TESTS OF PROFIT MAXIMIZATION AND ECONOMIC EFFICIENCY AND THEIR APPLICATION TO FARMS IN THE DOMINICAN REPUBLIC

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INTRODUCTION

In March and April of 1976 an agricultural production survey was taken of 1,800 farms in the Dominican Republic. The survey focused on the farm as an economic unit and attempted to measure revenues and costs of agricultural activities and revenues from non-farm sources as well as the pattern and techniques of agricultural production.[1] Among the main research objectives of the survey was to identify the most disadvantaged groups among the rural farming population and the constraints which prevent them from increasing their productivity and income.

One of the most commonly used indicators of the quality of life is average per capita income. The results from the survey allow us to compute average per capita gross and net income, because detailed information was collected concerning the family size, the value of production of all crops, livestock and processed products produced on the farms, the total cost of farm production, and the total amount of non-farm income. This study will concentrate upon the analysis of farm income. The principal objective of this study is to identify the characteristics of the most successful farms,

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[1]For a more complete description of the sample, see Appendix A.

so that the feasibility of relevant policies to increase the income of the poorest farms (the target group) can be studied.

Testing for profit maximization is an appropriate first step in the analysis of income, because the application of neo-classical theory in the analysis of farms in less developed countries is questionable. Chapter I therefore reviews some of the literature relating to tests for profit maximization which have been used on farms in less developed countries and uses such a test on the data from the Dominican Republic. Chapter II goes on to identify the target group in the Dominican Republic which is in most need of development assistance. Finally, Chapter III employs the profit function in the analysis of the economic and technical efficiency of the farms with special reference to variables which are related to policies which affect the target group.

CHAPTER I

TEST TO DETERMINE IF FARMERS IN THE DOMINICAN REPUBLIC ARE PROFIT MAXIMIZERS

Before applying a test to determine if farmers in the Dominican Republic are profit maximizers, Section 1 of this chapter evaluates the importance of economic rationality in the study of farms in LDCs. In Section 2 empirical evidence of economic rationality in LDCs is reviewed. The methodology used in this chapter is discussed in Section 3. Finally, a review of the results of the application of the methodology in two studies is presented, along with the results of this study on the Dominican farms, in Sections 4 through 5.

1. The Importance of Economic Rationality as a Theory of Development

One of the principal hypotheses of micro-analysis of economic behavior is that "profit maximization serves as a reasonable first approximation to the goal of the firm."[1] Much of neo-classical theory is based upon this hypothesis, so that the tools developed for studying the firm reflect

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[1]Walter Nicholson, Microeconomic Theory, Basic Principles and Extensions (Hinsdale, Ill: Dryden Press, 1972), p. 178.

the model of the firm as a profit maximizer. Marginalism is an example of such a tool: profits are measured by deducting the costs of production from total revenue and the necessary condition for profit maximization is that marginal revenue equals marginal cost.

Whether the hypothesis is a reasonable approximation to the goal of farms in less developed countries is debatable. Competing models of farmer behavior in LDCs generally fall into three broad categories: the "inert or lazy peasant," the "utility maximizer," and the "profit maximizer."

Theodore W. Schultz in his book Transforming Traditional Agriculture[1] advocates the last model. He claims that farmers maximize returns from the given factors of production at their disposal and that there are no major inefficiencies in the allocation of factors. "Farmers," he says, "are efficient but poor."[2] He cites two studies of poor farmers, one of Panajachel, Guatemala, and one of Senapur, India. The latter study by W. David Hopper[3] used Cobb-Douglas production functions in which input observations for 43 farms were regressed against the farmers' expected output. The marginal products determined by

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[1]T. W. Schultz, Transforming Traditional Agriculture (New Haven: Yale University Press, 1964), p. 38.

[2]Ibid.

[3]W. David Hopper, "Allocative Efficiency in Traditional Indian Agriculture," Journal of Farm Economics 47 (August 1965): 611-624.

these functions were used to establish implicit prices in the allocations made by the average farmers. Hopper found a close correspondence between the various price estimates, and also found that they closely matched actual market prices.

Michael Lipton,[1] on the other hand, rejects Schultz's marginal value product equalization theory (MVPE) in favor of the concept of a "survival algorithm" in which the peasant practices cultivation given "different tastes, leisure preferences, risk aversions, tenancy arrangements and castes"[2] which may not always reflect profit-maximizing motives. He posits the following six objections:

> (1) Owing to rainfall variability there is no unique marginal physical product associated with any factor.
> (2) The farmer requires risk premium, and the risk is abnormally large owing to the high rainfall variance, and of an abmormally severe outcome, starvation. Utility maximization can allow for some trade-off between variance and expected profit; MVPE cannot.
> (3) Even under certainty, imperfect factor markets render it impossible, even secularly, for a utility maximizer to acquire that set of factors allowing him to approximate as closely to profit maximization as his utility function allows.
> (4) Even if factor markets were perfect...some farmers' economic behavior is trammeled by constraints--heredity job allocations, land inheritance rules--that prevent the full expression of economic rationality.
> (5) The secular constancy of environment in under-developed countries needed for learning any optimizing algorithm has been disrupted by population growth and by development planning.

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[1]Michael Lipton, "The Theory of the Optimizing Peasant," Journal of Development Studies, April 1968, p. 341.

[2]Ibid.

(6) The adoption of MVPE by each would still not be optimal for all. A planner would reject MVPE in favor of factor allocations allowing for risk, for the effect of income distribution and monopoly on relative prices, for inter-farm differences in reinvestment rates, and for economies of scale to the plot.[1]

Lipton furthermore rejects the empirical evidence presented by Schultz by pointing out that Hopper's production functions omit dung (4% of total input value in Indian agriculture). This at first view seems simple, but Lipton claims that it is difficult if not impossible to correctly specify production functions, so the ratios derived from such functions have no operational significance.

The "inert or lazy peasant" is considered to be ignorant of technical possibilities or satisfied with what he has in spite of such possibilities. It is doubtful that this model commands much attention. Even Lipton rejects the validity of such a model which posits that the peasant is ignorant or stupid. He points out that even seemingly conservative or odd practices merely reflect risk aversion.[2] The implicit, if not explicit, assumption of all development economists who deal with the agricultural sector of LDCs is that the farmer is an optimizer of some kind, be it profit maximizer or utility maximizer. To assume that the farmer is inert or lazy implies that there is little or nothing that can be done to increase agricultural productivity or output in LDCs.

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[1]Ibid, pp. 331-332. Note that these points are not presented in their entirety.

[2]Ibid, p. 341.

This brings us to the policy implications of economic rationality. If it can be shown that the farmer is efficient and maximizes profits given the factors of production, the optimal policy would be to increase the factors of production at his disposal in the form of credit, capital infrastructure (e.g., irrigation systems), land reform, and education. If it can be shown that the farmer maximizes utility and avoids risk, then policy prescriptions should include crop risk insurance, negotiable credit terms, price guarantees, and other risk-averting policies. Empirical study of alternative models of farmer behavior is therefore necessary to discover which models are most plausible. The next section of this paper will briefly review some of these empirical studies before reviewing the methodology used in this study.

2. Empirical Evidence of Economic Rationality of Farmers in LDCs

The Hopper study of 43 farms in Senapur, India, mentioned above, and a study by Pan A. Yotopoulos[1] of 430 farms in the Epirus region of northern Greece will be briefly reviewed, because they provide examples of the use of the widely accepted marginal theory of production which equates profit maximization with allocative (or price) efficiency. They are only two of many such studies which have been made in LDCs.[2]

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[1]Pan A. Yotopoulos, Allocative Efficiency in Economic Development: A Cross Section Analysis of Epirus Farming (Athens: Center of Planning and Economic Research, 1968), p. 82.

[2]See also: (footnote continued next page)

The Hopper study used data from 43 farms studied during the peak period (September to December, when there is scarcity pressure on resources) of 1954. The data were gathered for wheat, barley, peas, and gram, and included information on land, labor, bullock time, and irrigation water. As noted above, Cobb-Douglas functions were employed to determine the marginal products of the inputs when regressed against the farmers' expected output.

The price of barley was used as the numeraire to establish an implicit price in barley terms for each product estimated from each factor allocation. It is hypothesized that if a farmer is operating under competitive conditions in product and factor markets and allocates his inputs efficiently, the following condition will be met: $Py_i \frac{\partial Y_i}{\partial X_{ij}} = Py_k \frac{\partial Y_k}{\partial X_{kj}} = Px_j$, where Py_{ik} is the expected price for products Y_i and Y_k; Px_j is the price of factor X_j; and $\frac{\partial Y_{ik}}{\partial X_{i,kj}}$ is the marginal physical product of X_j in the production of Y_i and Y_k.

In other words, if the farmer operates efficiently, the estimated price of each factor of production and each product

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V. Chennareddy, "Production Efficiency in South Indian Agriculture," Journal of Farm Economics 49 (November 1967): 816-820.

Benton F. Massell, "Farm Management in Peasant Agriculture: An Empirical Study," Food Research Institute 7 (1967): 205-215.

Benton F. Massell and R. W. M. Johnson, Economics of Small Holder Farming in Rhodesia. A Cross Section Analysis of the Two Areas, Stanford University Food Research Institute Studies Supplement to Vol. 8, 1968.

G. S. Sahota, "Efficiency of Resource Allocation in Indian Agriculture," American Journal of Agricultural Economics 50 (August 1968): 584-605.

would be the same. The results as seen in the following table show that the price estimates are quite close.

TABLE 1.--Results from the Hopper study of Senapur, India; average product price, implicit price estimates for each factor based on its production use at the average product price[1]

	Barley	Wheat	Pea	Gram	Average
Average price	1.00	1.325	.943	.828	
Price of:		Used in production of:			
Land (acre)	4.4156	4.0288	4.4051	4.8446	4.4235
	(1.0555)	(.8553)	(1.1853)	(.8568)	
Bullock time (hour)	.06956	.07457	.08203	.08338	.07738
	(.01165)	(.00983)	(.01802)	(.01561)	
Labor (hour)	.00857	.00971	.00867	.00758	.00863
	(.00261)	(.00367)	(.00210)	(.00300)	
Irrigation water (750 gal.)	.03548	.03259	.03054	.03154	.03254
	(.01216)	(.00776)	(.01111)	(.02341)	

Source: Hopper, p. 620, Table 5.

[1]Standard errors in parentheses.

Finally, the implicit prices in barley terms were compared with actual market prices. Once again, Hopper found that the implicit prices were close to actual market prices.

TABLE 2.--Results from the Hopper study of Senapur, India; relative prices of products and factors

Product or factor	Relative barley price	Barley price adjusted to rupees	Actual market price
Barley (md.)	1.00	Rs. 9.85	Rs. 9.85
Wheat (md.)	1.325	13.05	14.20
Pea (md.)	.943	9.29	10.40
Gram (md.)	.828	8.16	10.85
Land (acre)	4.4235	43.57	8.00 to 30.00 (annual cash rent only)
Bullock time (hour)	.07738	.7622	?
Labor (hour)	.00863	.0850	.068 (cash kind only)
Irrigation water (750 gal.)	.03254	.3205	?

Source: Hopper, p. 621, Table 6.

The Yotopoulos study is based upon a sample survey which was carried out in April of 1964 in Epirus, the least developed area of Greece. Once again, the Cobb-Douglas production function was employed with labor, land, live capital, equipment, and plant (farm structures) as the independent variables whose marginal products were estimated.

He found that the average marginal product of labor (24.64 drachmas per man-day) was lower than the weighted average wage rate as reported in the questionnaire (52.25 drachmas).[1]

The marginal product of land when compared to agronomists' estimates of the opportunity cost of land showed little difference (75.51 drachmas per stremma as opposed to the estimate of 80-100 per stremma).

Yotopoulos compares the results of his study with the main results of research (up to 1967) on cross-sectional production functions from different countries. The table is reproduced here and provides an interesting summary of results from around the world of research on allocative efficiency.

As was pointed out at the beginning of this section, the most common measure of profit maximization is allocation efficiency. Before discussing an alternative methodology for the study of profit maximization, it should be noted that some work is also being done on the study of farmers as utility maximizers. A relevant example of such studies is one by John

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[1]Yotopoulos, pp. 194-203.

TABLE 3.--Comparison of results of studies on allocative efficiency

PRODUCTION ELASTICITIES AND RATIO OF MARGINAL PRODUCT TO OPPORTUNITY COST FOR SELECTED CROSS-SECTIONAL PRODUCTION FUNCTION STUDIES

Location of Sample	Type of Farming	Elasticity of Production[a]				Ratio of Marginal Product to Opportunity Cost			Reference
		Labour	Land	Other Services	Sum	Labour	Land	Other Services	
India	General arable land	.56	.08	.25	.89	n.a.	n.a.	n.a.	Sarkar (1957)
Greece, Epirus[b]	Mixed	.44	.10	.11	.65	.87	.90	.91	Present study
India, Uttar Pradesh	Wheat, sugar-cane	.43	.23	.35	1.01	.68	.95	2.13	Agrawal and Foreman (1959)
U.S.A.	Crop	.33		.60	.93	n.a.		n.a.	Heady (1952)
Taiwan, Tainan	Cereals	.33	.44	.31	1.08	2.84	.58	.99	Wang (1959)
U.S.A., Alabama	Crops	.32	.39	.46	1.17	.38	4.01	1.01	Heady and Shaw (1954)
India, Andhra Pradesh	Mixed	.26	.14	.13	.53	.21	.05	.35	Agrawal and Foreman (1959)
Austria	Mixed	.26	.13	.61	1.00	.54	.92	1.50	Tintner (1958)
Israel	Mixed	.12	-.01	.67	.78	.86	n.a.	1.09	Mundlak (1961)
Canada, Alberta	Wheat, beef	.20	.39	.34	.93	1.21	2.58	1.01	Darcovich (1958)
International	General	.28	.39	.33	1.00	n.a.	n.a.	n.a.	Bhattacharjee (1955)
International	(Hypothesized)	.70	.10	.20	1.00	n.a.	n.a.	n.a.	Tinbergen and Polak (1950)

a. For all functions the elasticities are significantly different from zero at a probability level ≤ 5 percent. The only exception is the elasticity of land for the Israel function.

b. Elasticities and marginal productivities are computed by averaging the relevant estimates of regressions R_{10}, R_{11} and R_{12}. The relevant opportunity costs are estimated at 29.00 Drs., 90.00 Drs., and 1.15 Drs., for labour, land and other services respectively.

n.a. Not available.

Source: Tables 10.1 and 10.4; E.O. Heady and J.L. Dillon, *Agricultural Production Functions*, Ames, Iowa: Iowa State University Press, 1961, Chapter 17; A.A. Walters, «Production and Cost Functions: An Econometric Survey», *Econometrica*, Vol. 31, No. 1-2, (1963), pp. 1-66, Table IV; Y. Mundlak, *An Economic Analysis of Established Family Farms in Israel, 1953-1958*, Jerusalem: The Falk Project for Economic Research on Israel, 1964, Tables 28 and 29.

Source: Yotopoulos, p. 212, Table 10.6.

L. Dillon and J. R. Anderson[1] which actually reappraises the results of the Hopper and Yotopoulos studies (as well as another such study by V. Chennareddy on South Indian agriculture). Dillon and Anderson found that the data from the Yotopoulos study did support the profit maximizing hypothesis. The results from the Hopper data were inconclusive and those of Chennareddy unfavorable. They therefore suggest that an alternative hypothesis based upon "utility maximization in the face of subjective risk" is a relevant one for further research.[2]

3. An Alternative Methodology for the Study of Profit Maximization

John Wise and Pan Yotopoulos[3] have formulated an alternate methodology for the determination of profit maximization which avoids the problems inherent in the specification of the disturbance term in a single-equation Cobb-Douglas model and the problem of simultaneous equation bias. Since this method will be applied to the data from the Dominican Republic survey, an abbreviated review of their methodology is in order.[4]

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[1]John L. Dillon and J. R. Anderson, "Allocative Efficiency, Traditional Agriculture and Risk," American Journal of Agricultural Economics 53 (February 1971): 26-46.

