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Resource allocation and productivity of cereal state farms in Ethiopia

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ABSTRACT

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Using a translog production function, cereal production on state farms in Ethiopia between 1980 and 1985 was analyzed. The farms were found to be operating at constant returns to scale. Manual labor was under-utilized, while machinery and other modern inputs were over-utilized. Elasticities of substitution between labor and these over-utilized inputs were low.

INTRODUCTION

Cereal crops constitute over 70% of the total grain production of Ethiopian state farms. At the national level, state farms contribute close to 4% of the nation's total cereal production. They cultivate about 3% of total cereal crop land, consume 75% of improved seeds, and absorb from 12% to 15% of the total agricultural budget of the nation (World Bank, 1987).

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There is a general perception among some Ethiopian agricultural policy makers and some donor agencies that cereal-producing state farms are technically inefficient, too costly to the nation, and compete inordinately with private and cooperative farms for scarce modern technical inputs, including advanced human capital. For the most part, the popular perceptions are more impressionistic than analytic. The popular perceptions are, however, based largely on some symptomatic problems facing the state farms. The state farms are, for example, unable to pay back bank loans despite higher output prices and larger input price subsidies than input and output price subsidies given to the private and cooperative farms. Faced with an alarming food deficit and population growth at an annual rate of close to 3%, the government continues to support the state farms.

The principal objective of this article is, therefore, to analytically examine the production characteristics of the cereal-producing state farms. If the analysis indicates that the modern technical inputs are over-supplied, for example, the marginal contribution of the inputs could be so low that withdrawal of a sizable proportion of the inputs would not significantly affect the output of the state farms. These scarce inputs could then be re-allocated to other farm types to increase their production.

BACKGROUND

The state farms are not completely new innovations of the socialist government of Ethiopia. The majority of the state farms are commercial farms that were nationalized following the 1974 revolution. The state farms as a whole attained institutional and legal status at the national level under the Ministry of State Farms Development that was established on 2 May 1979. The mandate of the Ministry is to: (1) organize state farms that may specialize, for example, in cereals, livestock, fisheries, and fruit and vegetable production; (2) establish model state farms that will encourage other farms currently using traditional modes of production to employ modern farming techniques; (3) produce agricultural commodities for domestic consumption and export markets; and (4) produce raw materials, such as cotton and oil seeds, for domestic processing agro-industries. The Ministry contains a large technical staff employed in applied research and extension, planning. engineering. horticultural sciences, organization and systems development, administration, personnel management, and finance.

The farms have experienced a rapid expansion in total cultivated land area (Abegaz). The total number of hectares planted to various crops by the state farms increased from 64 000 ha in the 1975/76 production season to 293 000 ha by the 1980/81 production season. These ha were planted to cereals, pulses, oil-seeds, industrial crops and cash crops. Out of the total ha planted to the crops on the state farms, about 21 500 ha (or 33.7%) and 206 200 ha (or 70.4%) were planted to cereals in the 1975/76 and 1980/81 production seasons, respectively.

DATA SOURCES

Cross-sectional time-series data (1980–1985) for all the state farms in nine *awrajjas* (districts) were collected from the records of the Ministry of State Farms Development for maize, barley, sorghum, and wheat production. Other variables for which data were collected include unskilled labor, machinery operating costs, expenses on modern yield-increasing inputs (fertilizer, improved seeds, herbicides, and pesticides), and rainfall in June, July, August and September. The rainfall data were collected from the Ethiopian Meteorological Services.

The four cereal crops were converted into gross value of output, that is, gross revenue from which cost of production is not deducted, by multiplying the output quantity of each crop by its price. The labor input is limited to unskilled labor, due to the absence of data on labor used in conjunction with machinery and for management, and it was measured in terms of labor-days. Rainfall was measured in millimeters, and all the remaining inputs were measured in terms of the Ethiopian Birr, which had an official exchange rate at $US1.00 = 2.05 Birr in 1989. Output prices are determined by a central planning committee, and the prices remained fixed during the 1980 to 1985 production period. The central planning committee assumes the role of a competitive market and determines prices on a *cost-plus* basis. These prices are, therefore, 'market' tools to which the state farms respond to formulate production decisions.

