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AGRICULTURAL DEVELOPMENT SYSTEMS EGYPT PROJECT

UNIVERSITY OF CALIFORNIA, DAVIS

THE STRUCTURE OF RICE TECHNOLOGY, FARMER
RATIONALITY, AND AGRICULTURAL POLICY IN EGYPT

By

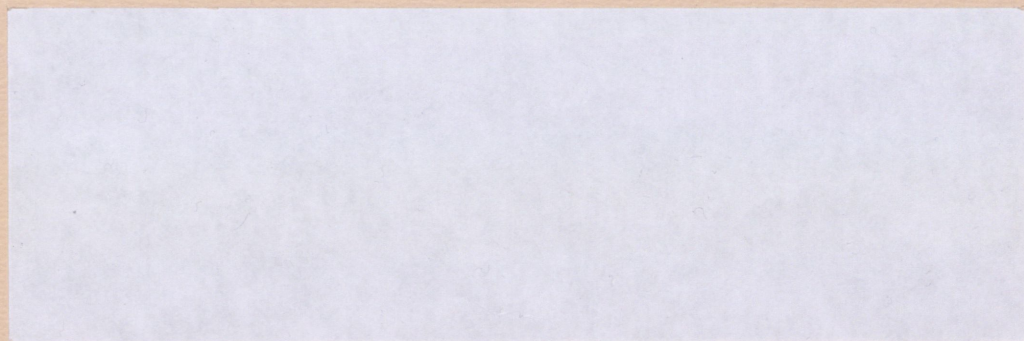
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WORKING PAPER

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**Agricultural Development Systems:
Egypt Project
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The Structure of Rice Technology, Farmer Rationality, and Agricultural Policy in Egypt

Egyptian agriculture is in the process of transition from traditional to modern agriculture, and many difficult policy decisions face Egypt's leaders in the formulation of agricultural policies which will improve the welfare of the Egyptian people. Economists face a difficult task in assessing Egypt's agricultural problems and in devising solutions to them because there is little sound economic and technical data available for Egyptian agriculture. The analysis of agricultural problems in Egypt is complicated by the complex systems of government administered prices, crop rotations, and input distribution. At present there appear to be few, if any, studies which provide econometric evidence on the structure of agricultural technology and the responsiveness of Egyptian farmers to changing economic conditions at the farm level.

The purpose of this paper is to investigate the structure of Egyptian rice technology in the important East Delta region and to use these findings to draw some preliminary inferences relevant to policy questions facing the Egyptian government. The econometric model is based on a homothetic version of the translog cost function. Based on the estimates of this model we perform tests on the structure of the technology and estimate and test hypotheses on input demand elasticities. These elasticities provide important information about the price-responsiveness of Egyptian farmers and about the economic effects of certain agricultural policies.

One fundamental question we investigate, using the cost function estimates, is whether Egyptian farmers make economically rational resource allocation decisions. This issue is relevant considering that many current policies appear to be based on the presumption that the central government

agency, the Ministry of Agriculture, can make better resource allocation decisions than the farmers themselves. Economic theory implies that economically rational farmers should make input decisions at the margin as a function of the opportunity cost of inputs. Therefore to test for farmer rationality we estimate the cost function with free (or black) market prices of inputs, rather than the government's administered prices which are less than black market prices. The empirical analysis shows that Egyptian rice farmers exhibit substantial responsiveness to the black market price for nitrogen fertilizer, and demand elasticities for fertilizer, labor, and animal power are found to be greater than one in absolute value. Thus we cannot reject the hypothesis of farmer rationality. Our results for labor demand behavior are consistent with Hansen's (1968) study which showed that agricultural labor markets in Egypt adjust to seasonal changes in demand as economic theory predicts.

Estimates of cross-price elasticities of demand also provide information about the economic effects of agricultural policies. One finding of importance to policy is that labor and mechanical power are not strong substitutes; in fact family labor is found to be quite complementary to mechanical power inputs. This finding, if true for other major field crops, would explain why wage rates have increased dramatically as Egyptian farmworkers have taken jobs in other Middle East countries in recent years (see Richards and Martin 1981). This finding suggests that policies to increase mechanization would not solve the "labor shortage" problem that has resulted. Interestingly, fertilizer rather than mechanical power is found to be the strongest substitute for labor in the rice production process. The finding of a high own-price elasticity of demand for fertilizer and a black market price several times the official price suggests that policy should be

aimed at increasing the supply of fertilizer, both to increase productivity and to help alleviate the labor problem.