[2]Ibid.

[3]John Wise and Pan A. Yotopoulos, "The Empirical Content of Economic Rationality. A Test for a Less Developed Economy," Journal of Political Economy 77 (November 1969): 676-1004.

[4]All of the equations which follow are taken directly from the article by Wise and Yotopoulos.

The following model is postulated:

$$Q_i = A_i f(K_i, L_i) = A_i K_i^{\alpha} L_i^{\beta}, \tag{1}$$

$$K_i = k r_i^{\eta} \quad \text{or} \quad r_i = \left(\frac{K_i}{k}\right)^{1/\eta}, \tag{2}$$

$$L_i = l w_i^{\varepsilon} \quad \text{or} \quad w_i = \left(\frac{L_i}{l}\right)^{1/\varepsilon}, \tag{3}$$

$$Q_i = q p_i^{-\lambda} \quad \text{or} \quad p_i = \left(\frac{Q_i}{q}\right)^{-1/\lambda}, \tag{4}$$

where Q_i, K_i, and L_i are, respectively, physical output, capital, and labor for firm i; r_i, w_i, and p_i are, respectively, the prices of capital, labor, and output for firm i; A_i is the "efficiency parameter," which varies from firm to firm; α and β are the elasticity coefficients of production and are assumed constant across firms; η and ε are the supply elasticities for capital and labor, respectively, and λ is the demand elasticity for output, which are also constant across firms; and k, l, and q are the intercepts of the supply functions for input and the demand function for output.[1]

After making the market clearing assumption and substituting from the production function, the total revenue V_i is given by

$$V_i = A_i' K_i^{\alpha(1-1/\lambda)} L_i^{\beta(1-1/\lambda)}, \tag{5}$$

where $A_i' = q^{1/\lambda} A_i^{(1-1/\lambda)}$.

and total profit is given by

$$\pi_i = A_i' K_i^{\alpha(1-1/\lambda)} L_i^{\beta(1-1/\lambda)} - \left(\frac{1}{k}\right)^{1/\eta} K_i^{(1+1/\eta)} - \left(\frac{1}{l}\right)^{1/\varepsilon} L_i^{(1+1/\varepsilon)}. \tag{6}$$

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[1] Wise and Yotopoulos, p. 981.

It is assumed that firms have knowledge of their production, cost and return functions and, given such knowledge, firms maximize profits with respect to each factor of production given the level of other factors.

Thus, the following equations give the profit maximizing condition for capital inputs irrespective of labor inputs

$$\frac{V_t}{K_t} = \frac{[1 + (1/\eta)]}{\alpha[1 - (1/\lambda)]}\left(\frac{1}{k}\right)^{1/\eta} K_t^{1/\eta},$$

or

$$\log V_t = a + \left(1 + \frac{1}{\eta}\right)\log K_t,^{1} \qquad (7)$$

where

$$a = \log \frac{[1 + (1/\eta)]}{\alpha[1 - (1/\lambda)]}\left(\frac{1}{k}\right)^{1/\eta}.$$

and the following equations give the profit maximizing conditions for labor inputs irrespective of capital levels.

$$\log V_t = b + \left(1 + \frac{1}{\epsilon}\right)\log L_t, \qquad (8)$$

where

$$b = \log \frac{[1 + (1/\epsilon)]}{\beta[1 - (1/\lambda)]}\left(\frac{1}{l}\right)^{1/\epsilon}.$$

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[1]Wise and Yotopoulos use the term "log" in the explanation of their methodology and its application to Greek data without specifying its base. In its application to Indian data they use the log to the base e or the natural log (ln). We shall therefore assume that "log" refers to the natural log and use "log" and "ln" interchangeably in the text of this chapter.

These two conditions for profit maximizing are necessary and they imply the third condition, which concerns the factor proportions that a profit maximizing firm would employ to achieve a given output.

$$\log K_t = \frac{(b-a)}{[1+(1/\eta)]} + \frac{[1+(1/\epsilon)]}{[1+(1/\eta)]} \log L_t. \tag{9}$$

These profit maximizing conditions are then expressed as functions of the exogenous efficiency parameter (A) of the firm.

$$\log A_t' + \text{constant} = \left[\left(1+\frac{1}{\eta}\right) - \alpha\left(1-\frac{1}{\lambda}\right)\right] \log K_t - \beta\left(1-\frac{1}{\lambda}\right) \log L_t$$

$$\log A_t' + \text{constant} = -\alpha\left(1-\frac{1}{\lambda}\right) \log K_t + \left[\left(1+\frac{1}{\epsilon}\right) - \beta\left(1-\frac{1}{\lambda}\right)\right] \log L_t. \tag{10}$$

The solution of this system gives

$$\log K_t = \frac{g}{[1+(1/\eta)]} \log A_t' + \text{constant}, \tag{11}$$

$$\log L_t = \frac{g}{[1+(1/\epsilon)]} \log A_t' + \text{constant}, \tag{12}$$

where

$$g = 1\Big/\left(1 - \frac{\alpha\,[1-(1/\lambda)]}{[1+(1/\eta)]} - \frac{\beta\,[1-(1/\lambda)]}{[1+(1/\epsilon)]}\right).$$

$$\log V_i = \log A_i' + \frac{\alpha[1-(1/\lambda)]}{[1+(1/\eta)]} g \log A_i' + \frac{\beta[1-(1/\lambda)]}{[1+(1/\epsilon)]} g \log A_i' + \text{constant}$$

$$\log V_i = g \log A_i' + \text{constant}. \qquad (13)$$

These systems of equations are then cast in terms of observable variables and the equations are formulated in a stochastic model using the errors in variables approach. It is assumed that input use and output levels are made up of two components: one is the unobservable ex ante profit maximization consideration expressed in the equation above, and the other is a random component made of deviations from profit maximization.

Thus

$$\begin{aligned} \log K_i &= X_{1i}^* = x_{1i} - u_{1i} \\ \log L_i &= X_{2i}^* = x_{2i} - u_{2i} \\ \log V_i &= Y_i^* = y_i - v_i \\ \log A_i' &= Z_i. \end{aligned} \qquad (14)$$

where the X_{1i}^*, X_{2i}^*, and Y_i^* are the systematic and unobserved profit maximizing components of log capital, log labor, and log output. The actual observed (in the logs) input and output levels which are used are the X_{1i}, X_{2i}, and Y_i and u_{1i}, u_{2i}, and v_i are the deviations from profit maximizing behavior.

The index of economic rationality is defined as

$$\frac{\text{var } X_{1t}^*}{\text{var } x_{1t}} = \frac{\text{var } X_{2t}^*}{\text{var } x_{2t}} = P. \tag{15}$$

where P is a measure of the success which a firm has in setting actual input and output levels equal to profit maximizing levels.

The two systems of equations presented in (7) through (9), and (11) through (13) can thus be rewritten in terms of observable variables and may therefore be estimated.

$$y_t - v_t = a + \left(1 + \frac{1}{\eta}\right)(x_{1t} - u_{1t}), \tag{7a}$$

$$y_t - v_t = b + \left(1 + \frac{1}{\epsilon}\right)(x_{2t} - u_{2t}), \tag{8a}$$

$$x_{1t} - u_{1t} = \frac{b - a}{[1 + (1/\eta)]} + \frac{[1 + (1/\epsilon)]}{[1 + (1/\eta)]}(x_{2t} - u_{2t}). \tag{9a}$$

$$x_{1t} = \frac{g}{[1 + (1/\eta)]} Z_t + u_{1t} + \text{constant} = X_{1t}^* + u_{1t}, \tag{11a}$$

$$x_{2t} = \frac{g}{[1 + (1/\epsilon)]} Z_t + u_{2t} + \text{constant} = X_{2t}^* + u_{2t}, \tag{12a}$$

$$y_t = gZ_t + v_t + \text{constant} = Y_t^* + v_t. \tag{13a}$$

Estimations of $(1 + \frac{1}{\eta})$ and $(1 + \frac{1}{\varepsilon})$ are obtained by regressing ln output on ln capital and ln output on ln labor respectively. These regressions give the least squares estimate of β, the slope of the regression line. The diagonal regression coefficients are then estimated by dividing the β's obtained from the least squares log regressions by the product moment correlation coefficients for the same variables. Least squares results are based on the hypothesis that the independent variables are error-free, while the dependent variable contains the

error component, and, for this reason, the results are inappropriate. The diagonal regressions, on the other hand, are used under the hypothesis that none of the variables is error-free; such estimates are therefore of more interest in this model. Estimates for $(1 + \frac{1}{\eta})$ and $(1 + \frac{1}{\varepsilon})$ indicate the degree of competitiveness in the markets for capital and labor. Estimates which are close to one justify the assumption of relatively competitive markets. The estimates of η and ε indicate the supply elasticities of capital and labor with respect to output.

The estimation of P (the index of economic rationality) is merely the product-moment correlation coefficient of capital with labor. The closer it is to one, the more firms are considered to be profit maximizers. In other words, if P = .7, it is assumed that 70% of the variance in the logs of capital and labor inputs is due to the systematic profit maximizing component of inputs.

This model is merely one attempt to measure profit-maximizing behavior on farms in LDCs. The strong assumption that errors in the inputs and output are due to departures from economic rationality (profit-maximizing behavior) has been criticized by Paul R. Johnson,[1] who points out that if the model were based upon the theory that farmers are taught from youth to apply so much capital and labor per unit of land, a

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[1]P. R. Johnson, "Discussion: A Test of the Hypothesis of Economic Rationality in a Less Developed Economy," American Journal of Agricultural Economics, May 1968, pp. 398-399.

high degree of correlation between inputs could be interpreted to support a purely traditional model.

This valid criticism should be kept in mind when the results of the applications of the model are examined.

3.1 Applications of the Model to Data from India and Greece

Yotopoulos has applied the model discussed above to two sets of data: one is a set of data from the Farm Management Studies of the Indian Ministry of Food and Agriculture (1957-1962),[1] and the other is the set of data from the 430 Greek farms of Epirus which was used in his study of allocative efficiency.[2]

The results of the two studies are presented below. The first study presents only the results of the diagonal regression. The second one, however, gives the results of the ordinary least squares regression, the diagonal regression, and the instrumental variable regression. Both studies split the data into two groups, one of small and one of large farms, to determine if there is a difference in profit maximization between the two.

Both studies show diagonal regression coefficients which are close to 1. The product-moment coefficient of correlation

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[1]Pan A. Yotopoulos and Jeffrey B. Nugent, Economics of Development, Empirical Investigations (New York: Harper and Row, 1976), pp. 93-94.

[2]John Wise and Pan.A. Yotopoulos, p. 994.

TABLE 4: Results from the Yotopoulos study of profit maximization on Indian farms

Economic Rationality Coefficients and Related Statistics

Relation Estimated	Quantity Estimated	Diagonal Regression Coefficients[a] All Farms ($n = 34$)	Small Farms ($n = 16$)	Large Farms ($n = 18$)
ln Output, V on ln Other Costs, K	$\left(1 + \frac{1}{\eta}\right)$	0.938 (0.026)	0.746 (0.044)	1.003 (0.039)
ln Output, V, on ln Labor, L	$\left(1 + \frac{1}{\epsilon}\right)$	0.195 (0.017)	1.119 (0.001)	1.355 (0.040)
ln Other Costs, K on ln Labor, L	$\frac{\left(1 + \frac{1}{\epsilon}\right)}{\left(1 + \frac{1}{\eta}\right)}$	1.274	1.502	1.351
ρ or P[b]		0.912	0.849	0.833
η		−16.1	−3.9	333.3
ϵ		− 1.2	8.4	2.8

Notes: The estimating equations are 11 to 13 in the text, with the profit-maximizing variables transformed into observable ones in the errors-in-variables context of equations 11*a* to 13*a* in the text. The variables are defined as:

V is total output in rupees.
K is other costs, that is, total cash outlays, including depreciation of capital equipment, with the exclusion of outlays referring to labor and to land.
L is labor days.
η is the elasticity of supply of K.
ϵ is the elasticity of supply of L.
P is the index of economic rationality.

"ln" before a variable indicates natural logarithm of that variable.

[a]Estimated by using the property $\beta_{12} = \rho_{12}\ (\sigma_1/\sigma_2)$, where 1 and 2 are the dependent and the independent variable respectively, in the least squares regression. Since the diagonal regression coefficient is $\frac{\sigma_1}{\sigma_2}$ sign σ_{12}, it can be estimated by β_{12}/ρ_{12}. Standard errors (in parentheses) are first approximations of the standard errors obtained by assuming that var $(b/r) \simeq$ (var $b)/r^2$ for the diagonal regression. This implies that we are neglecting the terms involving cov (b, r) and var (r), which have opposite signs and which, therefore, tend to cancel out.

[b]The economic rationality index, P, is defined as the proportion of the variance of the log in both inputs, which is due to variation in the systematic profit-maximizing components of the inputs, that is, $P = (\text{var } X^*_1/\text{var } x_1) = (\text{var } X^*_2/\text{var } x_2)$. It is estimated by the product-moment coefficient of correlation between log other costs and log labor.

Source: India, Government of: Ministry of Food and Agriculture (1957–1962), *Studies in the Economics of Farm Management*. Delhi. Reports for the year 1955–1956: Madras, Punjab, Uttar Pradesh, West Bengal; Report for the year 1956–1957: Madhya Pradesh.

Source: Yotopoulos and Nugent, p. 94, Table 6.1.

TABLE 5.--Results from the Wise, Yotopoulos study of profit maximization in Epirus, Greece

REGRESSION STATISTICS AND ESTIMATES OF THE ELASTICITY OF SUPPLY OF CAPITAL (η) AND LABOR (ϵ) AND OF THE INDEX OF ECONOMIC RATIONALITY (P) FOR A RANDOM SAMPLE OF FARMS, EPIRUS, GREECE

		COEFFICIENTS AND STANDARD ERRORS											
		All Farms (N = 430)				Small Farms (N = 289)				Large Farms (N = 141)			
REGRESSION NUMBER AND DESCRIPTION	QUANTITY BEING ESTIMATED	Least-Squares Regression	Diagonal Regression*	Instrumental Variable Regression†	Simple Correlation Coefficient ρ	Least-Squares Regression	Diagonal Regression*	Instrumental Variable Regression†	Simple Correlation Coefficient ρ	Least-Squares Regression	Diagonal Regression*	Instrumental Variable Regression†	Simple Correlation Coefficient ρ
(R1) Log output on log capital	$\left(1+\frac{1}{\eta}\right)$	.63626 (.02990)	.88739 (.04170)‡	1.23765 (.05815)‡	.7170	.55699 (.04075)	.88707 (.06490)‡	1.41276 (.10336)‡	.6279	.44217 (.06174)	.85164 (.11891)‡	1.64029 (.22903)‡	.5192
(R2) Log output on log labor	$\left(1+\frac{1}{\epsilon}\right)$	.86628 (.03918)	1.18636 (.05365)‡	1.62471 (.07347)‡	.7302	.73971 (.05541)	1.19501 (.08952)‡	1.93055 (.14461)‡	.6190	.72972 (.09243)	1.31150 (.16612)‡	2.35712 (.29856)‡	.5564
(R3) Log capital on log labor	$\frac{[1+(1/\epsilon)]}{[1+(1/\eta)]}$	1.36152§	1.33704 (.07065)‡	1.31274§	.6749	1.32805§	1.34717 (.12085)‡	1.36651§	.5497	1.65032§	1.53969 (.24723)‡	1.43701§	.4671
	η...	...	−8.9	...	...	...	−8.9	...	...	...	−6.7	...	...
	ϵ...	...	5.4	...	...	...	5.1	...	...	...	3.2	...	...
	P...	...	.6749‖	...	...	...	.5497‖	...	...	...	.4671‖	...	...