Finally. there are four major agro-ecological regions in which the cereal crops of the state farms are grown. The agro-ecological regions include the central highlands (at an average elevation range of 1800–3000 m above sea level (m.a.s.l.)). eastern highlands (above 1800 m.a.s.l.). southwestern highlands (at 1400–2400 m.a.s.l.), and southeastern highlands (above 1400 m.a.s.l.). Diverse characteristics of the central highlands are shared largely by Shoa, Gojam, Gonder and Wello provinces. Arsi, Balie-Goba and Hararghie provinces make up the eastern highlands. The southwestern highlands span Illubabor, Keffa and Wellega provinces. Sidamo and Gemu-Goffa provinces are in the southeastern highlands (Belete, 1978; Getahun, 1980; Provisional Military Government of Ethiopia, (1985).

ESTIMATION OF AWRAJJA LEVEL TRANSLOG PRODUCTION FUNCTION

Marginal productivity, partial income elasticities, returns to scale, and substitutability between input pairs were analyzed empirically with the following linearized model:

$$\hat{Q} = \hat{\delta}_0 + \hat{\delta}_l L + \hat{\delta}_i I + \hat{\delta}_m M + \hat{\delta}_j J + \hat{\delta}_y Y + \hat{\delta}_u U + \hat{\delta}_s S$$
$$+ \hat{\delta}_{lm} LM + \hat{\delta}_{ly} LY + \hat{\delta}_{lu} LU + \hat{\delta}_{ls} LS + \hat{\delta}_{ii} I^2 + \hat{\delta}_{ij} IJ$$
$$+ \hat{\delta}_{iu} IU + \hat{\delta}_{is} IS + \hat{\delta}_{yu} YU + \hat{\phi}_{mm} M^2 + \hat{\delta}_1 D_1 + \hat{\delta}_2 D_2$$
$$+ \hat{\delta}_3 D_3 + \hat{\delta}_5 D_5 + \hat{\delta}_6 D_6 + \hat{\delta}_7 D_7 + \hat{\delta}_8 D_8 + \hat{\delta}_9 D_9 + \hat{Z} \quad (1)$$

where Q is ln(gross income per ha); L is ln(labor-days per ha); I is ln(value of modern yield-increasing inputs per ha); M is ln(value of machinery services per ha); J is ln(June rain), Y is ln(July rain), U is ln(August rain), S is ln(September rain), D_1 is a dummy variable for awrajjas in the eastern highlands agro-ecological zone, D_2 a dummy variable for awrajjas in the southwestern highlands agro-ecological zone, D_3 a dummy variable for awrajjas in the southeastern highlands agro-ecological zone, D_5 a dummy variable for 1984, D_6 is a dummy variable for 1983, D_7 a dummy variable for 1982, D_8 a dummy variable for 1981. D_9 a dummy variable for 1980, $\hat{Z}$ represents regression residuals, and $\hat{\delta}$ and $\hat{\phi}$ are estimated coefficients. The regression coefficient $\hat{\phi}$ represents the estimator of the coefficients of the log-quadratic regressors in the translog function with 0.5 in front of the coefficients. The coefficient $\hat{\phi}$ is therefore defined as $\hat{\phi}_{nn} = 0.5\hat{\delta}_{nn}$, where the subscript nn stands for the relevant log-quadratic terms in the above equation. Finally, it should be emphasized that, given the definition of the time-related dummy variables, 1985 is the base year of this time series analysis.

Given the above empirical translog model and variables, productivity parameters of marginal revenue product (MRP), partial income elasticity with respect to each factor of production (η_i), output elasticity or returns to scale (H), and Allen partial elasticity of substitution (Θ_{ij}) between pairs of input factors are computed from the following relations:

$$\text{MRP}_i = \frac{\partial Q}{\partial \omega_i} = \left(\hat{\delta}_i + \sum_{j=1}^{n} \hat{\delta}_{ij} \ln \omega_j \right) \frac{Q}{\omega_i} \quad (2)$$