The first section of the paper provides a brief description of the Egyptian government's input policies and develops testable hypotheses for farmer rationality implied by economic theory. The second section describes the homothetic translog cost function and its use for estimation of input demand elasticities and testing the structure of the technology. The paper concludes with a discussion of the implications of the empirical findings for farmer rationality and the formulation of Egyptian agricultural policy.

I. Agricultural Policy and Farmer Rationality

In this section we briefly outline some aspects of agricultural policy and relate them to the question of farmer rationality which is fundamental to the design of agricultural policy.

A major component of Egyptian agricultural policy is the regulation of production through intervention in product and input markets and the enforcement of a centralized crop rotation. These policies are intended to manage agricultural production so as to be consistent with national policy objectives and to increase production efficiency. However, such policies appear to presume that the central decision-making agency, the Ministry of Agriculture, can make better resource allocation decisions than farmers themselves. This presumption contradicts the large agricultural development literature beginning with Schultz's work (1964) which has found farmers economically rational and efficient at farm-level decision making. Within this framework, economic theory suggests that such centralized policies will most likely distort agricultural incentives and lead to a less efficient resource allocation (Schultz 1978).

To illustrate the effects of Egyptian agricultural policy on farm-level productivity we consider distribution of nitrogen fertilizer. In 1966 Agricultural Law No. 53 was enacted to give the Ministry of Agriculture a monopoly over the distribution of fertilizers for each crop at a subsidized price. During the period 1973-78 the nitrogen quota per feddan (1 feddan = 1.04 acres) was about 31 kilograms (Antle and Aitah 1982). For other major field crops similar quotas were applied: between 38 and 62 kilos per feddan for wheat and maize and 46-62 kilos for cotton. To investigate the economic effects of this policy we can first use the standard theory of derived demand to conclude that each farmer's demand for fertilizer should be a function

of local technical and economic conditions. The relevant technical conditions vary according to soil quality, whether a leguminous crop such as berseem (clover) preceded rice, and so forth. The economic conditions vary with the prices of fertilizer, rice, and alternative crops such as corn and vegetables. Thus, theory predicts that the fertilizer use of economically rational farmers will vary with their local conditions with some farmers using more fertilizer than the quota if they can acquire it and others using less. There should be economic incentives for farmers to trade fertilizer in a black market, and indeed an active black market for fertilizer exists in Egypt. The survey data show that the average government price per kilogram of nitrogen was about 0.15 L.E., or only about 25 percent of the average black market price given in Table 1. Economically rational farmers should thus base their fertilizer allocation decisions on this price which represents the opportunity cost of using fertilizer.

To illustrate these relationships, we present the demand and supply conditions of a typical farmer in Figure 1. The Ministry of Agriculture's input supply policy is represented by S_g which is perfectly elastic at the government-subsidized price p_g up to the government quota f_g ; at f_g the supply function of the government becomes perfectly inelastic. The black market price p_b is several times higher than the government price, and an individual farmer should face a perfectly elastic supply of black market fertilizer at that price. If the farmer is economically rational he views p_b , rather than p_g , as the opportunity cost of using fertilizer. If his demand is $f_1 < f_g$ at the black market price he either sells quantity $(f_g - f_1)$ in the black market or allocates it to other crops (such as vegetables). Similarly, if the farmer's demand is $f_2 > f_g$ he may buy the quantity $(f_2 - f_g)$ in the black market.

Economically rational farmers will also respond to changes in the black market fertilizer price. Ceteris paribus, a higher p_b should be correlated with lower fertilizer use. However, if farmers follow the government regulations and always use quantity f_g , then clearly the observed fertilizer demand will not be a function of p_b .

Thus economic theory implies that economically rational farmers make input decisions at the margin as a function of the opportunity cost of inputs. The analysis of the nitrogen fertilizer input implies two testable hypotheses. First, all farmers will not apply the government-determined fertilizer quota, and some will most likely use more and some will use less than the quota according to local conditions. Second, the demand for fertilizer should be a function of the black market price for fertilizer. We can use these implications of economic theory to test the rationality of Egyptian rice farmers.