* Estimated by using the property $\beta_{12} = \rho_{12}(\sigma_1/\sigma_2)$. Since, as shown in Appendix 2, the diagonal regression coefficient is $\sigma_1/\sigma_2 \operatorname{sgn} \sigma_{12}$, it can be estimated by β_{12}/ρ_{12}.

† Estimated by using the property $\beta^*_{12} = 1/\beta_{21}$. By the use of the above footnote, we can estimate the instrumental variable regression coefficient by β_{12}/ρ^2_{12}.

‡ These are first approximations of the standard errors obtained by assuming that var $(b/r) \simeq$ (var $b)/r^2$ and var $(b/r^2) \simeq$ (var $b)/r^4$ for the diagonal regression and the instrumental variable regression, respectively. This implies that we are neglecting the terms involving cov (b, r) and var (r) which have opposite signs and which, therefore, tend to cancel out.

§ Obtained by dividing the coefficient of the appropriate log output on log labor regression by the coefficient of the appropriate log output on log capital regression, for example, .86628 ÷ .63626 for the ordinary least-squares regression for the group of all farms.

‖ The economic rationality index, P, is defined as the proportion of the variance of the log in both inputs that is due to variation in the systematic profit-maximizing component of the inputs, that is, P = var X^*_1/var x_1 = var X^*_2/var x_2. It is estimated by the product-moment coefficient of correlation between log capital and log labor.

Source: Wise and Yotopoulos, p. 994, Table 1.

for the estimate of P is, however, considerably higher for the Indian data.

The study of Greek farms included scattergrams of the least squares regressions. They are shown here because they allow us to get a feeling for the relationships which the model measures, and because they provide an interesting comparison with similar scattergrams generated from data from the Dominican Republic (see pp. 27-29).

4. Application of the Model to the Data from the Dominican Republic Sector Analysis Survey

4.1 Definition of Variables Used from the Dominican Data

The questionnaires from the Dominican Republic Survey included 1,275 pieces of information pertaining to the year March 1975 to April 1976 on crop, livestock and processed products production and input use; capital and net worth; and many other variables like farm size, land utilization, family size, and marketing. Duplication of the variables used in the study of the farms in Epirus, Greece was therefore not difficult.

Output is the total value of all farm production in Dominican pesos (1 peso = 1 U.S. dollar at 1976 official exchange rate). Labor is the total number of man-days employed in farm production and management; it includes both hired and family labor. Other costs, (capital) is the total value of all inputs used other than land and labor, and includes the depreciation of owned capital.

FIGURE 1.--Greek data: ln output on ln capital

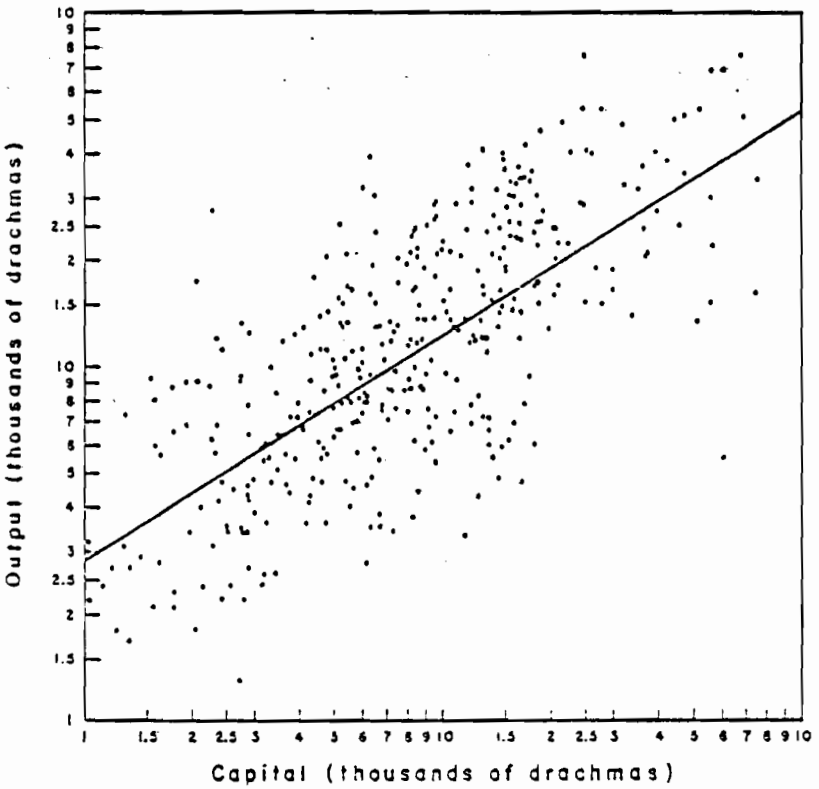

FIG. 1.—Scatter diagram and least-squares regression, log output on log capital

Source: Wise and Yotopoulos, p. 991, Figure 1.

FIGURE 2.--Greek data: ln output on ln labor

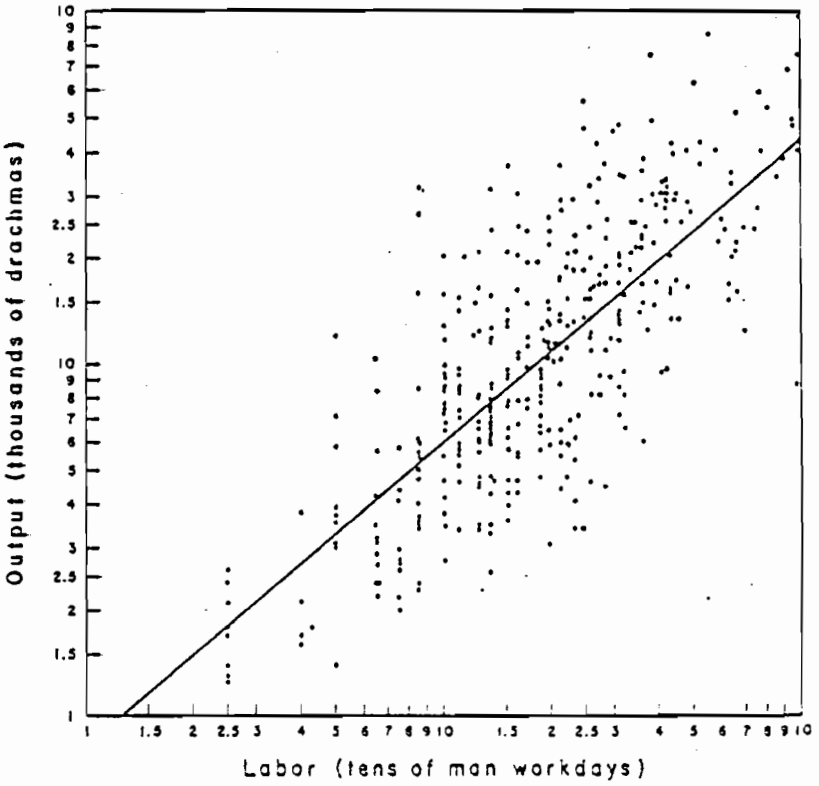

FIG. 2.—Scatter diagram and least-squares regression, log output on log labor

Source: Wise and Yotopoulos, p. 992, Figure 2.

FIGURE 3.--Greek data: ln capital on ln labor

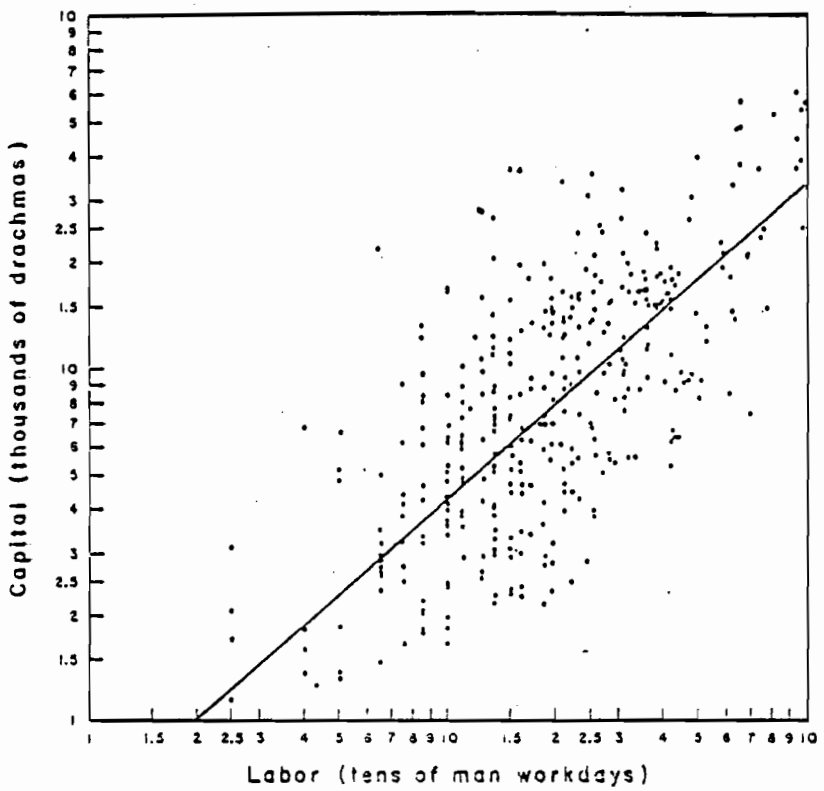

FIG. 3.—Scatter diagram and least-squares regression, log capital on log labor

Source: Wise and Yotopoulos, p. 993, Figure 3.

4.2 Results from the Dominican Republic Survey Data

The results from the application of the model to the data from the Dominican Republic can be seen first in Figures 4, 5, and 6 from the least squares regressions. Even before the diagonal regression coefficients are computed, it can be seen that the results are very similar to those from the Greek data. The scattergrams for the Dominican Republic show some observations with zero output and zero labor. These are considered to be valid observations because in some cases the crops were permanent and had not been harvested for the first time, some harvests were lost, and finally, in some cases no agricultural activities had taken place on the farms during the period for which the data was collected.

Table 9 shows the results of the regressions run on the weighted data.[1] The estimate for P, the so-called index of economic rationality, is .7174 for all farms. The table shows that the largest farm-size category has the highest index. In other words, on large farms, 71% of the variance in the natural logs of capital and labor is due to systematic profit maximizing behavior, while only 62% of the variance on small farms is profit maximizing.

The diagonal regression estimates of $(1 + \frac{1}{\eta})$ ln output on ln other costs and $(1 + \frac{1}{\varepsilon})$ ln output on ln labor have values close to one for all farm sizes, which is the limiting condition for perfect competition. These values reconfirm that the

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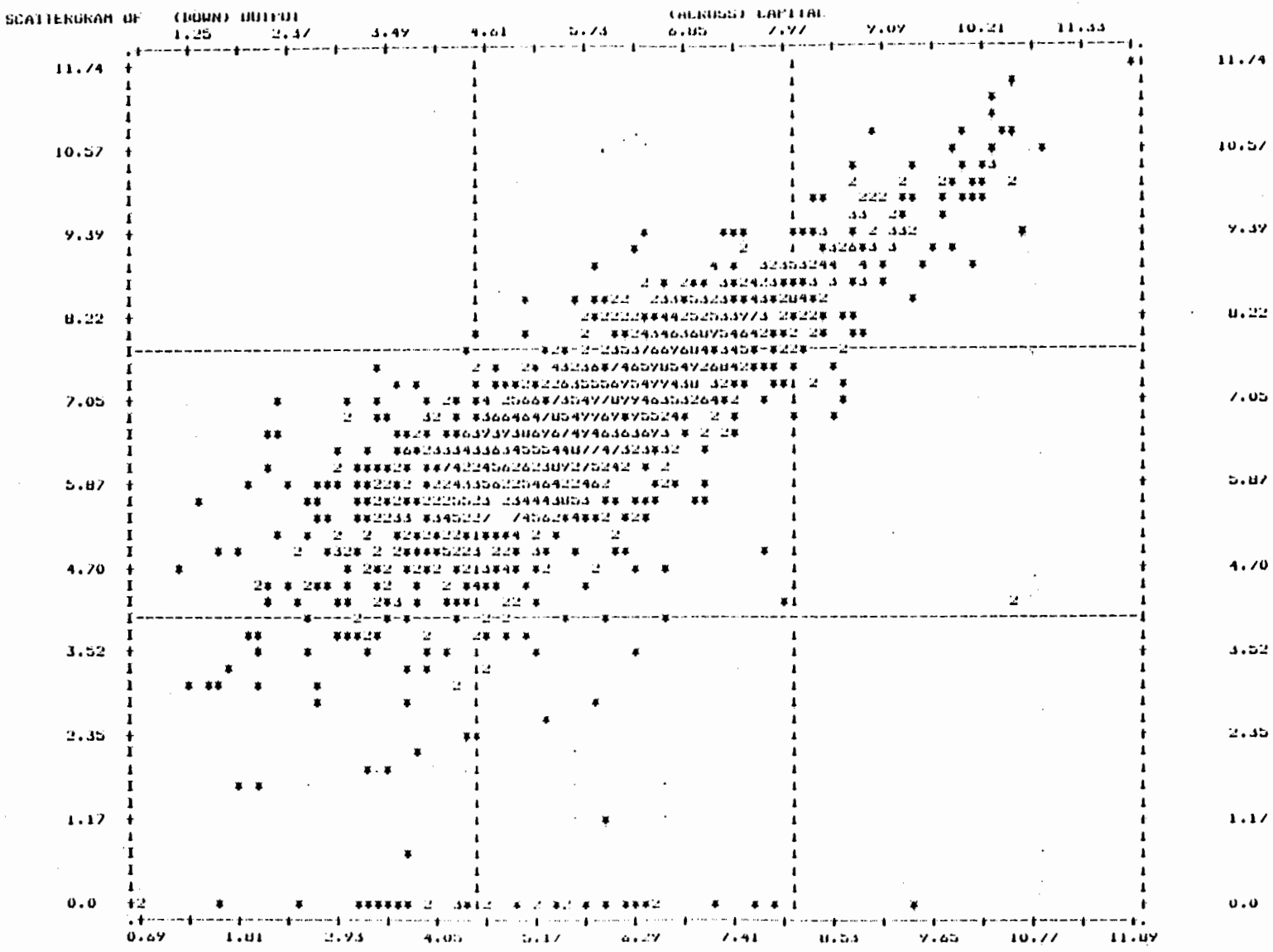
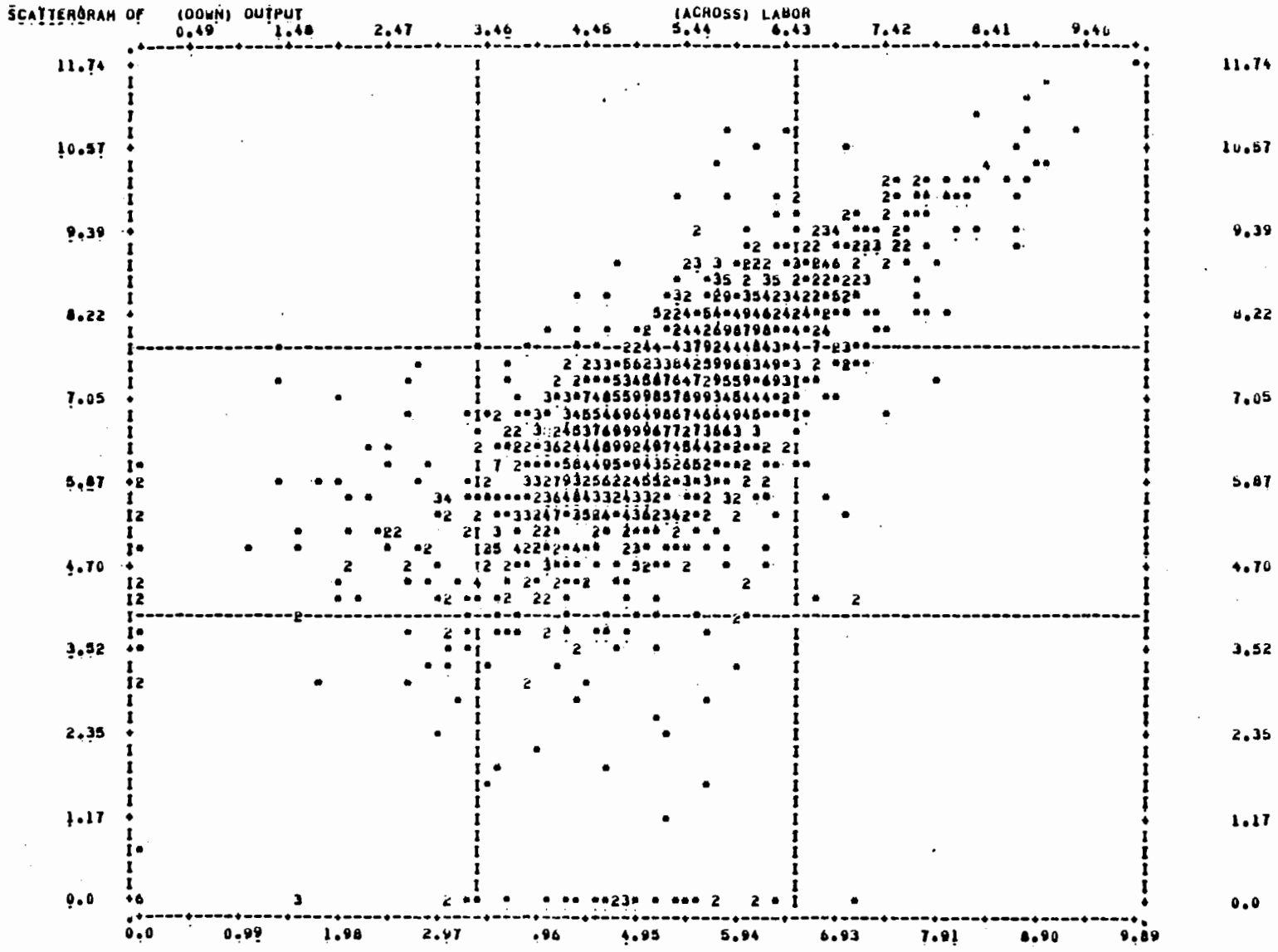
[1]See Appendix A for the explanation of the weighting procedures employed.

