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Benton F. Massell*

FARM MANAGEMENT IN PEASANT AGRICULTURE: AN EMPIRICAL STUDY†

This study examines the effect of farm management on the output of staple food crops in a sample of peasant farms in Rhodesia. We compare farmers with different levels of skill with respect to: (1) output of each crop, (2) differences in inputs employed, and (3) output net of differences in inputs. Production functions are fitted for each crop.

In Rhodesia, a growing number of African peasant farmers have begun to respond to the advice of the agricultural extension service and have attained substantially improved standards of farm management. These farmers have been classified by the government into three categories: Cooperators, Plotholders, and Master Farmers. (See *4*, p. 181).

A Cooperator is any farmer who uses fertilizer, carries out some crop rotation, and plants his crops in rows. A Plotholder is a farmer who is under tuition by an extension worker to become a Master Farmer. A Master Farmer is a farmer who has gone through the Plotholder stage and has reached specified higher standards of crop and animal husbandry as laid down by the Agricultural Department. In 1963, out of a total of 415 thousand African farmers in Rhodesia, there were 108 thousand Cooperators, 11 thousand Plotholders, and 14 thousand Master Farmers.

This study is based on data collected from a sample of 56 farms in Chiweshe Reserve, a peasant farming area in Rhodesia. The data were collected during the 1960–61 crop year which was an average season for crop production. Each farm was visited at least once a week during the entire crop year. In the sample there were 3 Master Farmers, 4 Plotholders, and 14 Cooperators. Due to the small numbers, we have combined the Master Farmers and Plotholders into a single group of "skilled" farmers. The Cooperators are referred to as "semi-skilled" and the remaining farmers as "unskilled." The comparisons referred to above relate to these three management groups.

Income in the area is derived principally from the production of three crops —corn, peanuts, and millet. The major part of crop output is consumed on the

* The author is Associate Professor, Food Research Institute, Stanford University.

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farm, although some surplus above subsistence "requirements" is frequently sold. Valuing output at local prices, the average per-farm output in the sample was \$83.32, of which \$51.56 consisted of corn. Sales in the particular year studied amounted to only 3.2 per cent of total output, although 45 of the 56 farms had some sales. The average number of acres cultivated was 10.6 of which 8.0 were planted to corn.

Output and Inputs

Output is measured in physical units—pounds harvested. There was little difference among farms in crop quality, so there is some justification in treating output as homogeneous. For comparability among crops, output of each crop is weighted by the average price paid in the area: \$2.72 per 200 pound bag for corn, \$9.80 per 180 pound bag for peanuts, and \$8.56 per 200 pound bag for millet.[1]

Land is measured in acres planted to each crop. But land is not homogeneous. Two types of soil were distinguished—red loam and sand soil. To distinguish between farms on red loam and those on sand soils, a soil dummy variable was used. This variable takes on the value one for a farm on red loam, zero otherwise. Soil type thus enters the production function as a shift variable.

Two kinds of fertilizer were used—chemical and organic. They were applied only to corn land. Organic fertilizer was measured in tons of manure compost, and chemical fertilizer in pounds.

Fixed capital consists of relatively simple farm implements such as an ox-drawn plow or cultivator. As an index of a farm's fixed capital inputs, the value of the implements at undepreciated replacement cost was used. This index omits the services of draft animals and investment in the land, neither of which was recorded in the survey.[2,3]

Labor was provided by members of the farm family. For each crop, labor input was classed according to the farm operation performed: applying manure to the soil; planting; weeding; and harvesting. Because labor appeared to be a limiting factor only at weeding time, the number of weeding-hours was used as the labor variable. Hours worked by children were weighted by one-half.[4]

The remaining variable is management. Management can relate to technical efficiency, i.e., output per unit of input, where inputs are aggregated in some manner. Or it can relate to allocative efficiency—the efficiency with which inputs are combined. An efficient farmer in this sense is one who takes advantage of opportunities for substitution among inputs. Although there is likely to be a

[1] The official Grain Marketing Board price for millet was \$3.23, but most millet was sold locally at an average price of \$8.56.

