ratios were used as a means of testing for inefficiencies in the combination of resources. The test variable becomes

$$d_{j,i} = b_i \overline{X}_j / b_j \overline{X}_i - P_i / P_j. \quad (6)$$

The marginal rate at which resources substitute at the geometric means are shown in table 5. In

[15] The author is indebted to Dr. C. B. Baker of the University of Illinois for suggesting these procedures.

the case of full owners, for example, $566 of land substitute for 1 week of labor; and ignoring the sign, the deviation from the respective price ratio is $100 of land for a week of labor. The other rates are interpreted according to the units indicated by the table.

From the estimates presented in table 5, most of the deviations are not highly significant.[16] The significant differences are in the deviations of the land-capital substitution rates for both classes of tenants. These are significant at a probability level of 1.0 percent.[17]

Although resource excesses and deficits (table 3) were observed for full owners, this test failed to show significant inefficiencies in resource combinations. This occurrence is related, at least partly, to the relatively larger variances of the marginal rates of substitution for owners.

As mentioned earlier, the significance of the differences between tenure classes in the deviations of marginal rates of substitution from the respective price ratios were tested also.[18]

---

[16] The hypothesis is that the deviation, $d_{j.i}$, is equal to zero. The test employed is

$$t=\frac{b_i\bar{X}_j/b_j\bar{X}_i-P_i/P_j}{s(B_{j.i})},$$

in which $s(B_{j.i})$ is the standard error of the marginal rate of substitution $(b_i\bar{X}_j/b_j\bar{X}_i)$ obtained from the variance formula:

$$V(B_{j.i})\doteq\left(\frac{b_i\bar{X}_j}{b_j\bar{X}_i}\right)^2\left(\frac{s^2_{b_i}}{b_i^2}+\frac{s^2_{b_j}}{b_j^2}-2r_{ij}\cdot\frac{s_{b_i}s_{b_j}}{b_i\,b_j}\right).$$

[17] The fact that there are resource malallocations in terms of land-capital combinations for the tenants was further revealed by testing the differences between resource marginal returns at the geometric means and those at the optimum. The statistic used was

$$t=\frac{M_{i.g}-M_{i.opt}}{s(m_{i.g})},$$

in which $M_{i.g}$ and $M_{i.opt}$ are, respectively, the marginal returns to resource X_i (i. e., $b_i\bar{Y}/X_i$) at the geometric mean and its optimum; and $s(m_{i.g})$ is the standard error of $M_{i.g}$.

[18] The test used was

$$t=\frac{d_{j.ik}-d_{j.il}}{s(d_{j.ik}-d_{j.il})},$$

in which $d_{j.i}$ denotes the deviation of the marginal rate of substitution of resource X_j for X_i from the inverse of the respective ratio of prices (table 5). The subscripts, k and l, are the tenure classes compared; and $s(d_{j.ik}-d_{j.il})$ is the standard error of the difference in deviations.

$$s(d_{j.ik}-d_{j.il})=\sqrt{V(d_{j.ik})+V(d_{j.il})};$$

and

$$V(d_{j.i})\doteq d^2_{j.i}\left(\frac{s^2_{b_i}}{b_i^2}+\frac{s^2_{b_j}}{b_j^2}-2r_{ij}\cdot\frac{s_{b_i}s_{b_j}}{b_ib_j}\right),$$

in which

$$d_{il.}=b_i\bar{X}_j/b_j\bar{X}_i-P_i/P_j.$$

TABLE 5.—*Marginal rates of substitution of resources at the geometric means by tenure classes and their deviations from the inverses of the respective resource price ratios*

MARGINAL RATE OF SUBSTITUTION

Tenure class	Land for labor	Capital for labor	Land for capital
	$/wk	*$/wk*	*$/$*
Full owners	566	23	25
Livestock-share renters	475	43	11
Crop-share-cash renters	460	44	10
ALGEBRAIC DEVIATIONS OF INVERSE OF PRICE RATIO FROM MARGINAL RATE OF SUBSTITUTION [1]			
Full owners	−100	−13	7
Livestock-share renters	−191	7	−7
Crop-share-cash renters	−206	8	−8
VALUE OF *T* FOR DIFFERENCE BETWEEN MARGINAL RATE OF SUBSTITUTION AND INVERSE OF PRICE RATIO			
Full owners	0. 18	0. 81	0. 39
Livestock-share renters	0. 89	0. 37	[2] 3. 50
Crop-share-cash renters	0. 93	0. 36	[3] 2. 67

[1] A deviation is the difference between the marginal rate of substitution and the inverse of the price ratio, that is, $d_{j.i}=B_{j.i}-P_{i.j}$ prices assumed are as before, and the inverses of the price ratios of concern here are rounded as follows: Labor/land=666; Labor/capital=36; Capital/land=18.