II. The Homothetic Translog Cost Function.

In this section we describe the empirical model we use to study the structure of East Delta rice production. The homothetic translog cost function we use is:

$$(1) \ln C = \alpha_0 + \sum_{i=1}^n \alpha_i \ln w_i + \frac{1}{2} \sum_{i=1}^n \sum_{j=1}^n \alpha_{ij} \ln w_i \ln w_j \\ + \sum_{i=1}^n \sum_{j=1}^m \beta_{ij} \ln w_i \ln z_j + \gamma_1 \ln Q + \gamma_2 (\ln Q)^2$$

where C is total cost, w_i are input prices, and z_j are fixed factors.¹ Assuming farmers choose inputs to minimize cost subject to their production function, Shepard's lemma gives us the cost share equations

$$(2) c_i = \frac{\partial \ln C}{\partial \ln w_i} = \alpha_i + \sum_{j=1}^n \alpha_{ij} \ln w_j + \sum_{j=1}^m \beta_{ij} \ln z_j, \quad i=1, \dots, n,$$

where $c_i \equiv x_i w_i / C$ and x_i is the cost-minimizing quantity of the i th input.

Input demand elasticities can be calculated by noting that equation (2) implies

$$(3) \ln x_i = \ln C + \ln c_i - \ln w_i$$

Using (3) the i th own-price demand elasticity is

$$(4) \eta_{ii} = \frac{\alpha_{ii}}{c_i} + c_i - 1,$$

the cross-price demand elasticities are

$$(5) \eta_{ij} = \frac{\alpha_{ij}}{c_i} + c_j, \quad i \neq j,$$

and the elasticity of the i th input with respect to the j th fixed factor is

$$(6) \quad \varepsilon_{ij} = \beta_{ij} + \sum_{i=1}^n \alpha_{ij} \ln w_i.$$

Also the Allen partial elasticities of substitution are given by

$$(7) \quad \sigma_{ij} = \eta_{ij}/c_j.$$

While the assumption of homotheticity does impose some structure on the model a priori, this assumption is useful because it eliminates output from the cost share equations and thus facilitates estimation (we return to this point below). Homotheticity is, however, much weaker than the homogeneity assumptions imposed by many production function models such as the Cobb-Douglas. The translog cost function also does not restrict the σ_{ij} a priori and thus allows for restrictions to be tested such as $\sigma_{ij} = 1$ implied by the Cobb-Douglas function. This hypothesis is tested by the parameter restrictions

$$(8) \quad \alpha_{ij} = 0, \beta_{ij} = 0, \text{ for all } i, j.$$

While such information has little policy relevance per se, it is important for the specification of econometric models on which policy decisions may be based.

Several tests for the validity of the translog model specification can be performed. The set of cost share equations (2) should satisfy the symmetry restrictions

$$(9) \quad \alpha_{ij} = \alpha_{ji}, \text{ for all } i \neq j.$$

The translog cost function is an approximation to the true function and is not globally concave. Concavity holds at the point of approximation $\ln w_1 = 0$, for all i , if the Hessian matrix of the cost function is negative semi-definite. This matrix can be shown to consist of diagonal elements $(\alpha_{11} + \alpha_1^2 - \alpha_1)$ and off-diagonal elements $(\alpha_{1j} + \alpha_1\alpha_j)$. In the next section we perform these tests for the validity of the model specification.

III. Data, Estimation, and Testing the Model

The rice production data we utilize come from the 1976-77 Farm Management Survey conducted by the Egyptian Ministry of Agriculture (Goueli and Hindy 1979). While the sample survey covered some 56 villages throughout Egypt, we investigate here the rice production technology for the East Delta region which comprises the Sharkia, Dakahlia, and Domiatte governorates.³ This relatively homogeneous region produces nearly 50 percent of Egypt's annual rice crop and contains 11 survey villages which represent 153 complete observations on individual farm rice production.