[2] All farmers owned or had the use of oxen and a plow. Although information was obtained on each farmer's livestock, the survey failed to reveal the extent to which cattle were used in the field. Ideally, one would want to know oxen-hours worked on each crop.

[3] Although detailed information was collected on each farm's stock of implements, we were not able to adjust these figures to take account of the unserviceability of some items. Of greater consequence, we have no information on the allocation of equipment among crops nor the intensity of equipment use. In the regression, we treat equipment as a stock variable, and as an input jointly available for use in cultivating all crops. An alternative (not tried here) would be to assume that the allocation of a farm's equipment among crops corresponds to the allocation of its land or its labor.

[4] Weeding must be undertaken during certain months, so using weeding-hours as the labor variable is roughly equivalent to measuring labor input only during these months. At other times, labor was not a limiting factor.

high correlation between technical and allocative efficiency, the two need not always be found together.

In the following analysis, we shall assume the skill category of a farmer serves as an index of farm management in both senses. If this assumption is valid, a farmer's skill rating can be used as a proxy for management by defining dummy variables as follows:

	M_1	M_2	M_3
Skilled	1	0	0
Semiskilled	0	1	0
Unskilled	0	0	1

The two variables M_1 and M_2 are included in the production function, but M_3 is excluded to prevent singularity of the moments matrix.

The Production Function

A Cobb-Douglas function was used to relate the output of each crop to the set of observed inputs used in producing the crop. The function can be written,

$$\begin{aligned} Y_{ij}^* &= b_{oi} + b_{1i}T_{ij}^* + b_{2i}L_{ij}^* + b_{3i}F_{cij}^* + b_{4i}F_{oij}^* \\ &\quad + b_{5i}K_j^* + b_{6i}S_j + b_{7i}M_{1j} + b_{8i}M_{2j} + u_{ij} \end{aligned} \tag{1}$$

where $Y =$ output
$T =$ land
$L =$ labor
$F_c =$ chemical fertilizer
$F_o =$ organic fertilizer
$K =$ fixed capital
$S =$ soil type dummy variable
$M_1 =$ skilled farmer dummy variable
$M_2 =$ semiskilled farmer dummy variable

and u is a stochastic term, i denotes the crop, j denotes the farm, and an asterisk denotes a logarithm. The coefficients b_7 and b_8 denote respectively the net contribution to output of skilled and semiskilled relative to unskilled managers.

As some farms used zero amounts of chemical or organic fertilizer, a constant was added to these variables before taking logs. The constant chosen in each case was 100.[5] To obtain the estimated production elasticities of these variables, the estimated regression coefficients were then multiplied by

$$\frac{X - 100}{X}$$ where $X =$ the value of the variable-plus-100, calculated at the geometric mean.

If both output and inputs are functionally related to a farm's management ability, then estimated production function coefficients may have management

[5] This procedure is not entirely satisfactory because the results depend on the constant chosen. The smaller this constant, the greater the spread between the zero and nonzero observations, tending to exaggerate the effect of fertilizer. On the other hand, as the constant becomes larger, the interfarm variation in the log of fertilizer-plus-constant becomes smaller and the regression coefficient less significant. The constant 100 seemed to strike a balance between the two extremes. The constants 1, 10, and 1,000 were also tried.

bias (*2, 3, 6*). This follows from the fact that better managers may tend both to use larger inputs and to obtain a larger output from a given set of inputs. If these differences in efficiency are not taken into account in estimating the coefficients, the estimates will be inconsistent. But if the dummy variables in equation (1) adequately summarize management, the coefficients will be estimated without management bias, using ordinary least squares.[6]

Empirical Results

All three regressions are significant at the one per cent level. But for peanuts and millet, less than half of the interfarm output variance is explained by the observed inputs. At the 5 per cent level, using a one-tail test, land, soil type, and both chemical and organic fertilizers are significant in the maize production function; fixed capital and skilled management in the peanut function; and land and labor in the millet function. Due to the large standard errors of many of the variables,[7] the results must be interpreted with caution.