[2] Significant at a probability level of 0.1 percent.

[3] Significant at a probability level of 1.0 percent. Other values of t are not significant at probability levels of 30 percent or less.

The results in table 6 show that for the values of t obtained, none of the observed differences in deviations are statistically significant at usually accepted probability levels. These findings imply that the differences between tenure classes in the average deviations of actual total costs of productive services from the minimum costs attainable, that is, in the overall inefficiencies (table 2), are not significant in a probability sense.

TABLE 6.—*Values of t for differences between tenure classes in the absolute deviations of marginal rates of substitution from the inverses of the respective price ratios* [1]

Tenure classes compared	Values of t for differences in deviations		
	Land-labor substitution	Capital-labor substitution	Land-capital substitution
Full owners vs. livestock-share renters	0. 69	0. 32	0. 00
Full owners vs. crop-share-cash renters	0. 52	0. 51	0. 20
Livestock-share renters vs. crop-share-cash renters	0. 87	0. 20	0. 40

[1] The deviations were shown in table 4.

TABLE 7.—*Marginal returns to resources and marginal return-opportunity cost ratios by tenure classes and value of t for differences of the ratios from unity*

Tenure class	Land	Labor	Capital services
MARGINAL RETURNS AT THE GEOMETRIC MEANS			
	$/$	*$/wk*	*$/$*
Full owners	0. 059	33. 50	1. 480
Livestock-share renters	0. 116	54. 79	1. 278
Crop-share-cash renters	0. 107	48. 98	1. 108
MARGINAL RETURN-OPPORTUNITY COST RATIO [1]			
Full owners	0. 98	0. 84	1. 35
Livestock-share renters	1. 93	1. 36	1. 16
Crop-share-cash renters	1. 78	1. 23	1. 01
VALUES OF T FOR DIFFERENCES OF THE RATIOS FROM UNITY			
Full owners	[2] 0. 03	[2] 0. 28	[3] 2. 33
Livestock-share renters	[4] 2. 69	[2] 0. 64	[2] 1. 07
Crop-share-cash renters	[4] 2. 99	[2] 0. 42	[2] 0. 06

[1] The opportunity costs assumed are as before: 6 percent per year for land, $40 per week for labor, and 10 percent per year for capital services.

[2] Nonsignificant at probability levels of 10 percent and less.

[3] Significant at a probability level of 1 to 5 percent.

[4] Significant at a probability level less than 1 percent.

Other Indicators of Inefficiencies

Using the basic estimating equation (1) and the resource prices, the optimum quanities of resources as well as output are achieved if

$$\frac{\partial\hat{Y}/\partial X_1}{P_1}=\frac{\partial\hat{Y}/\partial X_2}{P_2}=\frac{\partial\hat{Y}/\partial X_3}{P_3}=1 \qquad (7)$$

Both output (Y) and the resource categories (X_i) become variables subject to expansion or contraction, and marginal returns are equated with the respective resource prices. But under the phenomenon of increasing or constant returns to scale, the optimum output and the associated resource requirements would become infinitely large or indeterminate if all the variables were allowed to change simultaneously. Consequently, under these situations, attempts to estimate levels of efficiency with production permitted to vary may not yield plausible results.[19] Clues to inefficiencies, however, may be obtained by comparing the levels of marginal returns for different resources with the respective resource prices.

Departures of marginal returns from the prices (or opportunity costs) of the respective resources yielding the returns, are evidences of inefficiencies in some instances.[20] Estimates of the magnitudes of the departures serve as clues to the extent of the inefficiencies. But, in addition to the customary type of analysis, these estimates were tested for statistical significance, in order to estab-

[19] To obtain a plausible optimum, "decreasing returns to scale" is necessary. For practical purposes, this phenomenon is observed for livestock-share renters only—the sum of the production elasticities is less than one. However, some resources can be reasonably varied, holding others fixed, provided that the sum of the "variable" resources is also less than one. But the optimum solutions obtained would then be more analogous to the types needed for the "short-run," and these are not of concern here. But even at that, caution should be exercised in making estimates of this kind, as predictions removed from the means (geometric in this case) are subject to larger standard errors, and there is a possibility of extrapolation.