FIGURE 4.--Scattergram of ln output on ln capital (unweighted data)



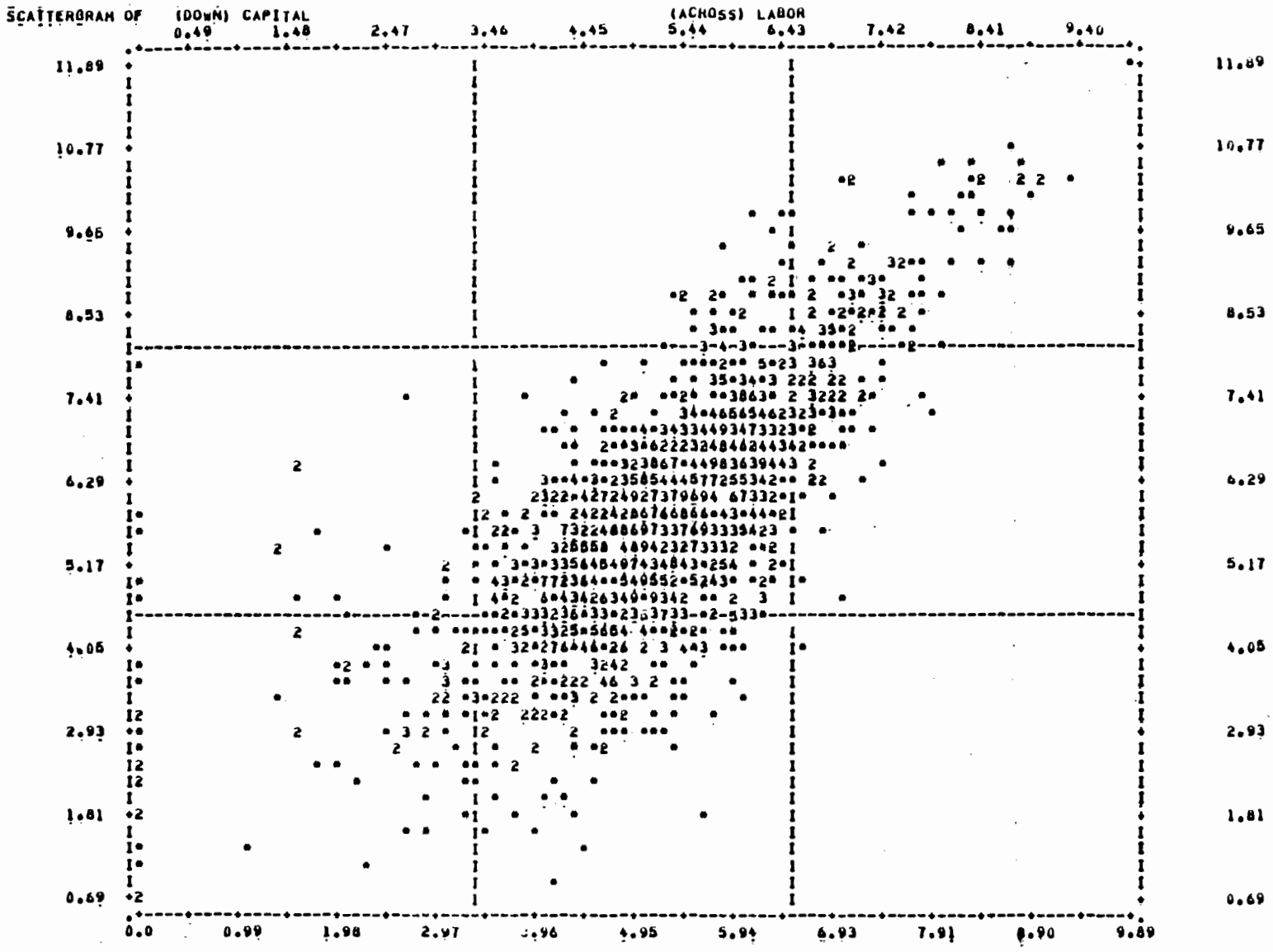
Source: Dominican Republic Sector Analysis Survey, April 1975-March 1976.

FIGURE 5.--Scattergram of ln output on ln labor (unweighted data)



Source: Dominican Republic Sector Analysis Survey, April 1975-March 1976.

FIGURE 6.--Scattergram of ln capital on ln labor (unweighted data)



Source: Dominican Republic Sector Analysis Survey, April 1975-March 1976.

TABLE 6.--Statistics from Figure 4, ln output on ln capital[1]

Correlation	.70117
R Squared	.49164
Significance	.00001
Standard Error of the Estimate	1.21756
Intercept	2.44515
Slope	.74088
Plotted Values	1,800

TABLE 7.--Statistics from Figure 5, ln output on ln labor[1]

Correlation	.64095
R Squared	.41081
Significance	.00001
Standard Error of the Estimate	1.31079
Intercept	2.34387
Slope	.85810
Plotted Values	1,800

TABLE 8.--Statistics from Figure 6, ln capital on ln labor[1]

Correlation	.72558
R Squared	.52646
Significance	.00001
Standard Error of the Estimate	1.11214
Intercept	1.10483
Slope	.91933
Plotted Values	1,800

Source: Dominican Republic Sector Analysis Survey, April 1975-March 1976.

[1]Run on unweighted data.

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TABLE 9:--Regression coefficients of input use and output for the weighted data from the Dominican Republic

Relation Estimated	Quantity Estimated	All Farms n = 1802		Small Farms (8-79 Tareas)[1] n = 989		Medium Farms (80-499 Tareas)[1] n = 606		Large Farms (500+ Tareas)[1] n = 207	
		Least Squares	Diagonal Regression	Least Squares	Diagonal Regression	Least Squares	Diagonal Regression	Least Squares	Diagonal Regression
ln Output on ln Other Costs (capital)	$1 + \frac{1}{\eta}$	.6766 (.0177)	1.009 (.0263)	.6542 (.0297)	1.139 (.0517)	.6135 (.0323)	1.004 (.0529)	.5858 (.0650)	1.100 (.1220)
ln Output on ln Labor	$1 + \frac{1}{\varepsilon}$	.8643 (.0232)	1.309 (.0351)	.7312 (.0348)	1.315 (.063)	.8213 (.0456)	1.395 (.0780)	.8497 (.0703)	1.318 (.1091)
ln Capital on ln Labor	$\frac{1 + \frac{1}{\varepsilon}}{1 + \frac{1}{\eta}}$	1.277	1.297	1.118	1.155	1.339	1.389	1.450	1.198
Pearson Correlation of Other Costs with Labor	P	.7174		.6179		.6117		.7113	
Supply Elasticity for Capital	η	111.11		7.19		250.00		10.00	
Supply Elasticity for Labor	ε	3.24		3.18		2.53		3.145	

Source: Sector Analysis Survey, April 1975-March 1976.

[1]One tarea is equal to 1/16 of a hectare or .154 acre.

errors in variables model is the most appropriate. It is consistent with the hypothesis that neither the dependent nor the independent variables are free of error and that "the errors in all variables are equally important."[1] On the other hand, the results from the ordinary least squares are not as accurate because the hypothesis that the independent variables of capital and labor are free of error is incorrect.

The supply elasticities for capital and labor are all positive and reasonable with the exception of the high supply elasticity of capital for medium-sized farms. This high elasticity implies that it is easier for them to expand output by hiring more capital services. In other words, they have more access to capital than do small or large farms.

In the analysis of the results from the Greek data, Wise and Yotopoulos note that splitting the sample into two subsets does not change the results drastically. The same can be said for splitting the data from the Dominican survey into three subsets. However, Wise and Yotopoulos go on to state that "therefore, we have no reasons to suspect that we have been fitting a nonhomogeneous population of farms."[2] The same cannot be said for the Dominican farms. They in fact comprise farms from 8 tareas to 18,000 tareas (1.23 to 2,780 acres) from all regions in the country. They cultivate from one to twenty crops per

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[1]Wise and Yotopoulos, p. 995.

[2]Ibid, p. 997.

farm, and there are seventy-one different possible crops with an infinite number of crop combinations. They raise up to eight different types of animals and process up to fifteen types of processed products. Therefore, aside from criticisms of Paul R. Johnson noted in part three of this chapter, we might also add the observation that given the technical necessity of combining a certain amount of inputs to produce outputs, it would be difficult to find a group of farms for which the model did not produce results similar to those discussed in this chapter.

Putting aside the critiques for the moment, we shall merely point out that according to the model discussed in sections three through six of this chapter, the farmers in the Dominican Republic act as profit maximizers. Based upon these results we shall assume that they are and proceed to Chapter II where Gini coefficients and analysis of variance will be used to determine the target group for agricultural planners.

CHAPTER 2

DETERMINATION OF THE TARGET GROUP; DESCRIPTION OF FARM AND FAMILY INCOME BY REGION AND FARM SIZE GROUP

1. The Calculation of Gross Income

The figures presented below are derived from standard income accounting techniques. Gross farm income is the total value of production from all crops, livestock, and processed products produced on the farm, and non-farm income is all income acquired from non-farm sources like artisan work, interest and dividends, agricultural work on other farms, work in other sectors and transfers of income from emigrants.[1]

2. Description of the Size of Gross Farm and Non-Farm Income by Farm Size

The average gross income per family is DR$2,629 per year, of which DR$2,185 is produced on the farm. The small farms (8-79 tareas);[2] average less than one half of the national average with a gross family income of DR$1,249 and are more dependent upon non-farm sources of income than are the medium size and large farms. The medium sized farms (80-499 tareas) average

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[1]See Appendix B for a more thorough discussion of the computation of gross farm income.

[2]One tarea = $\frac{1}{16}$ of a hectare or .154 acre.

DR$2,881 in net family income, 14% of which is acquired from non-farm sources. As expected, the large farms (500+ tareas) have the largest average gross family income, DR$9,276, and are least dependent upon non-farm sources. (Refer to Table 10.)

The relationship between farm size and gross family income is thus positive and overwhelming. Both gross farm and non-farm income increase as farm size increases, but the former increases by almost ten times from the small to the large farm size category, while the latter increases by only three times. The relationship between farm size and gross farm income will be explored more thoroughly in the next section.

TABLE 10.--Gross income and gross farm income in DR$ by farm size

	Total Gross Income	Gross Farm Income	Non-Farm Income	Non-Farm as % of Total
Total Pais	2629	2185	444	16.9
8-79 tas.	1249	895	354	28.3
80-499 tas.	2881	2477	404	14.0
500+ tas.	9726	8602	1124	11.6

Source: Dominican Republic Sector Analysis Survey, April 1975-March 1976.

2.1 Gini Coefficients of Land and Gross Farm Income Distribution

The relationship between farm size and gross farm income is of fundamental importance. We will therefore explore the

data on land and gross farm income with the use of the Gini index or concentration coefficient. This index is designed to summarize data on the distribution of land or income (or any other chosen variable) among receivers by measuring the area between the "Lorenz curve"[1] and the so-called "line of equality," as a proportion of the total area under the "line of equality." The Lorenz curve shows the percent of the variable to be measured which pertains to a given percentage of the receivers, and the "line of equality" shows what the Lorenz curve would look like if the percentage of the variable to be measured is equal to the percentage of the receivers to which it pertains for all percentiles of the receivers. This explanation becomes more comprehensible when it is presented with the help of a graph. Figure 8 shows the "line of equality," the Lorenz curve, the area between the two and the area under the "line of equality." If the area between the line of equality and the Lorenz curve is equal to zero ($a = 0$), then that area over the total area under the "line of equality" is also equal to zero ($a/b = 0$), and there is complete equality of distribution of the variable in question. The ratio a/b is the Gini index; the larger the value of (a) is, the larger will be the ratio of a/b (the Gini index). The larger the value of the Gini index is, the greater will be the inequality of the distribution of the variable in question.

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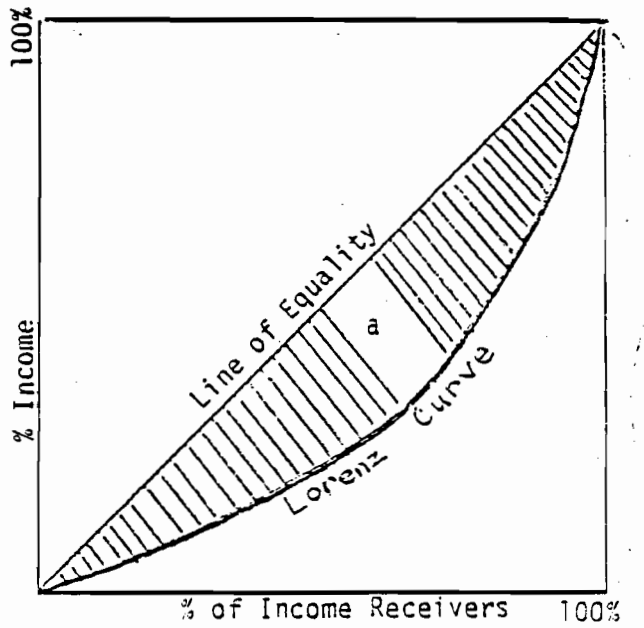
[1]The Lorenz curve usually shows income distribution but can be used to show the distribution of any variable among receivers.