$$= \eta_i = \frac{\partial \ln Q}{\partial \ln \omega_i} = \hat{\delta}_i + \hat{\delta}_{ii} \ln \omega_i + \sum_{j=1}^{n} \hat{\delta}_{ij} \ln \omega_j \qquad \text{for} \quad i \neq j \quad (3)$$

$$H = \sum \eta_i \quad (4)$$

$$\Theta_{ij} = -\left[\frac{\eta_i \eta_j (\eta_i + \eta_j)}{\eta_i^2 \hat{\delta}_{jj} + \eta_j^2 \hat{\delta}_{ii} - \eta_i \eta_j \left(2\hat{\delta}_{ij} + \eta_i + \eta_j \right)} \right] \quad (5)$$

where ω's are proxies for variables, and $\hat{\delta}$'s are appropriate coefficients determined through the estimation of equation (1).

RESULTS

The estimated coefficient values of the agro-ecological dummies show that regional differences among the cereal-producing state farms are statistically insignificant (Table 1). That is, if the state farms in each agro-ecological region are supplied with the same set of factors of production per ha, it seems that they would produce approximately the same level of gross income per ha. This result is reasonable given the fact that the state farms' cereal production practices are centrally planned. Furthermore, scientific research, modern technology, skilled human capital applied to various aspects of farm management, and the institutional ability of the state farms to evaluate new and old information appear to 'wash-out' or to effectively control any sources of regional variation in gross farm income per ha.

The state farms, on the other hand, appear to be susceptible to temporal factors (Table 1). This is indicated by the negatively significant coefficients of the temporal dummy variables, which suggest that the state farms produced below 1985 levels in earlier years. Compared to the 1985 production year, the temporal impacts have a range of -0.252 Birr per ha in 1980 to -0.378 Birr per ha in 1983. These negative coefficients may indicate that productivity has been increasing on state farms. It should, however, be remembered that 1980–1984 were the years during which Ethiopia was severely affected by drought. But, it is likely that much of the impact of drought is picked up by the rainfall variables, whose coefficients were statistically significant. Productivity impacts of the other variables are examined next.

There appears to be an important relationship between gross income per ha and employment of farm labor per ha. The MRP of labor, computed at the geometric means of the variables, is 17.82 Birr per ha and it is significantly different from zero. The MRP of the labor input might be measuring two components: (a) the true MRP of unskilled (temporary) labor per ha, and (b) an upward bias due to the probable existence of a positive correlation between the unskilled labor and skilled (permanent) labor that is not included in the model due to data limitations. It is difficult to estimate the exact level of the bias in the MRP. The MRP per ha is, however, about nine times the daily minimum wage rate of 1.92 Birr paid by the state farms. Given government's intervention in the farm labor market with minimum daily wage fixed at 1.92 Birr over time and space, it may not be reasonable to compare the MRP of labor to the daily minimum wage. But, if it is assumed that 1.92 Birr is a measure of marginal resource cost (MRC)

TABLE 1

Translog function regression estimates for state farms

Variable	Coefficient	Coefficient estimate [a]	T-ratio	p-value [b]
Intercept	$\hat{\delta}_0$	−13.077 (2.092×10^{-6})	−3.117	0.0041
Labor days (L)	$\hat{\delta}_l$	−0.134	−0.158	0.8758
MYI inputs (I)	$\hat{\delta}_m$	1.203	3.832	0.0008
Machinery (M)	$\hat{\delta}_m$	1.497	2.633	0.0146
June rain (J)	$\hat{\delta}_j$	0.886	4.603	0.0001
July rain (Y)	$\hat{\delta}_y$	2.492	4.685	0.0001
August rain (U)	$\hat{\delta}_u$	4.718	3.370	0.0026
September rain (S)	δ_s	−3.532	−2.657	0.0138
Interaction variables				
LM	$\hat{\delta}_{lm}$	0.315	3.472	0.0020
LY	$\hat{\delta}_{ly}$	−0.439	−3.614	0.0014
LU	$\hat{\delta}_{lu}$	−0.183	−1.485	0.1506
LS	$\hat{\delta}_{ls}$	0.333	2.500	0.0196
I^2	$\hat{\phi}_{ii}$	0.032	1.710	0.1001
IJ	$\hat{\delta}_{ij}$	−0.149	−3.544	0.0017
IU	$\hat{\delta}_{iu}$	−0.535	−2.912	0.0076
IS	$\hat{\delta}_{is}$	0.440	2.443	0.0223
M^2	ϕ_{mm}	−0.229	−2.864	0.0086
YU	δ_{yu}	−0.210	−2.301	0.0304
Intercept shifting dummies				
Eastern highlands (D_1)	$\hat{\delta}_1$	−0.230 (0.794)	−0.978	0.3379
SW highlands (D_2)	$\hat{\delta}_2$	0.151 (1.163)	1.405	0.1730
SE highlands (D_3)	$\hat{\delta}_3$	0.027 (1.027)	0.191	0.8499
1984 Production year (D_5)	$\hat{\delta}_5$	−0.286 (0.751)	−2.290	0.0311
1983 Production year (D_6)	$\hat{\delta}_6$	−0.378 (0.685)	−2.825	0.0094
1982 Production year (D_7)	$\hat{\delta}_7$	−0.311 (0.733)	−3.020	0.0059
1981 Production year (D_8)	$\hat{\delta}_8$	−0.374 (0.688)	−3.017	0.0060
1980 Production year (D_9)	$\hat{\delta}_9$	−0.252 (0.777)	−2.141	0.0427