Summary statistics for the farm-level data are presented in Table 1. The reader should note that the prices are village averages reported by individual farmers and are all free-market (or black-market) prices obtained from the survey. These prices must be distinguished from the official Government prices for rice paid to farmers, and the prices at which fertilizers are sold at the village cooperatives. As we noted above, economic theory predicts that farmer behavior depends on the opportunity cost of inputs as would be represented by free (or black) market prices rather than administered prices. Therefore, to test the hypothesis that farmers are price-responsive we estimate the model with these market prices.

The model is specified with prices for hired labor, mechanical power, animal power, and nitrogen and phosphate fertilizers. The acreage under cultivation and the family labor input are included in the model as fixed factors of production. This assumption appears to be reasonable for land in the context of short-run production analysis, and also because farmers' acreage decisions are constrained by exogenous factors such as the government-administered crop rotation system. The family labor variable

probably should not be treated as a fixed factor, strictly speaking. However, without more detailed information about the opportunity cost of family labor (such as household production and off-farm employment opportunities) we cannot estimate a separate input demand function for family labor and, therefore, we treat it as a fixed factor.

The reader should note that the terms involving output do not enter the cost share equations (2) because the technology is assumed to be homothetic.² Given that the input prices are exogenous at the farm level, this assumption is very useful because it puts the cost-share equations in the form of a set of reduced-form equations. To estimate the set of cost share equations they must be transformed from theoretical to econometric form. We follow the usual ad hoc practice adopted in the literature (Binswanger 1974, Berndt and Wood 1975) and assume an additive random error structure for the share equations which satisfies Zellner's (1962) seemingly unrelated regression (SUR) model. Since the cost shares sum to unity and the covariance matrix is singular, we also follow the practice introduced by Berndt and Christensen (1973) of dropping one equation from the system and iterating the Zellner procedure to convergence. Magnus (1978) shows these estimates are consistent and asymptotically normal and converge to maximum likelihood estimates if the errors are normally distributed. Barten (1969) has shown maximum likelihood estimates are invariant to which equation is deleted so it makes no difference which equation we drop from the system for estimation. The criterion for convergence is based on the parameter estimates and the software used for the estimates presented here was developed by White (1978). One problem with this statistical procedure is that the dependent variables, the cost shares, are necessarily constrained to the (0,1) interval, and the econometric model

should take this fact into account. However, Woodland (1978) has found that the usual SUR estimates were very close in several cases to estimates which explicitly accounted for the limited range of the dependent variables. Thus, there does appear to be some evidence that the usual SUR model is an adequate approximation.

To test the hypothesis that the α_{ij} parameters are symmetric (equation 9) the unrestricted model was estimated with the iterative SUR procedure (the phosphate equation is excluded for all estimation reported here). The test statistic for symmetry is $F(6,580) = 1.87$, which indicates nonrejection of the hypotheses at all conventional significance levels. Therefore, the symmetry restriction was imposed and the model was re-estimated. The parameters and their standard errors are presented in Table 2. The likelihood ratio test for the hypothesis that all slope coefficients equal zero is strongly rejected by a Chi-square statistic of $\chi^2(28) = 154.02$ which is significant at all conventional levels. The Hessian matrix was computed at the point of approximation but the test for negative semi-definiteness at the point of approximation was inconclusive. Thus, except for this qualification, the translog specification satisfies all the tests for validity it was subjected to.

Since the phosphate equation was dropped for estimation, its parameters are obtained by the symmetry of the α_{ij} and by the linear homogeneity of the cost function in input prices which implies

$$\sum_i \alpha_i = 1, \sum_j \alpha_{ij} = 0, \sum_j \beta_{ij} = 0$$

for all i . These restrictions were used to obtain the phosphate equation estimates.

In Table 4 we present the Allen partial elasticities of substitution and their standard errors based on the parameter estimates in Table 2. These values clearly differ substantitally from unity, although the standard errors are relatively large in some cases. To test the hypothesis of strong separability of the production technology and elasticities of substitution equal to one we test the Cobb-Douglas restrictions (8). The likelihood ratio test for zero slope coefficients is equivalent to this test and is overwhelmingly rejected by the data, so the Cobb-Douglas function is strongly rejected.