[20] If the return to a resource at the margin is greater than the resource price, it means that the use of the resource could be extended profitably. If the return is less than the resource price, it means one of 3 things: (1) that some other resource is limitational, (2) that the resource in question is used in excess of the optimum quantity, or (3) both.

lish some confidence as to the nature of resource readjustments that should take place.[21]

Marginal returns (table 7) are the additional returns per unit of input if one more unit of the resource is added at the geometric means. The rather high marginal return of 48.0 percent to capital services for full owners suggests that, on the average, capital is the limiting resource for them: The difference between this marginal return and the opportunity cost is significant at the 5-percent probability level, while the differences for the other resources are not significant.

In order to increase net returns, the use of capital could be extended until its marginal return equals (or approaches) the opportunity cost of 10 percent. With an increase in the use of capital, the marginal productivities of both land and labor that are now below their opportunity costs of 6 percent and $40 per week, respectively, would be increased.

Superficially, land appears to be slightly in excess for full owners. However, as the marginal return is not significantly below 6 percent one might conclude that capital rationing operates more to limit the use of capital services rather than to limit the use of land. In essence, the findings further support the hypothesis that prior commitments to land purchases force restrictions in the use of nonland capital.

Unlike full owners, all the marginal returns for the tenant classes are above the opportunity costs of the resources. It means that the use of all the resources might be extended profitably. But land appears to be the only "limitational" resource: The differences between the marginal returns to land and its opportunity cost are significant at the 1-percent probability level (table 7). Therefore, for the firm, the quantity of land should be extended.[22]

The levels of marginal returns to capital services and labor for the tenant classes could logically be expected. They are not significantly above the opportunity costs. Presumably, one reason for this is the joint contribution of landlords and tenants to the total farm assets, coupled with the sharing of risks of larger scale operations. The higher marginal return to labor for the tenants is indirectly a function of the greater amount of farm assets used in combination with labor.

Notably, all the marginal returns under crop-share-cash renting are lower than those under livestock-share renting. This situation could be related to (1) superior management on the livestock-share farms or (2) different combination of enterprises, or (3) both. These inferences are based primarily on the larger regression constant observed for the livestock-share renters (table 1). Put in another way: the estimate of a marginal return depends also upon the height of a marginal productivity curve, which is a function of a constant. The regression constant is one of the parameters that define the constant associated with the marginal productivity curve. Differences in the size of the constant could be due to differences in management or enterprise combinations.

Some Implications for Further Research

The level of inefficiency, in terms of resource combinations, under each tenure class appears to be unimportant because the average reductions in costs, especially percentagewise, are small and do not differ significantly between the tenure classes. These observations then introduce the possibility that either no real economic problems exist for the broad tenure classes or the methods used are inadequate for detecting the inefficiencies present. On the one hand, it could be argued that the differences are hidden by the aggregative nature of the analytical model. On the other, within the

[21] The t test was applied. That is

$$t=\frac{M_i-P_i}{s(m_i)},$$

in which M_i is the marginal return $(b_i\bar{Y}/\bar{X}_i)$ to resource, X_i; P_i is the opportunity cost of the respective resource; and $s(m_i)$ is the standard error of the marginal return.

$$s(m_i)=\sqrt{A^2\frac{1}{n}\left(s_y\frac{b_i\bar{Y}}{\bar{X}_i}\right)^2-c_{ii}\left(s_y\frac{\bar{Y}}{\bar{X}_i}\right)^2}.$$

The factor A is the adjustment for logarithmic transformation taken to the base 10; c_{ii} denotes the diagonal element for the variable X_i in the variance-covariance matrix. (The variance formula used was obtained from an unpublished manuscript by H. O. Carter and H. O. Hartley of Iowa State College entitled, "A Variance Formula for Marginal Productivity Estimates Using the Cobb-Douglas Function.")

[22] As mentioned previously, a part of this shortage in land could stem from the "undervaluation" of land, as dollar input, by the tenants.

broad tenure classes the heterogeneity of tenure arrangements (*5*) could have canceled the inefficiencies (if any) present.[23] Therefore, both facets of the problem require further inquiry.