The coefficients for management and soil type can be converted into elasticities. The sum of the elasticities is then .990 for corn, .753 for peanuts, and .901 for millet. For peanuts, this sum is significantly less than unity at the 5 per cent level, using a two-tailed test. Thus the results are consistent with constant returns in corn and millet production, but suggest decreasing returns in producing peanuts. There may be some unobserved factor, such as labor quality, that enters into the peanut production function (Table 1).

From the estimated elasticities one can obtain a set of estimated marginal productivities. The marginal productivity of factor k in producing crop i is denoted by f_{ki} and is given by

$$f_{ki} = E_{ki} \frac{Y_i}{X_{ki}} \tag{2}$$

where E_{ki} = the elasticity of factor k in producing crop i,
Y_i = the output of crop i, and
X_{ki} = the amount of input k used in producing crop i.

TABLE 1.—ESTIMATED REGRESSION COEFFICIENTS*

Input	Corn	Peanuts	Millet
Land	.507 (.153)	.280 (.178)	.478 (.193)
Labor (weeding)	.068 (.156)	.180 (.144)	.255 (.110)
Fixed capital	–.062 (.095)	.220 (.132)	.102 (.135)
Chemical fertilizer	.168 (.064)	...	...
Organic fertilizer	.198 (.076)	...	...
Soil type	.166 (.081)	.006 (.091)	.135 (.096)
Skilled management	.078 (.110)	.272 (.156)	–.303 (.160)
Semiskilled management	–.020 (.078)	.145 (.105)	.085 (.108)
Multiple correlation coefficient	.754	.554	.597

* (...) indicate that the input is not used in producing this crop. Regression coefficients are stated first, followed by the respective standard errors in parentheses.

[6] For alternative ways to deal with this problem, see *5* and *6*.
[7] Presumably due to multicollinearity.

TABLE 2.—ESTIMATED MARGINAL VALUE PRODUCTIVITIES*
(*Dollars per unit of measure*)

Input	Corn	Peanuts	Millet
Land (*acres*)	3.04	2.96	4.28
Labor (*weeding hours*)	.012	.028	.036
Fixed capital (*dollar cost*)	—	.087	.025
Soil type (*per acre*)	.86	.20	1.04
Chemical fertilizer (*dollar cost*)	1.69	...	...
Organic fertilizer (*tons*)	3.19	...	...
Skilled farmer	3.23	3.64	-2.51
Semiskilled farmer	- .83	1.94	.70

* Dots (...) indicate that the input is not used in producing this crop.

The estimated marginal productivities were calculated at the means of the variables Y_i and X_{ki} and consequently relate to the "average" farm.[8] These figures appear in Table 2.

Returns to Resources

The marginal productivity of land ranges from $2.96 to $4.28. There is no opportunity to bring more land under cultivation, as farmers used all of the arable land.

A dollar's worth of chemical fertilizer contributes $1.69 at the margin to the output of corn. In the United States, the marginal productivity of fertilizer typically falls within the range, $1.50 to $2.00 per dollar spent,[9] so that the results do not suggest much scope for greater fertilizer use.

The marginal productivity of (weeding) labor ranges from 1.2 to 3.6 cents per hour. Although the positive marginal product implies that output could be raised by using more labor, the return is undoubtedly too low to justify the additional effort. And this return relates only to weeding which is undertaken during just a part of the year. Because of the low return to labor on the farm, many farmers spend a considerable part of the year away from the reserve working for wages.

The average annual earnings of all Africans in wage employment in Rhodesia in 1960 was $237.20, higher in the cities and lower for African workers on European farms. This includes some persons who worked less than a full year. If we take 40 weeks as the average worked in the year, the average weekly wage figures out to $6.00. And if we take 50 hours as the average workweek, the average hourly wage amounts to 12 cents. The return from such labor exceeds the return from working on one's own plot. This is likely to be especially true for farmers with only a small landholding.