The parameters in Table 2 can be used to calculate demand elasticities according to formulae (4), (5), and (6) at any data point. Since these elasticities are linear functions of the parameters, their standard errors are also easily computed. The elasticities and their standard errors are presented in Table 3. While we discuss the policy implications of these elasticity estimates below, we note here that they imply substantial price-responsiveness by farmers. All the precisely estimated own-price elasticities satisfy the hypothesis of negativity implied by economic theory, whereas the machinery and phosphate elasticities are small and positive but have large standard errors. The apparent price inelasticity of phosphate may be explained by the fact that most farmers use very little phosphate (see Table 1). Its use is probably more a function of local soil conditions than economic conditions. We discuss the machinery results in detail in the following section.

IV. Implications for Agricultural Policy

In this section we use the findings of the empirical analysis to test the hypotheses related to farmer rationality discussed above and to discuss several important policy questions, including the regulation of the agricultural sector and labor and mechanization policies.

It was shown in Section I that economically rational farmers would use nitrogen fertilizer as a function of the black market price. Our estimate of the elasticity of fertilizer demand, which is statistically significant and greater than one in absolute value based on the black market price, clearly supports the hypothesis that farmers respond to this price in their fertilizer allocation decisions. Another piece of evidence supporting the rationality of farmers is the distribution of fertilizer per feddan for farmers in our sample, shown in Figure 2. This histogram shows that while the average is near the government quota, many farmers use either more or less, as theory predicts they would, as a function of local economic and technical conditions. Thus, if farmers were to follow the government's quota, most of them would be producing with a fertilizer input level which would be both economically and technically inefficient. This evidence strongly suggests that the government fertilizer distribution system is both ineffectual, because farmers clearly do not conform to the quota, and inappropriate and serves mainly to distort incentives and reduce productivity.

The cross-elasticities of demand show a high degree of substitution between hired labor, animal power, and fertilizer. This relationship can be explained in part by the fact that organic fertilizers are also used which require a substantial human labor and animal power input for transportation and application. As we note below, this relationship is of particular interest in view of the current labor market situation.

Another major policy issue facing Egyptian leaders concerns the agricultural labor market. The input demand elasticity for hired labor is estimated to be greater than one in absolute value and thus indicates that farmers are very sensitive to wage rate changes. This finding for labor demand is consistent with Hansen's (1968) study which showed that agricultural labor markets in Egypt adjust to seasonal changes in demand. In recent years there has been an unprecedented increase in rural wage rates, apparently due to the outmigration of Egyptian workers to other Middle East countries (Richards and Martin 1981). The current debate over an appropriate policy for this "labor shortage" problem has raised the question whether the government should further encourage mechanization. Our estimates of cross-elasticities of demand show a very small and statistically insignificant substitution between hired labor and mechanical power input, and a quite large and statistically significant degree of complementarity between family labor input and mechanical power. These results, if they generalize to other major field crops, might help explain why wage rates have risen so sharply in recent years. This finding also suggests that a policy which subsidizes mechanization would have relatively little effect on the "labor shortage" problem.

The inelasticity of the demand for mechanical power can perhaps be explained by the fact that it is used primarily for particular operations such as field preparation, water pumping, and threshing. While human and animal labor can substitute for mechanical power in these operations, the use of mechanical power is far superior in economic and technical terms. Another factor may be that a nonprice rationing system determines mechanical power use. In some villages the primary source of tractors and pumps for farmers

who do not own them is the village cooperative which rents tractors at a government-subsidized price, and the mechanical input of machinery owners is not likely to be a function of the market rental rate. Both the low own-price and cross-price elasticities in Table 3 are consistent with these facts.

IV. Conclusions and Future Research

Our estimates of the homothetic translog cost function show Egyptian rice farmers are responsive to input prices in making their input decisions. While these estimates are preliminary and based on a single product analysis, they are consistent with the large literature showing most farmers are economically rational. In addition the own-price and cross-price elasticities of input demand provide some insight into fertilizer, labor, and mechanization policies currently being pursued or considered by the Egyptian government. There is clearly a need for more single-product studies as well as multi-product studies, which account for the complex multiple cropping system in Egypt, in order to examine in detail the efficiency and equity implications of alternative policies. However, we feel these preliminary findings leave little doubt that any rational policy must be based on the assumption of rational farmers.