The differences in the patterns of deviations (resource excesses and deficits) from the optimum resource combinations by tenure classes, however, suggest that each tenure class represents a different "problem situation" for further inquiry as the causes for deviations from the optima conceivably vary according to tenure status. Furthermore, for a similar production level, the average livestock-share farms had the lowest total resource requirement. Presumably, this was due partly to different management and combinations of products.

Limitations of the Equation Model

Functions of the Cobb-Douglas type have certain weaknesses that limit their use but do not preclude them as tools for further research. They still have certain advantages over other types of functions (*12*), and may be useful under given situations if they are used cautiously.

One source of difficulty is the aggregation of products and factors (*9*). Because of the kind of data available, the output variable was aggregated to total production, although it was recognized that certain biases may stem from such aggregation. This question, however, is particularly relevant if it is true that "imperfections" in leasing cause deviations from optimum combination of enterprises. The value of production from a given stock of resources is reduced accordingly; therefore the effects of product combination may be reflected in the coefficients of the estimating equations.

Different functions for crops and livestock would reduce the biases that may arise but would not eliminate them, as crop combinations and livestock combinations may also differ between tenure classes. That is, apart from differentials in price effects, the physical responses of different products to similar resources are not the same. For multiple-product firms, a certain level of aggregation is necessary. Adequate information on the division of resources between crops and between kinds of livestock usually is not available from cross-section samples of farms (*1*).

The aggregation of factors of production into resource categories presents another weakness. Productivity estimates of a resource may be expected to change if the categories of other resource inputs are altered. That is, the differences between tenure classes in the use of land or labor need not be the same if capital services are broken down further.[24] Lumping of capital services, however, conceals the way in which more specific capital items are used. Inefficiencies in the use of such items as fertilizer and other variable productive services would be necessary in a rigorous analysis.

The exclusion of management as a factor may pose another limitation. Unless management is uniform between tenure groups in the universe, differences in the estimating equations will not be explained completely. Further, if management happens to be intercorrelated with any other resource category for any particular tenure group, its effects are likely to cause overestimation of the production elasticity of the resource with which it is positively correlated (*7, pp. 16-23; 2*). This problem is only a special case of the general problem of intercorrelation which affects regression analysis adversely.

The question of intercorrelation is of concern also in analysis of labor productivity. With a relatively small variation in labor inputs in a sample of farms (owing partly, perhaps, to weaknesses in measurements) labor productivity may be underestimated through biases in the regression coefficients. But an attempt can be made to reduce these biases by purposive or stratified sampling.

Further Application of the Methods Used

The crucial observation made in the study reported here invites serious doubts as to whether the traditional tenure classes studied—full owners and full tenants—differ in the aggregate with respect to the level of efficiency achieved in terms of resource combinations. Even with refinements of the methods used, it is suspected that further analysis of these classes would not show meaning-

[23] D. Gale Johnson has observed that "* * * the nature of deviations from optimum [resource allocation] are quite subtle and not immediately obvious from a cursory examination of American farms operating under different types of tenure arrangements (*6, p. 114*)."

[24] Certain guidelines in the aggregation of factors are available (*9*).

ful differences. If differences were observed, the specific causes would not be identified. As the small values obtained for deviations from optimum resource combinations suggest that the inefficiencies of individual observations may be canceled by the efficiencies of other individual observations, it is implied that analytical models should be oriented toward isolation of the specific arrangements of tenure that may be impediments to production efficiency.

Removing the effects of some factors that are not directly associated with tenure per se is necessary. An attempt was made to do so by considering only the younger owners for comparative purposes. Theoretically, factors such as quality of labor, managerial ability, capital position of the firm, and work preferences affect resource use and productivity estimates and are important to the extent that they are functionally related to the age of farm operators. Further adjustments for "age effects" should therefore be considered.

Still it is not apparent that the effects of specific tenure characteristics can be so easily isolated even within more comparable tenure-age groups because different tenure arrangements may generate forces going in opposite directions. For example, the incentives of a financially encumbered full owner need not be the same as those of an unencumbered owner. Also, the effects of nonoptimum cost-sharing arrangements may be offset by the sharing of uncertainties under share leases. Thus the results may remain confounded. It is then suggested that further analysis that attempts to isolate the effects of tenure arrangements should focus attention on the specific tenure arrangements themselves, using the conventional tenure classification only as an initial device. If estimating equations are used for this purpose, they would of necessity entail a relatively large sample of each tenure class that could be broken down into "cells" of adequate sizes, based on the tenure arrangements to be controlled.