The marginal return to a ton of organic fertilizer in corn production is $3.19. The only cost of organic fertilizer is the labor cost of preparing and applying it, so that the marginal product is a return to labor. As an average of 16 hours was spent applying a ton of organic fertilizer the return to this labor is 20 cents per

[8] The geometric mean was used for logged variables and the arithmetic mean for the remaining variables.

[9] I am indebted to Vernon Ruttan for this figure.

hour. Two points deserve mention. First, the return to manure application is considerably greater than the return to weeding. Second, manure application is undertaken early in the season when the opportunity cost of labor is low in terms of other farm operations foregone. This suggests that it would pay for farmers to use more manure—up to the point where the marginal return to manure application equals the marginal return to weeding. The fact that less than this optimal amount of manure was used suggests that livestock availability was an effective constraint.[10]

In the regression a gross measure of fixed capital was used. It appears reasonable to assume that the equipment has an average life of 10 years and that the stock is growing at about 3 per cent per year. Under these assumptions, and assuming linear depreciation, the net stock may be some 55 per cent of the gross stock, and depreciation may equal roughly 10 per cent of the gross stock. As the gross rate of return is 11 per cent, the net rate of return figures out to 2 per cent. If this is taken as the annual marginal return on investment in fixed capital, it must be judged as low by any standards. The results suggest that the area is overcapitalized with respect to implements.[11]

Allocative Efficiency

Allocative efficiency relates to the degree to which the given stock of resources is used—given the level of technology—to maximize output. Any discrepancy in the marginal productivities of a factor in different uses implies that output can be raised with no increase in resources.

In the area studied there is evidence that farmers strive for self-sufficiency; there is no presumption that resources are allocated so as to maximize output valued at market prices. It is nevertheless of interest to examine the extent to which the actual allocation deviates from an output-maximizing allocation. This measure provides an index of the cost of self-sufficiency.

The marginal productivities of both land and labor are highest in growing millet, suggesting that the market value of output would be raised by shifting resources from corn and peanuts into millet production.[12] However, the resulting gain is relatively small.[13] The actual value of output was \$63.04 on the average farm. If both labor and land were reallocated so as to equalize the marginal productivities of each input in producing all crops, the gain would be \$3.30 or 6.7 per cent.

[10] There is evidence that some farms could (given their livestock) have used a greater amount of manure. But the regression results are consistent with livestock being a limiting factor on some farms even if it was not limiting on every farm.

[11] As noted above, some of the equipment is in a bad state of repair. The return to capital expenditure on new implements—if these implements are properly maintained—is doubtless substantially higher than the results here suggest. Moreover, investment in some types of equipment is likely more profitable.

[12] Using an F test, the difference in the marginal productivities in different uses was found to be significant for both inputs. See *1*.

[13] Moreover, as millet is grown for home consumption, one must ask whether the additional millet grown could be marketed. If it could be sold to other farmers in the reserve at the local price in exchange for corn and peanuts, the farmer would benefit. If not, the only alternative might be to sell to the Grain Marketing Board at a much lower price. At the GMB price, the marginal productivity of land in growing millet is lower than in either of the other uses; and the marginal productivity of labor in growing millet is lower than for peanuts and only marginally higher than for corn.

TABLE 3.—MEAN ECONOMIC PERFORMANCE OF SKILLED, SEMISKILLED, AND UNSKILLED FARMERS

	Skilled	Semiskilled	Unskilled
Technical efficiency relative to unskilled farmers (*dollars*)	4.36	1.81	——
Output (*dollars*)			
Corn	80.96	58.04	43.13
Peanuts	47.00	21.93	13.21
Millet	11.01	14.83	11.30
Total	138.96	94.80	67.64
Acreage			
Corn	11.76	7.91	7.22
Peanuts	2.31	1.57	1.37
Millet	2.13	1.12	.94
Total	16.20	10.61	9.53
Yield (*dollars per acre*)			
Corn	6.88	7.34	5.98
Peanuts	20.35	13.97	9.64
Millet	5.17	13.24	12.02
All crops	8.58	8.93	7.10
Yield (*pounds per acre*)			
Corn	506	540	440
Peanuts	374	257	176
Millet	120	310	280
Adjusted yield (*dollars per acre*)			
Corn	7.39	6.86	6.17
Peanuts	20.45	13.64	9.68
Millet	5.31	12.52	12.29
All crops	8.79	8.40	7.25

Management

Table 3 presents summary data for the average farm in each management group. Relative to farmers in the other groups, the skilled farmers obtained larger output of corn and peanuts, but a lower millet output. For the three crops combined, the skilled farmer obtained 47 per cent more output than the semiskilled farmer and more than twice as much output as the unskilled farmer.