FIGURE 7.--Lorenz Curve



b= total area under "line of equality"

Columns 1 and 2 of Table 11 show the numerical values of the Lorenz curve for the distribution of land among receivers. We can see immediately that the distribution of land among farms is quite unequal. For example, 9.42% of the farms have less than 15 tareas of land. As a group they hold only .52% of the land covered by the survey. On the other hand, 1.58% of the farms have 2,000 tareas or more, and they hold 26.72% of the land covered in the survey. The Gini index summarizes the information in columns one and two by showing that the inequality of land distribution among farms is .693.

We are interested not only in the distribution of land among farms, but also in the distribution of gross farm income among farms and the relationship between the two distributions. Table 12 shows the distribution of gross farm income among farms by income group. We see, once again, that the bottom 7.8% of the farms receive (produce) .13% of the total value of production calculated for the sample, while 3.31% of the farms receive (produce) 35.13% of the gross farm revenue. The Gini index for the distribution of gross farm income is .661.

The similarity between the distribution of land and gross farm income can be seen more clearly when we compute the percent of land and the percent of gross farm income which pertains to the farm families in each farm-size category. Columns two and three of Table 13 show the percentage of land and the percentage of gross farm income (respectively) which pertain to each percentile of the farms defined in column one.

TABLE 11.--Distribution of land

Land Bracket in Tareas	(1) Percent Receivers	(2) Percent Land
Land Group		
Dummy	0.00	0.00
< 15	9.42	0.52
15 - 19	4.77	0.39
20 - 24	5.57	0.58
25 - 29	4.06	0.53
30 - 34	4.32	0.66
35 - 39	2.83	0.50
40 - 44	3.57	0.72
45 - 49	2.03	0.47
50 - 59	6.69	1.73
60 - 69	6.00	1.85
70 - 79	5.46	1.97
80 - 99	5.32	2.28
100 - 149	10.86	6.17
150 - 199	6.69	5.39
200 - 249	4.73	4.91
250 - 299	1.70	2.24
300 - 499	6.62	11.64
500 - 799	4.29	12.48
800 - 999	1.12	4.64
1000 - 1499	2.00	10.63
1500 - 1999	0.36	2.98
> 1999	1.58	26.72
TOTAL	99.99	100.00

GINI INDEX LAND GROUP = 0.693

Source: Dominican Republic Sector Analysis Survey, April 1975-March 1976

TABLE 12.--Distribution of gross farm income

Income Bracket in DR$	(1) Percent Receivers	(2) Percent Income
Income Group		
Dummy	0.00	0.00
< 50	4.14	0.01
50 - 99	3.73	0.12
100 - 199	5.92	0.38
200 - 299	6.86	0.79
300 - 399	5.14	0.81
400 - 499	5.70	1.17
500 - 599	4.70	1.18
600 - 699	4.07	1.21
700 - 799	5.00	1.74
800 - 899	3.73	1.44
900 - 999	4.49	1.96
1000 - 1199	5.39	2.71
1200 - 1399	5.28	3.11
1400 - 1599	6.73	4.65
1600 - 1799	2.72	2.10
1800 - 1999	2.70	2.34
2000 - 2999	8.40	9.41
3000 - 3999	4.79	7.63
4000 - 4999	2.51	5.17
5000 - 5999	1.57	3.90
6000 - 7999	2.08	6.67
8000 - 10000	1.52	6.30
> 9999	3.31	35.13
TOTAL	100.47	99.93

GINI INDEX INCOME GROUP = .661

Source: Dominican Republic Sector Analysis Survey, April 1975-March 1976

TABLE 13.--Distribution of land and gross farm income by land groups

Land Bracket in Tareas	(1) Percent Receivers	(2) Percent Land	(3) Percent Gross Farm Income
Land Group			
Dummy	0.00	0.00	0.00
< 15	9.42	0.52	1.39
15 - 19	4.77	0.39	1.19
20 - 24	5.57	0.58	2.45
25 - 29	4.06	0.53	1.33
30 - 34	4.32	0.66	1.57
35 - 39	2.83	0.50	1.38
40 - 44	3.57	0.72	1.36
45 - 49	2.03	0.47	.81
50 - 59	6.69	1.73	3.41
60 - 69	6.00	1.85	4.13
70 - 79	5.46	1.97	3.38
80 - 99	5.32	2.28	3.76
100 - 149	10.86	6.17	8.39
150 - 199	6.69	5.39	6.29
200 - 249	4.73	4.91	6.45
250 - 299	1.70	2.24	2.80
300 - 499	6.62	11.64	13.01
500 - 799	4.29	12.48	12.60
800 - 999	1.12	4.64	2.41
1000 - 1499	2.00	10.63	6.25
1500 - 1999	0.36	2.98	3.19
> 1999	1.58	26.72	12.45
TOTAL	99.99	100.00	0.00

Source: Dominican Republic Sector Analysis Survey, April 1975-March 1976.

When the values in columns two and three are ranked, the correlation appears to be high. In fact, the rank correlation of the percentages of land and gross farm income pertaining to the farm families of each farm size is .7229 (using Kendall's Tau) or .9063 (using Spearman's Rho). Table 14 shows the rankings and the rank correlations referred to.

3. Review of the Size of Gross Farm and Non-farm Income by Zone and Region

The difference in average gross farm income and average total gross income among zones is much smaller than the difference observed among farm-size groups. Average non-farm income ranges from DR$404 to DR$557, and average gross farm income ranges from DR$1,881 to DR$2,322. Zone C has the highest total income as well as the highest farm income. Zone A ranks second with respect to both and Zone B ranks last. (See Table 15.)

Unfortunately, the zonal partition of the country hides some of the regional differences in gross income. Zone A is made up of Region 1, which has the highest gross income, Region 2, which ranks 4th, and Region 3, which ranks last. Zone B is made up of Regions 5 and 6, which rank 5th and 6th, and Zone C has Regions 4 and 7, which rank 2nd and 3rd.

Table 16 shows that except for very slight changes in order, the ranking of categories by gross <u>farm</u> income is very similar to that of <u>total</u> gross income; Region 1 is first, Regions 4 and 7 follow, 2 and 5 are next, and 3 and 6 are last.

TABLE 14.--Rank correlation of % land and % gross farm income by land group

Land Bracket in Tareas	(1) Percent Receivers	(2) Rank of Percent Land	(3) Rank of Percent Gross Farm Income
Land Group			
Dummy	0.00		
< 15	9.42	4	6
15 - 19	4.77	1	2
20 - 24	5.57	6	9
25 - 29	4.06	5	3
30 - 34	4.32	7	7
35 - 39	2.83	3	5
40 - 44	3.57	8	4
45 - 49	2.03	2	1
50 - 59	6.69	9	13
60 - 69	6.00	10	15
70 - 79	5.46	11	12
80 - 99	5.32	13	14
100 - 149	10.86	18	19
150 - 199	6.69	17	17
200 - 249	4.73	16	18
250 - 299	1.70	12	10
300 - 499	6.62	20	22
500 - 799	4.29	21	21
800 - 999	1.12	15	8
1000 - 1499	2.00	19	16
1500 - 1999	0.36	14	11
> 1999	1.58	22	20
TOTAL	99.99		

Rank Correlation
Spearman's rho .9063
Kendall's tau .7229

Source: Dominican Republic Sector Analysis Survey, April 1975-March 1976.

FIGURE 8.--Dominican Republic: zones and regions

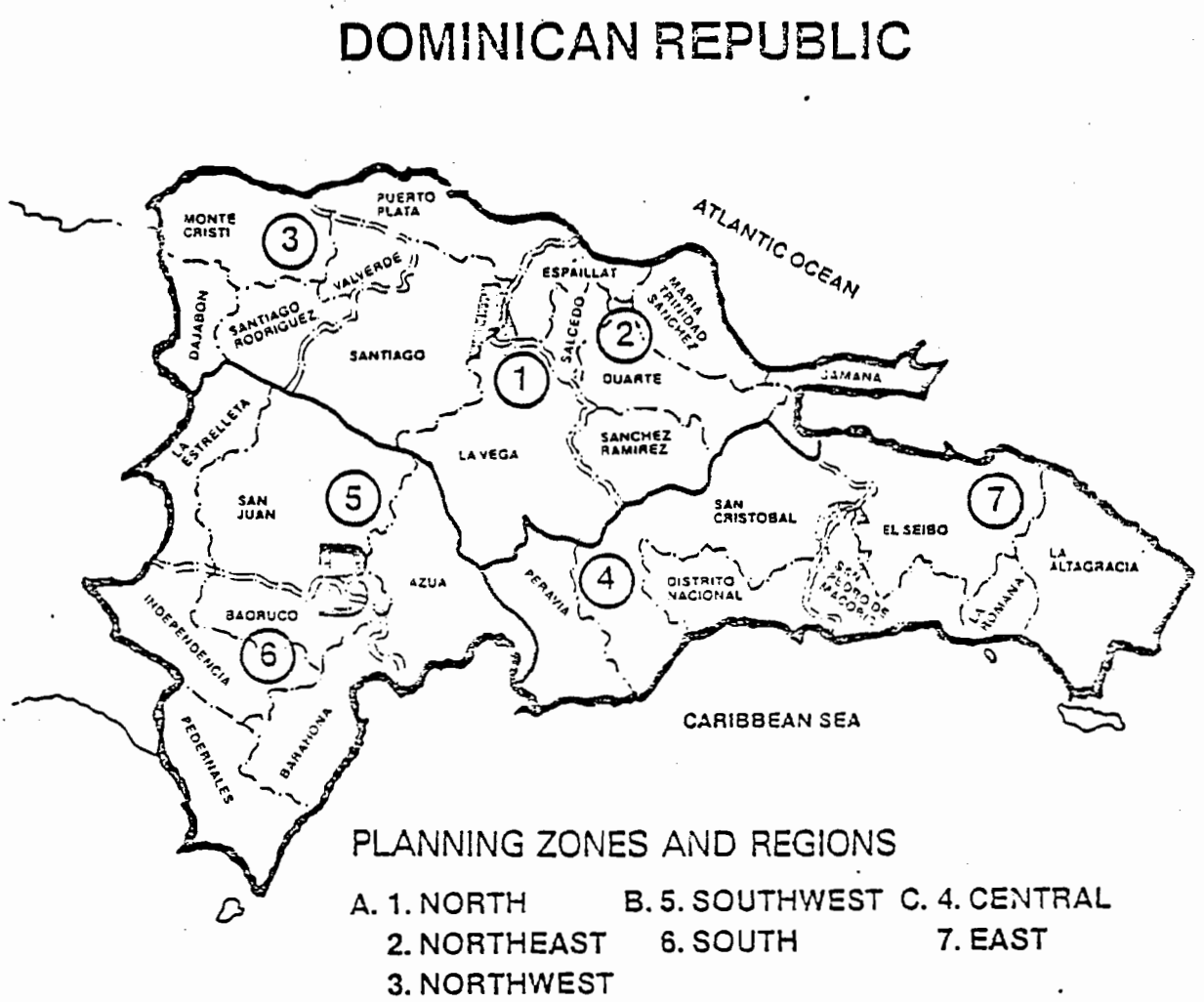


TABLE 15.--Gross income and gross farm income in DR$ by zone

Farm Size (Tareas)	Total Gross Family Income	Gross Farm Income	Non-Farm Income	Non-Farm as Percent of Total
Zone A	2641	2236	405	15.3
8-79	1120	766	354	31.6
80-499	2788	2436	352	12.6
500+	11576	10565	1011	8.7
Zone B	2258	1881	404	16.7
8-79	1194	982	212	17.8
80-499	3296	2819	477	14.5
500+	6197	4908	1289	20.8
Zone C	2879	2322	577	19.4
8-79	1642	1143	499	30.4
80-499	2771	2330	441	15.9
500+	8311	7079	1232	14.8

Source: Dominican Republic Sector Analysis Survey, April 1975-March 1976.

TABLE 16.--Gross income and gross farm income by region

	Total Gross Family Income		Gross Farm Income		Non-Farm Income
	DR$	Rank	DR$	Rank	DR$
Zone A					
Region 1	3169	(1)	2645	(1)	531
Region 2	2368	(4)	2007	(5)	373
Region 3	1631	(7)	1482	(7)	152
Zone B					
Region 5	2337	(5)	2040	(4)	305
Region 6	2117	(6)	1624	(6)	495
Zone C					
Region 4	2871	(2)	2274	(3)	605
Region 7	2859	(3)	2397	(2)	469

Source: Dominican Republic Sector Analysis Survey, April 1975-March 1976

3.1 Differences among Zones and Regions

Analyses of variance are used to test the hypothesis that the mean gross farm income is the same across zones, regions, and farm-size categories. The findings in Tables 17-A and 17-B support the hypothesis at the zonal level. At the regional level it is rejected with a 90% level of confidence.

Tables 18-A and 18-B indicate that among zones there is a significant difference in the gross farm income for small farms and large farms, and that among regions the most significant differences are among small farms and medium farms. Zonal differences among medium-size farms are non-existent and regional differences among large farms have a low F ratio of 1.455 with an 80% level of confidence. The regional level is therefore the most appropriate disaggregation for analysis and will be used for all farm size categories.

Table 19 shows that the regional differences do not lend themselves to easy summarization. In fact, we have a three way split among zones. Region 4 in Zone C excels in the small-farm category, Region 5 of Zone B excels in the medium size category, and Region 1 of Zone A excels in the large size category. We are, however, left with the conclusion that Regions 3 and 6 are definitely the lowest income producers in the country.

TABLE 17-A.--Results from two-way analysis of variance of the zonal and farm-size differences in the mean gross farm income

Source of Variation	Number of Observations	F Ratio	Significance of F
Zones (3)	1802	.446	.999
Farm Sizes (3)	1802	207.484	.001
2-way interaction		4.761	.001

TABLE 17-B.--Results from two-way analysis of variance of the regional and farm-size differences in the mean gross farm income

Source of Variation	Number of Observations	F Ratio	Significance of F
Regions (7)	1802	1.872	.081
Farm Sizes (3)	1802	209.383	.001
2-way interaction		4.761	.001

Source: Dominican Republic Sector Analysis Survey, April 1975-March 1976.

TABLE 18-A.--Results from one-way analyses of variance of the zonal differences in the mean gross farm income within farm-size categories

Source of Variation	Number of Observations	F Ratio	Significance of F
Small Farms Zones (3)	989	6.949	.001
Medium Farms Zones (3)	606	.786	.456
Large Farms Zones (3)	207	3.019	.051

TABLE 18-B.--Results from one-way analyses of variance of the regional differences in the mean gross farm income within farm-size categories

Source of Variation	Number of Observations	F Ratio	Significance of F
Small Farms Regions (7)	989	4.718	.000
Medium Farms Regions (7)	606	2.131	.048
Large Farms Regions (7)	207	1.455	0.195

Source: Dominican Republic Sector Analysis Survey, April 1975-March 1976.