Despite the possible weaknesses of the basic estimating equation model, it would appear that the procedures as presented in this paper and as refined could be extended usefully to the analysis of efficiency within other statistical populations of agricultural firms. It will not displace other methods such as the use of cost curves, but the analysis will be less partial in that it considers the use of all resources simultaneously. Nor will it replace the use of analysis of variance or covariance models; they provide different kinds of information and could well be used as complements.

Literature Cited

(*1*) Beringer, Christoph.
1956. Estimating enterprise production functions from input-output data on multiple enterprise farms. Jour. Farm Econ. 38: 923–930.

(*2*) Griliches, Zvi.
1957. Specification bias in estimates of production functions. Jour. Farm Econ. 39: 8–20.

(*3*) Heady, E. O.
1952. Economics of agricultural production and resource use. New York. Prentiss-Hall. Chs. 20–22.

(*4*) Heady, E. O.
1955. Marginal resource productivity and imputation of shares for a sample of rented farms. Jour. Political Econ. 63: 500–511.

(*5*) Hurlburt, V. L.
1954. Farm rental practices and problems in the midwest. Iowa Agr. Expt. Sta. Res. Bul. 416, Pp. 78–120, Illus. (North Central Regional Pub. 50.)

(*6*) Johnson, Gale.
1950. Resource allocation under share contracts. Jour. Political Econ. 58: 111–123, Illus.

(*7*) Johnson, G. L.
1956. Problems in studying resource productivity and size of business arising from managerial processes. In E. O. Heady, et al., Editors, Resource Productivity, Returns to Scale, and Farm Size. Pp. 16–23. Ames, Iowa State College Press.

(*8*) Ottoson, Howard W.
1955. The application of efficiency to farm tenure arrangements. Jour. Farm Econ. 37: 1341–1353.

(9) Plaxico, James S.
1955. Problems of factor-product aggregation in Cobb-Douglas value productivity analysis. Jour. Farm Econ. 37: 644–675, Illus.

(10) Schickele, Rainer.
1941. Effect of tenure systems on agricultural efficiency. Jour. Farm Econ. 23: 185–207.

(11) Schultz, T. W.
1940. Capital rationing, uncertainty and farm-tenancy reform. Jour. Political Econ. 48: 309–324.

(12) Tintner, Gerhard
1944. A note on the derivation of production functions from farm records. Econometrica 12: 26–27.

Factors Affecting Prices of Pears

By Ben H. Pubols

What makes the price of a particular crop of pears and why prices tend to change from year to year are questions of special concern to growers, processors, and others interested in the production, marketing, and pricing of pears. The market structure for pears, as for other fruits, is a complex one, and throughout the marketing season, various forces exert their influence upon the season average price received by growers. Statistical data representing all of the price making factors for any particular crop are not available but, for a large number of agricultural commodities, the size of production and stocks, the level of national income, and the production of closely competing commodities are usually of considerable importance. In this study, an attempt has been made to measure the influence of these factors on prices of all West Coast pears, all Pacific Coast Bartlett pears sold for fresh use, Bartletts sold for canning, Pacific Coast pears other than Bartletts, and pears other than those grown on the Pacific Coast. Although these factors do not account for all price changes, they do explain a rather considerable amount of variation in the prices received. It is hoped that measurements of the price making influence of some of the excluded factors can eventually be made.

Of the various deciduous and citrus fruit crops, pears have ranked fifth in value of production in recent years. The 1957 pear crop of about 32 million bushels was valued at nearly $63 million. About 90 percent of this crop was grown in the Pacific Coast States of California, Oregon, and Washington, where production has trended upward in contrast to a decline in other States.

In these 3 States, about 75 percent of the annual production consists of Bartlett pears, and the rest of fall and winter varieties, of which the D'Anjou leads. In the other 22 States for which data are available, production consists also of a number of varieties including the Bartlett. But separate figures by varieties are not available. Most of these States are in the eastern half of the United States.

Utilization of pears as between fresh use and use for processing varies considerably by varieties and to some extent by location of production. In recent years, from 65 to 75 percent of the Pacific Coast Bartlett crop has been processed, chiefly by canning. Most of the rest was sold for fresh use, and a relatively small quantity was used in the households of the farmers who grew them. Fresh market sales were heaviest from July through December, with only relatively minor quantities shipped after January 1.

In contrast, over the same years, from about 18 to 23 percent of the Pacific Coast pear crop other than Bartlett was processed, also chiefly by