Footnotes

¹A full quadratic expansion would include linear and quadratic terms for the $\ln z_j$, however, these terms do not enter the share equations (2) and are therefore not included in equation (1).

²When the technology is homothetic the cost function can be written $C = f_1(Q) f_2(w_1, \dots, w_n)$, where $f_1(Q)$ is a monotonic increasing function and $f_2(\cdot)$ is a convex function of the w_i .

³For an in-depth survey of available data on field crop production in the East Delta region, see Antle and Aitah (1982).

Table 1

Summary Statistics for East Delta Rice Production, 1976-77
Means and (Standard Deviations)

Variable	Quantity	Price*
Hired Labor (man-days)	102.5 (223.4)	0.64 (0.14)
Animal Power (hours)	158.1 (263.3)	0.24 (0.03)
Mechanical Power (hours)	192.4 (312.3)	1.33 (0.31)
Nitrogen (kg)	98.9 (179.7)	0.61 (0.14) ?
Phosphate (kg)	19.9 (58.2)	0.42 (0.10)
Land (feddan)	3.1 (4.8)	--
Family Labor (man-days)	42.5 (70.8)	--
Output (kg)	6110.1 (9024.9)	0.09 (0.01)

Sample size = 153

*All prices in Egyptian pounds per unit.

Table 2

Restricted Iterated SUR Estimates of the Translog Cost Function,
East Delta Rice Production, 1976-77

	Equation:			
	Hired Labor	Animal Power	Mechanical Power	Nitrogen Fertilizer
<u>Prices:</u>				
Hired Labor	-0.031 (0.062)	-0.017 (0.040)	-0.006 (0.048)	0.100* (0.041)
Animal Labor	-0.017 (0.040)	-0.048 (0.050)	-0.088* (0.039)	0.059 (0.035)
Mechanical Power	-0.006 (0.048)	-0.088* (0.039)	0.251* (0.061)	-0.118* (0.048)
Nitrogen	0.100* (0.041)	0.059 (0.035)	-0.118* (0.048)	-0.033 (0.053)
Phosphate	-0.040 (0.032)	0.098* (0.034)	-0.111 (0.066)	0.045 (0.062)
<u>Fixed Factor:</u>				
Land	0.022* (0.006)	-0.023* (0.006)	-0.040* (0.012)	0.038* (0.012)
Family Labor	0.012* (0.004)	0.014* (0.004)	0.023* (0.008)	-0.017* (0.008)
Intercept	0.111 (0.082)	0.149 (0.089)	0.170 (0.111)	0.382* (0.095)

Note: Standard errors in parentheses.
 Test for Parameter Symmetry: $F(6,580) = 1.871$.
 Test for Zero Slope Coefficients: $\chi^2(28) = 154.02$.
 *Significant at the 5 percent level.

Table 3

Input Demand Elasticities Based on the Translog Cost Function
for East Delta Rice, Egypt, 1976-77.

	Equation:				
	Hired Labor	Animal Power	Mechanical Power	Nitrogen	Phosphate
<u>Prices:</u>					
Hired Labor	-1.190 (0.581)	-0.043 (0.355)	0.095 (0.084)	0.711 (0.250)	-1.997 (0.296)
Animal Labor	-0.045 (0.378)	-1.311 (0.445)	-0.041 (0.068)	0.474 (0.213)	5.358 (1.774)
Mechanical Power	0.057 (0.457)	-0.209 (0.343)	0.011 (0.107)	-0.144 (0.294)	-5.274 (3.479)
Nitrogen	0.943 (0.389)	0.691 (0.264)	-0.041 (0.084)	-1.039 (0.322)	2.527 (3.284)
Phosphate	-0.376 (0.305)	0.890 (0.298)	-0.175 (0.115)	0.292 (0.379)	0.260 (0.413)
<u>Fixed Factor:</u>					
Land	0.043 (0.082)	-0.090 (0.086)	0.315 (0.108)	-0.147 (0.092)	-0.163 (0.071)
Family Labor	0.008 (0.082)	-0.052 (0.088)	0.379 (0.108)	-0.203 (0.902)	-0.174 (0.072)

Note: Standard errors in parentheses.