TABLE 19.--Gross farm income by zone, region, and farm size

	All Farms		8-79 tareas		80-499 tareas		500+ tareas	
	DR$	Rank	DR$	Rank	DR$	Rank	DR$	Rank
All Farms	2185		895		2477		8602	
Zone A	2236	(2)	766	(3)	2436	(2)	10565	(1)
Region 1	2644	(1)	752	(6)	2467	(3)	11334	(1)
Region 2	2010	(5)	784	(4)	2695	(2)	8518	(4)
Region 3	1488	(7)	767	(5)	1670	(7)	10973	(2)
Zone B	1881	(3)	982	(2)	2819	(1)	4908	(3)
Region 5	2041	(4)	1182	(2)	3596	(1)	4496	(7)
Region 6	1621	(6)	546	(7)	1728	(6)	5033	(6)
Zone C	2322	(1)	1143	(1)	2330	(3)	7079	(2)
Region 4	2275	(3)	1285	(1)	2375	(4)	5396	(5)
Region 7	2404	(2)	972	(3)	2199	5)	9760	(3)

Source: Dominican Republic Sector Analysis Survey, April 1975-March 1976.

4. Per Capita Gross Income

Gross income per capita is the final item chosen for the discussion of gross income. We know at the outset that if a farm has a low per capita gross income, the per capita net income is lower. We can therefore point out, even at the gross income level of analysis, that the average per capita income for the smallest farm size category is inadequate; it is DR$195, which is less than half of the per capita gross income of medium-size farms and only 15% of that of large farms (see Table 19-A).

If we focus in at the regional level, we see more clearly where the real poverty pockets are within the country. All of the regions bordering Haiti have a lower gross farm income per capita than the other regions. However, according to the figures presented in Table 19-B, the farms with the lowest per capita gross farm income are the smallest farms in Region 6 followed by the smallest farms in Regions 1 and 2.

It seems appropriate to close the discussion of gross income with the observation that even before the costs of production are deducted from revenue, farm families with less than 80 tareas in the farm have an inadequate total income. The alternatives that remain open for improving this situation are the following: increase non-farm income by making more work available off the farm, increase farm revenue by making more of the basic factors of production available or increase farm revenue by increasing the economic efficiency of the farms.

TABLE 19-A--Gross income and gross farm income per capita by zone and farm size

	Total Gross Family Income Per Capita	Gross Farm Income Per Capita
	DR$	DR$
All Farms	392.39	326.12
8-79 tareas	195.16	139.84
80-499 tareas	411.57	353.86
500+ tareas	1314.32	1162.43

TABLE 19-B--Per capita gross farm income by region and farm size

	All Farms	8-79 tareas	80-499 tareas	500+ tareas
	DR$	DR$	DR$	DR$
Region 1	383.37	114.87	341.41	1450.89
Region 2	304.12	127.27	371.58	1144.21
Region 3	251.26	138.71	240.76	1729.19
Region 4	349.91	188.54	393.65	737.70
Region 5	272.01	166.29	447.11	456.19
Region 6	219.59	71.60	240.13	689.87
Region 7	399.36	175.03	316.20	1542.09

Source: Dominican Republic Sector Analysis Survey, April 1975-March 1976.

Before a choice among alternatives can be recommended, we must proceed to examine the efficiency with which resources are employed.

CHAPTER 3

THE PROFIT FUNCTION AND ITS APPLICATION TO THE ANALYSIS OF THE ECONOMIC EFFICIENCY OF THE TARGET GROUP

The methodology employed in this chapter is discussed in Section 1. A review of its application to Indian agriculture is contained in Section 2. Finally, the results of the application of the methodology to the data from the Dominican Republic Sector Analysis Survey are presented in Section 3.

1. A Review of the Methodology

The methodology employed in this chapter was developed by Lawrence Lau and Pan A. Yotopoulos in the article "A Test for Relative Efficiency and Application to Indian Agriculture." The methodology is applied to farms but is not restricted to agriculture. The methodology attempts to measure economic efficiency. In the opinion of the authors, "the minimum requirements for a useful concept of economic efficiency" are:

1. It should account for firms that produce different quantities of output from a given set of measured inputs of production. This is the component of differences in <u>technical efficiency</u>.
2. It should permit different firms to vary in their ability to maximize profits, that is, in equating the value of the marginal product of each variable factor

of production to its price. This is the component of price efficiency.

3. It should account for the fact that firms may operate at different sets of market prices.[1]

The authors claim that "by using the profit function we will encompass all these requirements into the single concept of economic efficiency."[2]

1.1 The Profit Function

Profit is defined as current revenues less current total variable costs, where P' is profit, and P is unit price

$$(1) \quad P' = F(X_1, \ldots, X_m; Z_1, \ldots, Z_n)$$

$$P' = pF(X_1, \ldots, X_m; Z_1, \ldots, Z_n)$$

$$(2) \quad - \sum_{i=1}^{m} c_i' X_i$$

and c_i' is the unit price of the ith input.

The marginal productivity is

$$(3) \quad p \frac{\partial F(X:Z)}{\partial X_i} = c_i', \qquad i = 1, \ldots, m$$

so $c_i = c_i'/p$, can be defined as the normalized price using p as numeraire.

$$(4) \quad \frac{\partial F}{\partial X_i} = c_i, \qquad i = 1, \ldots, m$$

The profit is also deflated by the price of output, and equation (5) becomes the "Unit-Output-Price" (UOP) profit:

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[1]Lawrence Lau and Pan A. Yotopoulos, "A Test for Relative Efficiency and Application to Indian Agriculture," American Economic Review 61 (March 1971): 95.

[2]Ibid.

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$$(5)\quad P = \frac{P'}{p} = F(X_1, \ldots, X_m; Z_1, \ldots, Z_n) - \sum_{i=1}^{m} c_i X_i$$

The key to the development of the profit function is that equation (4) may be solved for optimal levels of the inputs X_i^*'s

$$6)\quad X_i^* = f_i(c, Z), \qquad i = 1, \ldots, m$$

so the profit function becomes a function of only the price of output, the price of variable inputs, and the quantity of fixed inputs.

$$(7)\quad \Pi = p\left[F(X_1^*, \ldots, X_m^*; Z_1, \ldots, Z_n) - \sum_{i=1}^{m} c_i X_i^*\right] = G(p, c_1, \ldots, c_m; Z_1, \ldots, Z_n)$$

$$(8)\quad \Pi = pG^*(c_1, \ldots, c_m; Z_1, \ldots, Z_n)$$

$$(9)\quad \Pi^* = \frac{\Pi}{p} = G^*(c_1, \ldots, c_m; Z_1, \ldots, Z_n)$$

The UCP profit functions can be used to analyze profit maximizing price taking firms without explicitly specifying or solving their production functions, because there is a <u>set of dual transformation relations between the production function, the cost function, the revenue function, and the profit function</u>. The following is discussed by Daniel McFadden:

1) Standard production possibility sets which have convex input structures are characterized uniquely by their input functions. The standard cost structures and the convex input structures are one to one.

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2) A duality also exists between standard production possibility sets with concave output structures and their unique revenue functions.

3) If a firm treats prices as given and behaves as a profit maximizer, then the profit function can be derived as a function of the revenue structures.

4) Thus, a profit function can be derived from a unique standard production possibility set.[1]

The last transformation is summarized by Lawrence Lau:[2]

	Primal	Dual
Function:	Production Function	UOP Profit Function
Variables:	Quantities: X_i	Normalized prices: c_i
Passive Variables:	Fixed inputs: Z_j	Fixed inputs: Z_j

Transformation

(i)	$P^* = F(X_1,\ldots,X_m,Z_1,\ldots,Z_n) - \sum_{i=1}^{m} c_i X_i$	$\Pi^*(c_1,\ldots,c_m,Z_1,\ldots,Z_n)$	
(ii)	$\frac{\partial F}{\partial X_i} = c_i$	$c_i = \frac{\partial F}{\partial X_i}$	
(iii)	$X_i = -\frac{\partial \Pi^*}{\partial c_i}$	$\frac{\partial \Pi^*}{\partial c_i} = -X_i$	(I-16)
(iv)	$\frac{\partial F}{\partial Z_i} = \frac{\partial \Pi^*}{\partial Z_i}$	$\frac{\partial \Pi^*}{\partial Z_i} = \frac{\partial F}{\partial Z_i}$	
(v)	$F = \Pi^* - \sum_{i=1}^{m} \frac{\partial \Pi^*}{\partial c_i} c_i$	$\Pi^* = F - \sum_{i=1}^{m} \frac{\partial F}{\partial X_i} X_i$	
(vi)	Z_i	Z_i	

[1]Daniel McFadden, "Cost, Revenue, and Profit Functions; A Cursory Review," in An Econometric Approach to Production Theory, ed.

[2]Lawrence Lau, "Some Applications of Profit Functions," Memorandum No. 86-A, November 1969, Research Center in Economic Growth, Stanford University, Stanford, California.

Therefore, the firms' supply and factor demand functions can be directly derived from the UCP profit functions

$$(10) \quad X_i^* = -\frac{\partial \Pi^*(c, Z)}{\partial c_i}, \quad i = 1, \ldots, m,$$

$$(11) \quad V^* = \Pi^*(c, Z) - \sum_{i=1}^{m} \frac{\partial \Pi^*(c, Z)}{\partial c_i} c_i$$

1.2 Relative Economic Efficiency

The use of the profit function in the analysis of price and technical efficiency requires the definition of such parameters in the production function.

$$(12) \quad \begin{aligned} V^1 &= A^1 F(X^1, Z^1); \\ V^2 &= A^2 F(X^2, Z^2) \end{aligned}$$

"A" represents the technical efficiency parameter which can be compared for two firms with comparable endowments, technology, and input prices. If they are equal, there is no difference in the technical efficiency of the firm.

Differentiating the function with respect to the variable inputs they derive

$$(13) \quad \begin{aligned} \frac{\partial A^1 F(X^1, Z^1)}{\partial X_j^1} &= k_j^1 c_j^1 \\ \frac{\partial A^2 F(X^2, Z^2)}{\partial X_j^2} &= k_j^2 c_j^2 \\ k_j^1 \geqq 0,\ k_j^2 &\geqq 0,\ j = 1, \ldots, m \end{aligned}$$

which equates the marginal products of the inputs to their normalized prices. The ks represent the deviations from the equalities. Only if the ks equal 1 are the firms price efficient.

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Referring back to the relevant duality theorems, they show the UOP profit function corresponding to the production function

$$V = AF(X, Z) \quad \text{is}$$

$$(14) \qquad \Pi^* = AG^*(c/A, Z)$$

so II* for the two firms can be written

$$(15) \qquad \begin{aligned} \Pi_b^1 &= A^1 G^*(k_1^1 c_1^1/A^1, \ldots, k_m^1 c_m^1/A^1; \\ &\qquad Z_1^1, \ldots, Z_n^1) \\ \Pi_b^2 &= A^2 G^*(k_1^2 c_1^2/A^2, \ldots, k_m^2 c_m^2/A^2; \\ &\qquad Z_1^2, \ldots, Z_n^2) \end{aligned}$$

and the demand and supply curves can be derived from the UOP profit functions. The former by differentiating with respect to $k_j^1 c_j^1$'s and $k_j^2 c_j^2$'s

$$(16) \qquad \begin{aligned} X_j^i &= -A^i \frac{\partial G^*(k^i c^i/A^i; Z^i)}{\partial k_j^i c_j^i} \\ &= \frac{-A^i}{k_j^i} \frac{\partial G^*(k^i c^i/A^i; Z^i)}{\partial c_j^i}, \\ &\qquad i = 1, 2; j = 1, \ldots, m \end{aligned}$$

and the latter by using the correspondence shown in (11)

$$(17) \qquad \begin{aligned} &= A^i G^*(k^i c^i/A^i; Z^i) \\ &\quad - A^i \sum_{j=1}^{m} c_j^i \frac{\partial G^*(k^i c^i/A^i; Z^i)}{\partial c_j^i}, \\ &\qquad i = 1, 2 \end{aligned}$$

Rather than derive (16) and (17) the UOP profit functions can be examined:

$$(18) \qquad \begin{aligned} \Pi_a^i &= V^i - \sum_{j=1}^{m} c_j^i X_j^i \\ &= A^i G^*(k^i c^i/A^i; Z^i) \\ &\quad + A^i \sum_{j=1}^{m} \frac{(1 - k_j^i) c_j^i}{k_j^i} \\ &\quad \cdot \frac{\partial G^*(k^i c^i/A^i; Z^i)}{\partial c_j^i}, \qquad i = 1, 2 \end{aligned}$$

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From it the following hypotheses can be tested:

$$A^1 = A^2 \text{ and } k^1 = k^2$$

because: $\frac{\partial \pi_a^i}{\partial A^i} > 0$; profit increases with the level of technical efficiency for given normalized prices.

2) When $k_j^i = 1$ for $j = 1 \ldots, m$, the actual and behavioral profit functions coincide.

It is the approach defined in (18) which the article employs. The UOP Profit Functions are used in lieu of the production, demand, and supply functions. This is done by specifying G within the context of a Cobb-Douglas Function.

1.3 The Formulation of the Cobb-Douglas Case

Lau and Yotopoulos present the transformation of the Cobb-Douglas Production Function with decreasing returns into its profit function.

$$Y = A\left(\prod_{i=1}^{n} X_i^{\alpha_i}\right)\left(\prod_{j=1}^{m} Z_j^{\beta_j}\right)$$

where $\mu = \sum_{i=1}^{n} \alpha_i < 1$

The UOP profit function is:

$$\Pi^* = A^{(1-\mu)^{-1}}(1-\mu) \cdot \left(\prod_{i=1}^{n} (c_i/\alpha_i)^{-\alpha_i(1-\mu)^{-1}}\right) \cdot \left(\prod_{j=1}^{m} Z_j^{\beta_j(1-\mu)^{-1}}\right) \tag{19}$$

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Lau and Yotopoulos go on to develop the actual UOP profit functions and demand functions for the Cobb-Douglas

$$\Pi_u^i = \left[(A^i)^{1-u)^{-1}}\left(1 - \sum_{j=1}^{m} \alpha_j/k_j^i\right)\right]\left[\prod_{j=1}^{m}(k_j^i)^{-\alpha_j(1-u)^{-1}}\right]\left[\prod_{j=1}^{m}\alpha_j^{-\alpha_j(1-u)^{-1}}\right] \cdot \left[\prod_{j=1}^{m}(c_j^i)^{-\alpha_j(1-u)^{-1}}\right]\left[\prod_{j=1}^{n}(Z_j^i)^{\beta_j(1-u)^{-1}}\right], \quad i = 1, 2 \tag{20}$$

$$X_l^i = (A^i)^{(1-u)^{-1}}(\alpha_l/k_l^i c_l^i)\left[\prod_{j=1}^{m}(k_j^i)^{-\alpha_j(1-u)^{-1}}\right]\left[\prod_{j=1}^{m}\alpha_j^{-\alpha_j(1-u)^{-1}}\right] \cdot \left[\prod_{j=1}^{m}(c_j^i)^{-\alpha_j(1-u)^{-1}}\right]\left[\prod_{j=1}^{n}(Z_j^i)^{\beta_j(1-u)^{-1}}\right], \quad i = 1, 2; \quad l = 1, \ldots, m \tag{21}$$

Equation (20) can be reduced to

$$\Pi_u^i = (A_u^i)\left[\prod_{j=1}^{m}(c_j^i)^{-\alpha_j(1-u)^{-1}}\right] \cdot \left[\prod_{j=1}^{n}(Z_j^i)^{-\beta_j(1-u)^{-1}}\right]. \quad i = 1, 2 \tag{23}$$

and rewritten as

$$\Pi_u^1 = A_u^1\left[\prod_{j=1}^{m}(c_j^1)^{-\alpha_j(1-u)^{-1}}\right] \cdot \left[\prod_{j=1}^{n}(Z_j^1)^{\beta_j(1-u)^{-1}}\right] \tag{25}$$

$$\Pi_u^2 = A_u^1(A_u^2/A_u^1)\left[\prod_{j=1}^{m}(c_j^2)^{-\alpha_j(1-u)^{-1}}\right] \cdot \left[\prod_{j=1}^{n}(Z_j^2)^{\beta_j(1-u)^{-1}}\right] \tag{26}$$

where

$$\alpha_j^* \equiv -\alpha_j(1 - \mu_j)^{-1}; \tag{27}$$

and

$$\beta_j^* \equiv \beta_j(1 - \mu_j)^{-1} \tag{28}$$

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The natural logarithms of equations (25) and (26) are

$$(29) \qquad ln\ \Pi_*^1 = ln\ A_*^1 + \sum_{j=1}^{m} \alpha_j^* \ ln\ c_j^1 + \sum_{j=1}^{n} \beta_j^* \ ln\ Z_j^1,$$

$$(30) \qquad ln\ \Pi_*^2 = ln\ A_*^1 + ln \frac{A_*^2}{A_*^1} + \sum_{j=1}^{m} \alpha_j^* \ ln\ c_j^2 + \sum_{j=1}^{n} \beta_j^* \ ln\ Z_j^2 \cdot$$

So if $A^1 = A^2$ and $k^1 = k^2$, then $A_*^1 = A_*^2$. Thus, in the final functional form, the price (k) and technical (A) effects are not separable so A_* denotes economic efficiency and can be compared for the two firms.