TABLE 1 (continued)

Other statistics (OLS)	
R^2/Adjusted R^2	0.9138/0.8240
F-value/p-value	10.174/0.0001
Durbin–Watson (d)	2.222
White test: chi-squared = −7.36E16, df = 52, p-value [c] = 1.0000	
Pooled Sample Size (1980 to 1985): 50	

[a] Numbers in parentheses under a coefficient estimate represent the anti-log of coefficients which were estimated as logarithms.
[b] p-value indicates probability that the true value of the coefficient is zero, generated by the OLS package.
[c] Generated by the White test for heteroskedasticity.

for employing an additional unit of labor services in the state farms, the MRP of labor appears to indicate a disequilibrium between the minimum wage rate offered by the state farms and the wage rate at which the unskilled workers are willing to offer their services.

The gap between the MRP of labor and the MRC can be reduced, or eliminated, by employing more labor per ha on the state farms. As illustrated in Table 2, increasing labor employment per ha by 10% while holding other inputs constant, reduces the MRP of labor by only 1.7%. A substantial number of unskilled workers per ha would have to be employed to bring the MRP of labor in line with the MRC, and economic logic suggests that the state farms should do just that. It is, however, interesting to note that the state farms are unable to attract as many workers as needed with the minimum daily wage. In most cases, farm workers are unwilling to offer their services at the minimum wage rate. The alternative to raising the minimum wage rate taken by the Ethiopian Government has been to impose a seasonal labor-quantity-quota on farmers' associations in order to ensure an adequate supply of seasonal labor to the state farms. Although the MRP of labor does not prove the existence of a disequilibrium in the farm labor market, the farm labors' reluctance to offer their services at the prevailing wage rate suggests that: (a) labor is paid less than its marginal revenue product, and/or (b) the Birr wage rate is not high enough to compensate for the dis-utility of work which perhaps is related to the psychic cost of being separated from family members, relatives, familiar environment and unappealing physical conditions, such as disease, in areas where some of the the state farms are located.

The marginal revenue product of the modern yield-increasing (MYI) inputs is negative (Table 2). Given the fact that the state farms control about four percent of the cultivable land and claim 12–15% of the government's capital allocated to the agricultural sector, it may not be

TABLE 2

Marginal revenue products generated at 10% above and below the geometric mean for state farms [a]

Input	Unit	10% above	Mean [b]	10% below
Labor	Days/ha	17.51	17.82 (2.135)	18.20
MYI inputs [c]	Birr/ha	−0.10	−0.11 (−3.161)	−0.12
Machinery services	Birr/ha	0.33	0.36 (3.173)	0.40
June rain	mm	0.46	0.50 (4.358)	0.55
July rain	mm	−0.41	−0.47 (−3.790)	−0.54
August rain	mm	1.26	1.28 (−2.537)	1.30
September rain	mm	−0.48	−0.54 (3.680)	0.62