Elasticities computed according to equations (4), (5), and (6).

Table 4

Allen Partial Elasticities of Substitution for
the Translog Cost Function

	Hired Labor	Animal Power	Mechanical Power	Phosphate	Nitrogen
Hired Labor	-11.226 (5.481)			Symmetric	
Animal Power	-0.398 (3.345)	-11.602 (3.938)			
Mechanical Power	0.099 (0.797)	-0.365 (0.599)	0.019 (0.187)		
Phosphate	-19.789 (16.052)	47.34 (15.85)	-9.301 (6.117)	13.684 (21.736)	
Nitrogen	5.730 (2.360)	4.197 (1.605)	-0.249 (0.511)	15.368 (19.947)	-6.316 (1.957)

Note: Standard errors in parentheses.

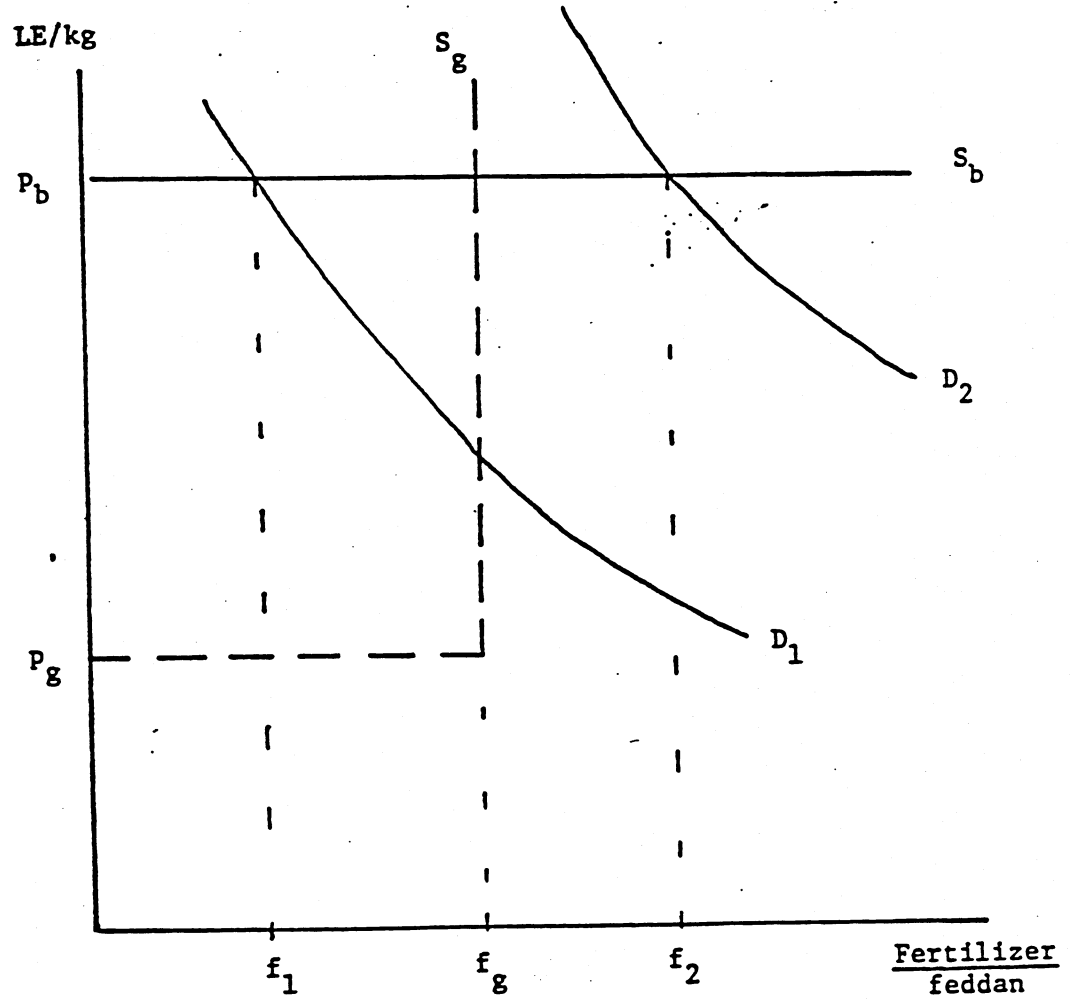


Figure 1. Farm-level fertilizer demand and supply.