Since normalized input prices could not be computed for lack of money prices of output, the Cobb-Douglas profit functions for the two firms were modified so that money profit and money wages could be used.

$$(31) \qquad ln\ \Pi_*^1 = ln\ A_*^1 - \alpha_1^* \ ln\ w + \beta_1^* \ ln K + \beta_2^* \ ln\ T$$

$$(32) \qquad ln\ \Pi_*^2 = ln\ A_*^1 + ln\ (A_*^2/A_*^1) + \alpha_1^* \ ln\ w + \beta_1^* \ ln\ K + \beta_2^* \ ln\ T$$

become

$$\begin{aligned} ln\ \Pi_*^1 &= ln\ \Pi'^1 - ln\ \ p \\ &= ln\ A_*^1 + \alpha_1^* \ ln\ w' - \alpha_1^* \ ln\ p \\ &\quad + \beta_1^* \ ln\ K + \beta_2^* \ ln\ T \end{aligned}$$

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or

$$\ln \Pi^1 = \ln A_*^1 + (1 - \alpha_1^*) \ln p + \alpha_1^* \ln w' + \beta_1^* \ln K + \beta_2^* \ln T$$

$$\ln \Pi^2 = \ln A_*^1 + (1 - \alpha_1^*) \ln p + \ln \left(\frac{A_*^2}{A_*^1}\right) + \alpha_1^* \ln w' + \beta_1^* \ln K + \beta_2^* \ln T$$

And the <u>final</u> estimating equation is

$$\ln \Pi = \alpha_0 + S + \sum_{i=1}^{4} \delta_i^* D_i + \alpha_1^* \ln w' + \beta_1^* \ln K + \beta_2^* \ln T \tag{33}$$

where

II = total revenue less total variable costs
W' = the money wage rate
S = farm size dummy variable
D = regional dummy variable
K = interest on fixed capital
T = cultivable land in acres

2. Review of the Application to Indian Agriculture

The results of the application of the profit function to Indian data are shown in Table 20. It should be noted that π, or profit, is total revenue less the cost of hired labor and imputed family labor only. Lau and Yotopoulos explain that variable costs other than labor were not deducted from total revenue, because they lacked the "price" of other costs which are necessary for the UOP profit function. Capital is defined as the interest on fixed capital which is 3% of the total value of fixed capital on the farm. Furthermore, the regression was run on grouped data, because it was obtained as averages of farms of a given size for each state. These facts should be kept in mind as the results are reviewed.

Table 20 shows that the coefficients of the wage rate and capital are both negative. While the authors can explain the sign for the wage rate according to economic theory, they blame the negative sign for capital on the mis-specification of the capital variable which assumes that there is proportionality between capital service flow and capital stock. The coefficient of cultivable land is positive as would be expected.

The most interesting conclusion drawn from the results is that small farms (under ten acres) are more economically efficient than large farms as shown by the negative coefficient of the farm-size dummy variable.

TABLE 20.--Results from the application of the profit function to Indian data

COBB-DOUGLAS PROFIT FUNCTION AND RELATED STATISTICS

Parameter	All Farms ($n=34$)
α_0	4.332
	(0.548)
S	−0.567
	(0.253)
δ_1^*	1.614*
	(0.549)
δ_2^*	−1.359*
	(1.274)
δ_3^*	−0.588*
	(0.485)
δ_4^*	0.296
	(0.715)
α_1^*	−2.141**
	(1.200)
β_1^*	−0.538
	(0.274)
β_2^*	1.797
	(0.253)
$\hat{\sigma}^2$	0.185
$\bar{R}^2$	0.896
F-Statistic	36.4

Source: Farm Management Studies

Notes: The estimating equation is

$$\ln \Pi = \alpha_0 + S + \sum_{i=1}^{4} \delta_i^* D_i + \alpha_1^* \ln w' + \beta_1^* \ln K + \beta_2^* \ln T$$

where

Π = profit, i.e., total revenue less total variable costs

w' = the money wage rate

S = dummy variable for farm size with value of one for large farms (greater than ten acres) and zero for small farms (less than ten acres)

D_i = regional dummy variable with D_1, D_2, D_3, D_4 taking the value of one for West Bengal, Madras, Madhya Pradesh, and Uttar Pradesh and zero elsewhere, respectively

K = interest on fixed capital

T = cultivable land in acres

$\hat{\sigma}^2$ = the estimate of the variance of the error in the equation

* Starred coefficients are not significantly different from zero at a probability level ≧95 percent

** Double-starred coefficients are not significantly different from zero at a probability level ≧95 percent; but they are significantly different from zero at a probability level ≧90 percent.

All other coefficients are significantly different from zero at a probability level ≧95 percent.

Two-tail test applies to the coefficients of the dummy variables; one-tail test to all other variables.

The standard errors of the estimated parameters are given in parentheses.

Source: Lau and Yotopoulos, p. 105, Table 1.

3. Application of the Profit Function to the Data from the Dominican Republic Sector Analysis Survey

The formulation of the profit function used by Lau and Yotopoulos will be used with the purpose of comparing the results from the two sets of data. Therefore, even though more information is available from the Dominican survey, only the cost of labor will be deducted from total revenue. The dependent variables will also be duplicated as closely as possible:

(1) the wage rate is the average wage paid for all work on the farm

(2) capital is 3% of the total value of fixed capital on the farm

(3) cultivable land is all land in crops plus fallow land

(4) the dummy variable for farm size has a value of one for farms over ten acres and zero for farms of ten acres or less

(5) there are six regional dummy variables, D_1 through D_6 taking the value of one for Regions 1 through 6. Region 7 has no dummy variable to avoid multicollinearity.

The regression is run on micro data which is weighted. Only farms with the total value of output and labor use greater than zero were included.

Table 21 gives the results of the duplication of the Lau-Yotopoulos estimating equation of Table 20 run on Dominican data. The coefficient of the wage rate is positive but insignificant and the coefficients of capital and land are positive and significant with a 99 percent level of confidence.

The lack of negative relationship between profit and the wage rate may be due to the imputed value of family labor, which

TABLE 21.--Duplication of the Lau-Yotopoulos estimating equation of Table 20 run on Dominican data

NUMBER OF OBS.	1715
MULTIPLE R	0.47536
R SQUARE	0.22596
ADJUSTED R SQUARE	0.22145
STANDARD ERROR	2.19112
F STATISTIC	50.1

PARAMETER	B	BETA	STD ERROR B	F
Z6	-1.348935 ***	-0.14522	0.27207	24.582
a	0.2632350	0.01065	0.58396	0.203
B1	0.3913248 ***	0.29612	0.03224	147.346
B2	0.3315048 ***	0.17620	0.04479	54.769
S	0.3570868 ***	0.07179	0.12887	7.678
Z1	0.4687050 ***	0.08329	0.21298	4.843
Z2	0.2342669	0.03721	0.21615	1.175
Z3	-1.134785 ***	-0.12553	0.26106	18.895
Z4	0.94109840-01	0.01390	0.22136	0.181
Z5	-0.1726815	-0.02323	0.23822	0.525
(CONSTANT)	3.954157			

Source: Dominican Republic Sector Analysis Survey 1976

Notes: The estimating equation is

$$\ln \Pi = \text{constant} + S + \sum_{i=1}^{6} Z_i D_i + a \ln W + B_1 \ln K + B_2 \ln T$$

Π = total value of production less cost of labor
W = money wage rate
S = dummy variable for farm size with value of one for large farms (greater than ten acres) and zero for small farms (less than ten acres)
D_i = regional dummy variable with D1,D2,D3,D4,D5, D6 taking the value of one for Regions 1 through 6 and zero for Region 7
K = 3% interest on fixed capital
T = cultivable land in tareas
* = coefficients are significantly different from zero at a probability level $\geq$ 90%.
** = coefficients are significantly different from zero at a probability level $\geq$ 95%.
*** = coefficients are significantly different from zero at a probability level $\geq$ 99%.
Two-tail test applies to coefficients of the dummy variables; one-tail test to all other variables.

is a large proportion of the cost of labor especially on small farms. There may be no relationship between the wage rate and the amount of family labor employed given the situation of underemployment in the Dominican Republic, where the employment rate for family labor is approximately 64 percent. The relevance of neo-classical theory under such circumstances is questionable. Furthermore, the data from the survey show that those regions in the Dominican Republic with the lowest average farm revenue also have lower than average wage rates. Since the regression results shows that the poorest regions are also the least efficient regions (discussed below), a statistically significant negative coefficient for the wage rate is not expected. Finally, it should be noted that for those farms which employed no hired labor, the value of family labor was imputed by using the national average wage rate. Since the same average was used for the wage variable in such cases the effect of the wage rate on profit is definitely diluted.

Unlike the results from the application to Indian data, the coefficient of capital is positive and very significant in spite of the implicit assumption that the flow of capital services as a ratio of the stock of capital is constant across farms.

Although the coefficient of cultivable land is significant, it is only 20 percent of the size of the coefficient from the Indian data. This is probably due to the fact that livestock makes up 35 percent of the gross value of production on the

Dominican farms. Since poultry and pork require no land, and cattle require a great deal of uncultivable land, the land variable as specified is not as important for Dominican farms.

The coefficients of the regional dummy variables for Regions 3 and 6 are negative and significant at a 99 percent level. The coefficients for Regions 2, 4, and 5 are insignificant. Finally, the coefficient for Region 1 is positive and significant with a 95 percent level of confidence. These results are comparable to the ranking of the regions according to total farm revenue in Table 15. This implies that the poorest regions in the country are also the least efficient. It should be noted that regional differences in land quality cannot be controlled so that the differences in coefficients among regions may not reflect efficiency but rather land quality. Both Regions 3 and 6 have less productive land than the other regions.

The coefficient of the farm size dummy variable, unlike that from the Indian data, is positive and significant at a 95 percent level. It must be noted, however, that the farm size groups used by Lau and Yotopoulos include some of the farms in the small farm size category (less than 12 acres) preferred by the Dominicans and all of the farms in the medium and large farm size categories (12 to 77 acres and greater than 77 acres respectively). The 10 acre definition, therefore, is not appropriate for analysis of the Dominican data, and the results are misleading. When the three farm size

categories are used, the results show that the significantly positive coefficient for the greater than 10 acre group is due to the medium farms and that the large farms (> 77 acres) are not significantly different from small farms:

Farm size	B	Std. Error B	F
12 to 77 acres	.3436	.130	6.906
More than 77 acres	.2027	.222	.837

The R^2 for the regression equation is .23 and is not comparable to the R^2 for the Indian data, because the regression was run on micro data rather than grouped data. Another reason for the low R^2 is that the regression was run on 1716 farms which have any combination of over fifty crops, six types of livestock, and more than fifteen types of processed farm products. Given such heterogeneity, there is much activity on the Dominican farms which cannot be accounted for with the regression equation employed. It will be shown later that a similar equation run on farms with fifty percent or more of their revenue from rice has a much higher R^2.

3.1 Independent Variable Options

3.1.1 Land

Since the farms in the Dominican Republic raise livestock, the use of only cultivable land in the regression equation is inappropriate and accounts for the low coefficient of the land variable. A more precise definition of the land variable would account for pasture land and other uses of land. Therefore, the

land variable will be changed by adding to cultivable land eighty percent of cultivated pasture, fifty percent of natural pasture, forty percent of the land for other uses, and ten percent of the forest and scrub. This will take into account the use of all land on the farm and account for its varied degrees of quality.

Table 22 gives the results of the regression when the definition of the land variable is changed. It shows that the coefficient of the land variable almost triples in size from .332 to .913. The three farm size categories were maintained and will be continued to be used, because they are considered to be more relevant. All other variables were left untouched.

The new land variable has an effect upon the farm size dummy variables such that their coefficients are now negative and significant. The coefficient for the large farms is -1.81 and that for the medium farms is -.56. They are both significant at a 99.9 percent level.

3.1.2 Capital

The capital variable will be changed by computing a ten percent interest on the value of fixed capital plus livestock and including the cost of depreciation. The latter is computed as a straight line depreciation by dividing the purchase price of the asset by its average life. It is computed for fixed capital and draft animals only.

The new capital variable reflects more accurately the cost of capital on the farm, because it includes the cost of

TABLE 22.--Profit function with land defined as including some proportion of all land on the farm

NUMBER OF OBS.	1715
MULTIPLE R	0.49963
R SQUARE	0.24963
ADJUSTED R SQUARE	0.24482
STANDARD ERROR	2.15799
F STATISTIC	51.9

PARAMETER	B	BETA	STD ERROR B	F
Z6	-1.533340 ***	-0.16507	0.26905	32.479
a	0.35957360-01	0.00145	0.57715	0.004
B1	0.2728233 ***	0.20645	0.03466	61.949
B2	0.9133016 ***	0.44630	0.08480	115.990
S1	-1.809400 ***	-0.21216	0.31564	32.861
S2	-0.5563800 ***	-0.10824	0.16663	11.229
Z1	0.3120339 **	0.05545	0.21016	2.204
Z2	0.1938693	0.03079	0.21284	0.830
Z3	-1.244418 ***	-0.13765	0.25727	23.396
Z4	0.38643630-01	0.00571	0.21721	0.032
Z5	-0.86086460-01	-0.01158	0.23491	0.134
(CONSTANT)	2.274392			

Source: Dominican Republic Sector Analysis Survey 1976

Notes: The estimating equation is

$$\ln \Pi = \text{constant} + \sum_{i=1}^{2} S_i F_i + \sum_{i=1}^{6} Z_i D_i + a \ln W + B_1 \ln K + B_2 \ln T$$

F_i = dummy variable for farm size with a value of one for large farms (F1 = more than 77 acres) and medium farms (F2 = 12 to 77 acres), and zero for small farms (less than 12 acres)

T = cultivable land plus 80% of cultivated pasture, 50% of natural pasture, 40% of land in other uses, and 10% of forest and scrubland

The definitions of all other variables and the asterisks are the same as those in Table 21.

holding capital as well as the cost of the deterioration of the capital caused by time and use. The latter reflects the flow of capital services.