[a] Note that an allocation of an input at 10% below or above its geometric mean would influence marginal revenue product (MRP) of the input through partial income elasticity of output with respect to that input:

$$\text{MRP} \pm 10\% = \overline{\text{MRP}}_i \left[\frac{1 \pm 0.10\eta_i}{1 \pm 0.10} \right]$$

where $\overline{\text{MRP}}_i = \eta_i(\overline{Q}_i / \overline{W}_i)$, η_i is partial income elasticity, W_i is any given input factor, Q_i is gross farm income per ha, and the bar notation indicates that both Q_i and W_i are evaluated at their geometric mean. See Yotopoulos (1967) for additional discussion.

[b] t-Ratios are in parentheses under the mean value of the marginal revenue product. All means are significantly different from zero with a p-value ≤ 0.0216.

[c] MYI, Modern yield increasing.

surprising that these results suggest that state farms have applied the MYI too intensively. Also, an additional reason which might explain the observed negative technical relationship for MYI is that economic issues such as cost minimization or profit minimization of cereal production practices are secondary to the government's promotion of state farms, which apparently has resulted in an excessive distribution of MYI inputs to the state farms.

For every additional Birr invested in machinery services per ha, the state farms' gross income increases by 0.36 Birr per ha (Table 2). Such a low level of marginal return is to be expected, given the current investment of approximately 204 Birr of machinery services per ha, which on the average generates about 3 Birr per ha on the cereal-producing state farms. On the whole, the marginal productivity of the machinery services would probably be increased if the state farms either cut back on current and future investment in machinery, or expand farm size while maintaining expenses on the machinery at current levels. Expanding state farms would, however, mean a reduction in cereal lands which would otherwise be cultivated by private farmers or producer cooperatives, and could have adverse consequences for these farmers.

The output elasticity for the state farms was 1.34 with a t-ratio of 0.457 and a p-value of 0.3258 when testing whether the elasticity is significantly different from one. Since the output elasticity is not significantly different from one, the state farms are experiencing constant returns to scale. Also, small changes in MRP observed in the sensitivity analysis in Table 2 suggest that large changes in machinery, MYI, and labor would be required for a substantial change in their MRP. Furthermore, examining the elasticities of substitution in Table 3 suggests that the controllable inputs, machinery, MYI, and labor, are not particularly good substitutes for each other. Therefore, the viability of substituting labor for machinery and MYI is subject to question.

TABLE 3

Substitutability of inputs in translog production function for cereal production on state farms evaluated at the mean of the data

Labor-days	MYI Inputs	0.27
	Machinery services	0.19
	June rain	1.00
	July rain	1.45
	August rain	1.28
	September rain	0.44
MYI inputs	Machinery services	0.28
	June rain	0.30
	July rain	0.38
	August rain	0.40
	September rain	−5.34
Machinery services	June rain	0.29
	July rain	0.13
	August rain	0.36
	September rain	0.13
June rain	July rain	1.00
	August rain	1.00
	September rain	1.00
July rain	August rain	4.00
	September rain	1.00
August rain	September rain	1.00

The value of the elasticity of substitution is evaluated at the geometric mean of each variable.

CONCLUSIONS

The results of this study neither support nor refute all of the unfavorable popular perceptions about the operation of state farms. The results do suggest that manual labor may be under-utilized, and that modern-yield increasing inputs, and machinery, are over-utilized. However, given the technology represented by this production function, the low wage rate, and social and political factors as discussed above, substituting the under-utilized labor for the over-utilized inputs would not be an easy task. However, increasing the wage rate could attract more labor to the state farms. Finally, this analysis does not support Abegaz's (1982) assertion that the temporal productivity of state farms is declining. At least between 1980 and 1985, this analysis suggests that productivity of the state farms was increasing. Perhaps the popular perception that the state farmers are 'too costly to the society' implicitly points to the financial loses that these farms incur due to seemingly undervalued cereal crops, whose prices are determined by a central planning committee rather than a free market. An important point to note is that although this research found that state farms are operating with constant returns to scale, it does not address whether the state farms are lower-cost producers than the producer cooperatives or the private farms. Additional research would need to be conducted to answer this question.

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