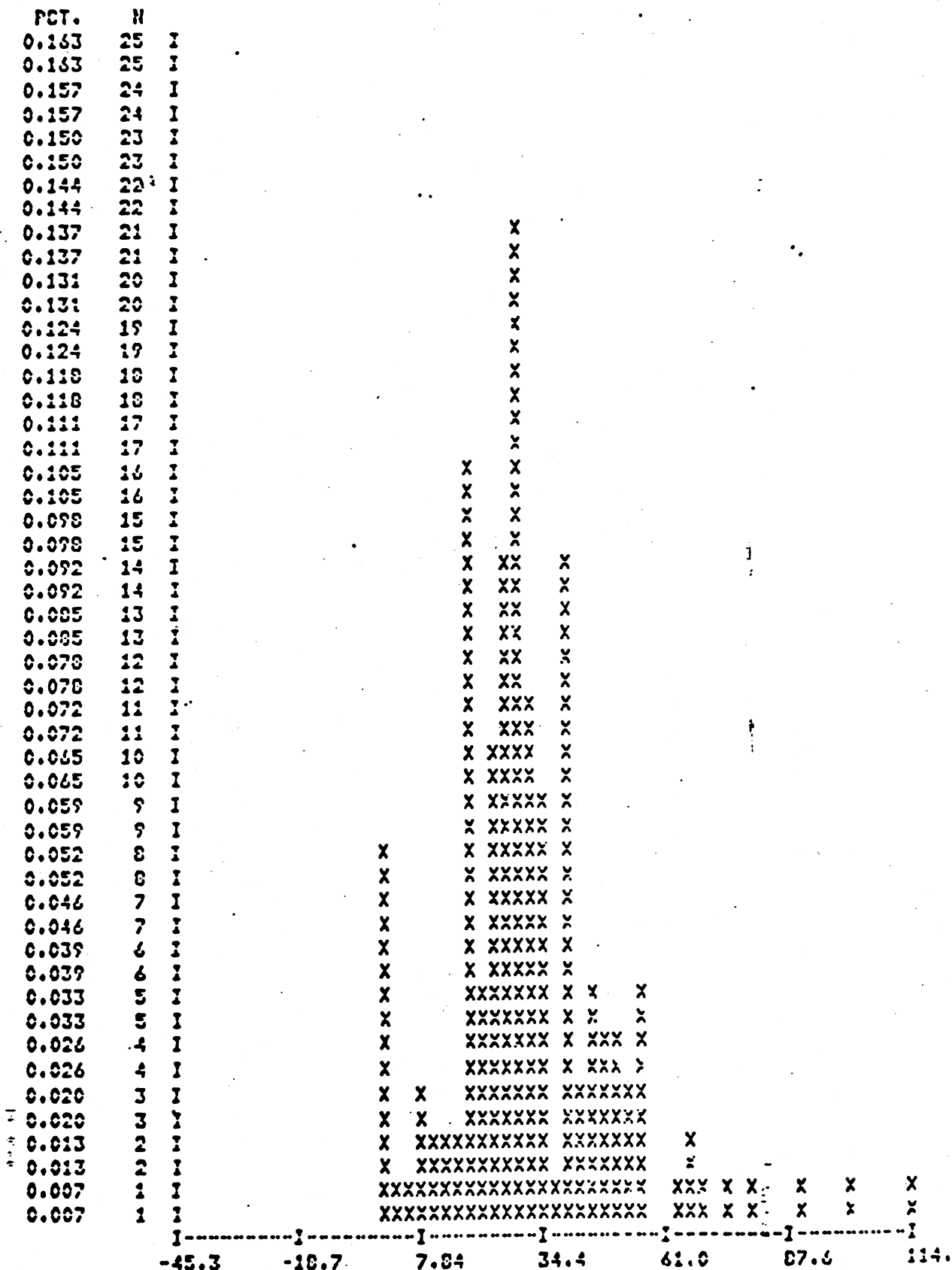


Figure 2. Histogram of Nitrogen Fertilizer Input per Feddan for Rice

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