On a per-farm basis, semiskilled farmers obtained a larger output of each crop than unskilled farmers. For all crops combined the output of the semiskilled farmer was 40 per cent greater.

Much of the intergroup difference in output (particularly between skilled farmers and the other groups) is due to differences in cultivated acreage. The acreage per farm of skilled farmers was 70 per cent greater than that of unskilled farmers. Semiskilled farmers had an average of 11 per cent more land than unskilled farmers.

But part of the intergroup differences in output was due to differences in yields. The figure for peanut yields are striking. Despite a larger acreage planted, skilled farmers obtained a much higher yield than farmers in the other groups—more than twice the yield obtained by unskilled farmers. The intergroup differences in corn yield are much less; yields were greatest among semiskilled farmers and lowest for the unskilled farmers. The millet figures are curious; semiskilled farmers received a slightly higher yield than unskilled farmers but both groups did much better than skilled farmers. Regarding overall yield (value of all crops per cultivated acre), both skilled and semiskilled did better than unskilled but, surprisingly, semiskilled farmers obtained a higher yield than skilled farmers.

The intergroup differences in yield can be attributed to differences in other factors used and in technical efficiency. First, consider soil type. We noted in Table 2 that, net of other inputs, output of each crop was higher on red loam than on sand soil; the difference is especially great for corn and millet. It is then noteworthy that the percentage of farmers on red loam differs among skill groups—57 per cent of the skilled and unskilled farmers, but 86 per cent of the semiskilled farmers.

To adjust for the intergroup differences in soil type, we weighted red loam and sand soil by their estimated marginal productivities to obtain an index of land of equivalent fertility units. On the basis of this land index, adjusted yields were calculated; a comparison of adjusted yields among groups is then net of intergroup differences in soil composition. The adjusted yields also appear in Table 3. Skilled farmers obtain a larger yield than semiskilled farmers in both corn and peanuts, and in overall crop output.

Factors other than soil type may also help explain yields. Table 4 presents figures on the use per farm and per acre of chemical and organic fertilizer, labor,

TABLE 4.—MEAN USE OF INPUTS BY MANAGEMENT GROUP

	Skilled	Semiskilled	Unskilled
Fixed capital (*dollars*)			
Total	114.80	48.00	37.00
Per acre	7.09	4.52	3.90
Chemical fertilizer (*dollars*)			
Total	7.36	6.42	4.20
Per acre of corn	.63	.81	.58
Organic fertilizer (*tons*)			
Total	6.80	4.20	2.82
Per acre of corn	.58	.53	.39
Labor (*weeding hours*)			
Corn	294	297	259
Peanuts	114	107	94
Millet	122	77	88
Total	530	481	441
Per acre	32.7	45.3	46.3

and fixed capital, by management group. Skilled farmers used more of all four inputs than semiskilled farmers who in turn used more than unskilled farmers. On a per-acre basis, however, semiskilled farmers used the most fertilizer. Also, the labor-land ratio was greatest for unskilled and least for skilled farmers.

The net marginal value productivities associated with each management group were presented in Table 2. These figures measure the contribution of management net of differences in the use of observed inputs. The estimated marginal productivities can be summed over crops to obtain an estimated total marginal product for each degree of skill. This measures the total differential efficiency of the average skilled or semiskilled farmer relative to the average unskilled farmer. These sums are $4.36 and $1.81, respectively, or 6.4 and 2.7 per cent of the average output of unskilled farmers.

The following picture emerges from the preceding discussion. Skilled farmers on the average obtained substantially more output than semiskilled farmers. Much of this difference was due to a larger cultivated acreage. On a per-acre basis, if differences in soil quality are taken into account the average yield of the skilled farmers was 5 per cent higher than that of the semiskilled farmers. And the difference in technical efficiency (output net of inputs) was 3.6 per cent.

Total output of semiskilled farmers was considerably higher than that of unskilled farmers, again largely because of differences in acreage. Total yield, adjusted for soil quality, was 16 per cent higher. Net of all inputs, outputs of semiskilled farmers exceeded that of unskilled farmers by 2.7 per cent.

The results strongly suggest the presence of an interaction between technical efficiency and crop. The skilled farmers were most efficient in production of peanuts, but least efficient in growing millet. This is confirmed by yield figures. The techniques of farming are fairly straightforward in an area like Chiweshe Reserve, providing little basis for crop specialization. However, agricultural extension workers have tended to focus on corn and peanuts, to the neglect of millet. Their rating of farmers may reflect this emphasis, and may take into account only factors related to the farmer's performance on corn and peanuts. Our results seem to call into question the relevance of the government rating scheme. It would be of interest to examine these relationships in greater detail using a controlled sample.

Possible shortcomings in the government rating scheme may explain why a farmer who is efficient at growing corn and peanuts is not especially efficient in growing millet; however, it fails to explain why he obtains below-average millet yields. This may be simply a result of the small sample size. There were only seven skilled farmers in the sample, two of whom obtained very low millet output.

Economic Opportunity and Management

The size of a farmer's plot of arable land is fixed by a complex set of factors governing land rights in the reserve. A more skilled farmer cannot, by virtue of his greater skill, choose to cultivate a larger holding. From the farmer's point of view, acreage and soil quality are fixed. The larger holdings of arable land of the skilled and semiskilled farmers cannot be said to result from the farmer's skill.

However, one can more plausibly turn the causation the other way round.

Farmers with a larger acreage have a better opportunity to earn an income from crop production. Farmers with a smaller holding of land have less opportunity to support their families from farm income alone, and may accordingly spend a larger part of the year in the employment centers, working for wages. Farmers with greater economic opportunities on the farm are likely to become more committed to good farming, and to spend more time trying to make a success of the farm venture. If a farmer has a greater economic opportunity on his farm, he can be expected to take farming more seriously: to be more responsive to agricultural extension advice, for example, and more willing to use fertilizer and to adopt improved patterns of crop rotation. In other words, he is likely to be more committed to good farm management.

To test the hypothesis that farm size is an important determinant of absenteeism from the farm, we ran a simple regression. The regression equation is written,

$$A = a_0 + a_1 T^* + u \qquad (3)$$

where A = the number of months the head of household was absent from the farm for 15 or more days,[14] T = the total arable acreage, u = a stochastic term, and the asterisk denotes a logarithm.

The value of r^2 is .16 indicating that acreage explains only a small part of the interfarm variation in number of months absent from the farm. However, the regression coefficient is highly significant; the estimated value of b is —3.47, with standard error 1.10, giving a t-ratio in excess of 3. The elasticity of A with respect to T (calculated at the mean of A) equals —1.12. Therefore, a reduction of acreage by one-half can be expected to be accompanied by approximately a doubling in number of months absent.

These results provide evidence that farm size influences commitment to farming; this may help explain the association between acreage and farming skill. A larger acreage provides a greater incentive to develop one's own farm and this creates a willingness to learn and to develop management skills. This interpretation is consistent with the results obtained above. Farm size is a determinant of the level of management. And farm size, together with quality of management, influence the inputs of chemical and organic fertilizers, fixed capital, and labor.

This interpretation also accounts for the difference among management groups in absenteeism from the reserve. Looking at heads of households, unskilled farmers were absent from the reserve an average of 4.2 months during the year, whereas semiskilled and skilled farmers were absent 1.9 and 0.3 months, respectively. The figures thus suggest a relationship between management and commitment to farming.

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