Table 23 shows that the coefficient for capital almost doubles when the new definition is used. The definition of all other variables remains the same as the original Lau-Yotopoulos formulation, except for the farm-size dummy variables which include the three Dominican definitions of farm size.

The change in the capital variable alone affects the coefficients of the farm-size dummy variables; that for the large farms is -.84 and is significant at a 99 percent level and that of medium farms is very small and insignificant.

3.1.3 Inclusion of Other Prices of Variable Inputs as Independent Variables

As noted before, more information is available from the Dominican Republic Sector Analysis Survey than was available from the Indian data. Aside from the wage rates, the prices for animal use, machinery use, fertilizer, irrigation, and seeds can therefore be included as dependent variables. These prices are defined as follows:

(1) the price of animal use is the price for one day of use

(2) the price of machinery use is the price of performing a given task per unit of land

(3) the price of fertilizer is the average price of all types of fertilizer per pound

TABLE 23.--Profit function with capital defined as including livestock and depreciation

NUMBER OF OBS.	1715
MULTIPLE R	0.50414
R SQUARE	0.25416
ADJUSTED R SQUARE	0.24937
STANDARD ERROR	2.15148
F STATISTIC	53.1

PARAMETER	B	BETA	STD ERROR B	F
Z6	-1.465797***	-0.15780	0.26741	30.046
a	-0.2358313	-0.00954	0.57910	0.166
B1	0.7457231***	0.41502	0.05105	213.346
B2	0.3340875***	0.17757	0.04394	57.820
S1	-0.8380658***	-0.09827	0.24516	11.685
S2	0.17467040-01	0.00339	0.13423	0.017
Z1	0.2953774*	0.05249	0.20892	1.999
Z2	0.38865090-01	0.00617	0.21079	0.034
Z3	-1.035435***	-0.11454	0.25681	16.257
Z4	-0.1292192	-0.01909	0.21809	0.351
Z5	-0.1559337	-0.02097	0.23413	0.444
(CONSTANT)	1.539387			

Source: Dominican Republic Sector Analysis Survey 1976

Notes: The estimating equation is

$$\ln \Pi = \text{constant} + \sum_{i=1}^{2} S_i F_i + \sum_{i=1}^{6} Z_i D_i + a \ln W + B_1 \ln K + B_2 \ln T$$

K = 10% of fixed capital plus livestock. The value of depreciation is also added.

F_i = dummy variable for farm size with a value of one for large farms (F1 = more than 77 acres) and medium farms (F2 = 12 to 77 acres), and zero for small farms (less than 12 acres)

The definitions of all other variables and the asterisks are the same as those in Table 21.

(4) the price of irrigation is the price for water per unit of land

(5) the price of seeds is the average price of all seeds per pound or per plant

When these independent variables are included in the equation, the total cost of their use is deducted from the revenue. In other words, the dependent variable, profit, is defined as total revenue less the cost of labor, seeds, machinery use, animal use, fertilizer, and water. (The capital and land variables are the same as the original Lau-Yotopoulos formulation, and the three Dominican farm sizes are used.)

The results of this regression are shown in Table 24. All of the coefficients for the additional prices included are very small. Those for animal and machinery use are negative, while those for fertilizer, water, and seeds are positive. Only the coefficients for machinery and water are significant. These results are difficult to explain according to economic theory, which supposes that profit should be higher when input prices are lower. Such results can be explained for the same reasons pointed out in Section 3, when the coefficient of the wage rate was discussed. Once again imputed prices were used for owned machinery, animal use, and saved seeds. The use of such inputs may have no relationship to the market prices or rental rates charged. The price of water for irrigation was also imputed because many farmers never pay for the water they use. Only the price of fertilizer was never imputed, because it was always purchased when used.

TABLE 24.--Profit function with the inclusion of other prices of variable inputs

NUMBER OF OBS.	1715
MULTIPLE R	0.42271
R SQUARE	0.17868
ADJUSTED R SQUARE	0.17100
STANDARD ERROR	2.48660
F STATISTIC	23.3

PARAMETER	B	BETA	STD ERROR B	F
Z6	-1.764964***	-0.17277	0.32796	28.961
a1	-0.5109789	-0.01880	0.67679	0.570
a2	-0.10700890-01	-0.02831	0.00924	1.340
a3	-0.50998930-01***	-0.11909	0.01196	18.171
a4	0.61644480-02	0.01027	0.01592	0.150
a5	0.50109510-01***	0.09106	0.01628	9.476
a6	0.39587830-02	0.00493	0.01982	0.040
B1	0.3685072***	0.25355	0.03943	87.333
B2	0.2931721***	0.14169	0.05669	26.746
S1	0.1575319	0.01680	0.25598	0.379
S2	0.5173502***	0.09119	0.15141	11.675
Z1	0.2666591	0.04309	0.24781	1.158
Z2	0.1329111	0.01919	0.25013	0.282
Z3	-1.480850***	-0.14895	0.30828	23.075
Z4	-0.2326308	-0.03125	0.25591	0.826
Z5	-0.9379759***	-0.11472	0.29719	9.961
(CONSTANT)	4.737626			

Source: Dominican Republic Sector Analysis Survey 1976

Notes: The estimating equation is

$$\ln \Pi = \text{constant} + \sum_{i=1}^{3} S_i F_i + \sum_{i=1}^{6} Z_i D_i + a_1 \ln W + a_2 \ln A + a_3 \ln M + a_4 \ln PRF + a_5 \ln I + a_6 \ln SD + B_1 \ln K + B_2 \ln T$$

II = total value of production less the cost of labor, seeds, fertilizer, water, machinery use and animal use
W = money wage rate
A = rent for one day of animal use
M = rent for completion of a given task by machine per unit of land
SD = price per pound or unit of seeds
PRF = price per pound of fertilizer
I = price for water to irrigate one unit of land

TABLE 24.--(Continued)

Notes:

F_i = dummy variable for farm size with a value of one for large farms (F1 = more than 77 acres) and medium farms (F2 = 12 to 77 acres), and zero for small farms (less than 12 acres)
D_i = regional dummy variable with D1,D2,D3,D4,D5, D6 taking the value of one for Regions 1 through 6 and zero for Region 7
K = 3% interest on fixed capital
T = cultivable land in tareas
The definitions of the asterisks are the same as those in Table 21.

Since the wage bill is the largest proportion of the variable costs for which prices are available, it is not surprising that the coefficients for the other prices of variable inputs are small. When they are aggregated they make up only thirty percent of the variable costs deducted from the total revenue.

The R^2 for this regression equation is .179, which is lower than those for the equations in Tables 21 through 23. This is probably due to the change in the dependent variable. The next section will discuss some other options for the definition of profit.

3.2 Dependent Variable Options

Thus far profit has been defined as total revenue less those variable costs for which prices are available. In the Dominican data, such variable costs make up sixty-two percent of the variable costs of the farm. Prices are not available for the other inputs, particularly those relating to the livestock and processed product enterprises.

When all variable costs are deducted from revenue, the regression equation has a lower R^2. This is probably due to the fact that the dependent variables do not take into account the prices for approximately forty percent of the total variable cost on the farms.

Another possibility for the computation of the dependent variable is the deduction of those general farm operating costs which are not directly related to production processes or

subsumed in the land and capital variables. Prices are not available for these costs, and once again their deduction from the dependent variable tends to reduce the explanatory power of the regression equation.

3.3 Inclusion of Other Dummy Variables

Aside from the farm size and regional dummy variables, there are other items of interest which can be captured by the use of other dummy variables. These are credit, irrigation, and land tenancy.

The dummy variable for credit will take the value of one for farms with credit and zero for farms without credit. The dummy variable for irrigation will be set to one for farms with irrigated land and zero for farms with no irrigated land.

Five tenancy types can be identified. Farms with fifty percent or more of their land owned by the farmer have no dummy variable. The other four tenancy types will be given a value of one for the dummy variable. They are farms with fifty percent or more of their land (1) rented for cash, (2) rented for payment in kind, (3) obtained from agrarian reform, and (4) held without title.

Table 25 gives the results of the run of this regression equation which contains all of these dummy variables. It shows that farms with credit are more efficient than farms without credit, and that farms with irrigation are more efficient than farms with no irrigated land.

TABLE 25.--Profit function with credit, irrigation, and tenancy dummy variables

NUMBER OF OBS.	1715
MULTIPLE R	0.52616
R SQUARE	0.27684
ADJUSTED R SQUARE	0.26965
STANDARD ERROR	2.12222
F STATISTIC	32.1

PARAMETER	B	BETA	STD ERROR B	F
E4	-0.4349485***	-0.04515	0.20378	4.556
a	-0.5892285	-0.02384	0.57672	1.044
B1	0.5092284***	0.28340	0.05816	76.657
B2	0.7170653***	0.35040	0.08947	64.238
S1	-1.880228***	-0.22047	0.31900	34.742
S2	-0.5171072***	-0.10024	0.16544	9.769
Z1	0.1889471	0.03358	0.20744	0.830
Z2	0.4626601D-01	0.00735	0.21145	0.048
Z3	-1.198754***	-0.13260	0.25795	21.597
Z4	-0.1711755	-0.02529	0.22167	0.596
Z5	-0.2305923	-0.03102	0.25183	0.838
Z6	-1.593866***	-0.17159	0.27339	33.989
C	0.4469183***	0.07937	0.12468	12.850
I	0.4348337D-01	0.00674	0.16384	0.070
E1	0.6128118*	0.03081	0.41154	2.217
E2	1.125149***	0.07349	0.31812	12.509
E3	0.5487075***	0.04874	0.24578	4.984
(CONSTANT)	1.356589			

Source: Dominican Republic Sector Analysis Survey 1976

Notes: The estimating equation is

$$\ln II = \text{constant} + C + I + \sum_{j=1}^{2} S_i F_i + \sum_{j=1}^{3} Z_i D_i + \sum_{j=1}^{4} E_i N_i + a \ln W + B_1 \ln K + B_2 \ln T$$

II = total value of production less cost of labor
W = money wage rate
F_i = dummy variable for farm size set to one for farms over 77 acres (F1) and farms of 12 to 77 acres (F2), and set to zero for farms less than 12 acres
D_i = regional dummy variables
K = 10% of fixed capital plus livestock. The value of depreciation is also added.
T = cultivable land plus 80% of cultivated pasture, 50% of natural pasture, 40% of land in other uses, and 10% of forest and scrubland

TABLE 25.--(Continued)

Notes:

I = dummy variable for irrigation with value of one for farms with irrigated land and zero for farms without irrigated land

C = dummy variable for credit with value of one for farms with credit and zero for farms without credit

N_i = dummy variable for land tenancy taking the value of one for farms with 50% or more of their land (N1) rented for cash, (N2) rented for payment in kind, (N3) obtained from agrarian reform, (N4) held without title. Farms with 50% or more of their land owned and farms which do not have 50% or more of their land in any category have no dummy variable.

The definitions of the asterisks are the same as those in Table 21.

With respect to land tenancy type, the results show that farms with fifty percent or more of their land rented for payment in kind (E2) or obtained from agrarian reform (E3) are more efficient than farms with the same proportion of owned land. On the other hand, farms with fifty percent or more of their land occupied without title (E4) are less efficient than those who own most of their land. For tenancy type E1 ($\geq$50% rented for cash) the null hypothesis cannot be rejected.

Since small farms are of particular importance, the same regression equation was run on farms of less than twelve acres. The farm size dummy variable was changed to represent three farm sizes within the small farm category. The value was set to one for farms of 3.86 acres to 7.88 acres (F2) and for farms from 7.88 acres to 12 acres (F1). The dummy variable was given a value of zero for farms of less than 3.86 acres. Table 26 presents the results of this regression equation run on small farms. It shows that there is no significant difference in efficiency among the three small farm sizes. Once again farms with credit and farms with irrigation are more efficient than farms without credit and without irrigation.

With respect to land tenancy, the only type which is statistically different from the group of farms with fifty percent or more of their land owned is tenancy type E2 with fifty percent or more of their land rented for payment in kind. As noted before, this is probably because sharecroppers do not own their own capital.

TABLE 26.--Profit function with credit, irrigation, and tenancy dummy variables applied to small farms

NUMBER OF OBS.	932
MULTIPLE R	0.49499
R SQUARE	0.24501
ADJUSTED R SQUARE	0.23109
STANDARD ERROR	2.07925
F STATISTIC	22.0

PARAMETER	B	BETA	STD ERROR B	F
E4	-0.1187931	-0.01180	0.30118	0.156
a	-0.3386356	-0.01369	0.78605	0.186
B1	0.5411915***	0.22801	0.07836	47.703
B2	0.7603928***	0.21866	0.19880	14.630
S1	-0.2780196	-0.05271	0.31862	0.761
S2	-0.1129640	-0.02252	0.23116	0.239
Z1	0.1941103	0.03614	0.26706	0.528
Z2	-0.6863997D-01	-0.01168	0.27259	0.063
Z3	-1.192019***	-0.14941	0.32499	13.453
Z4	0.3534049	0.04584	0.30943	1.304
Z5	-0.5106872***	-0.07824	0.31160	2.686
Z6	-2.032531***	-0.21833	0.37992	28.621
C	0.5118278***	0.08858	0.18425	7.717
I	0.4425484***	0.07184	0.22512	3.865
E1	-0.3885209D-01	-0.00233	0.48305	0.006
E2	1.167436***	0.09387	0.36046	10.489
E3	0.1183793	0.00969	0.38261	0.096
(CONSTANT)	0.9634512			

Source: Dominican Republic Sector Analysis Survey 1976

Notes: The estimating equation is

$$\ln \Pi = \text{constant} + C + I \sum_{j=1}^{2} S_i F_i + \sum_{j=1}^{6} Z_i D_i + \sum_{j=1}^{4} E_i N_i$$

$$+ a \ln W + B_1 \ln K + B_2 \ln T$$

F_i = dummy variable for farm size (set to one for farms of 3.87 to 7.88 acres (F2) and farms of 7.88 to 12 acres (F1) and set to zero for farms less than 3.87 acres. Farms over 12 acres were not included.

All other variables are the same as in Table 25. The definitions of the asterisks are the same as those in Table 21.

The coefficient for the wage rate is still not statistically significant and the coefficients of the regional dummy variables are similar to those of the regression run on all farms. (Compare Table 25 to Table 26.)

3.4 The Profit Function Applied to Rice Farms

Thus far the regressions have been run on all farms with revenue and labor use. The R^2s for most of these runs have ranged from .15 to .28, which is not surprising given the heterogeneous group of farms in the sample. In an attempt to control such heterogeneity a subset of farms will be chosen which are less diverse. The subset is all farms which produce fifty percent or more of their revenue from rice. Since rice is an important staple in the Dominican Republic, the results drawn from such analysis are relevant.

There are 109 farms in the sample which produce fifty percent or more of their revenue from rice. Applying the profit function to these farms only, requires the redefinition of the land and capital variables. Land is defined as all land in rice production and capital is defined as ten percent of fixed capital and depreciation. Livestock are not included in the capital variable, because they are not an important factor on rice farms. Profit is again defined as total revenue less the wage bill. All of the dummy variables are the same as those used in Tables 26 and 27.

The results of the regression are presented in Table 27. The coefficient of the wage rate is positive but not statistically

TABLE 27.--Profit function run on rice farms

NUMBER OF OBS.	109
MULTIPLE R	0.77376
R SQUARE	0.59870
ADJUSTED R SQUARE	0.52373
STANDARD ERROR	1.43624
F STATISTIC	7.86

PARAMETER	B	BETA	STD ERROR B	F
E4	-1.120927	-0.10812	0.86414	1.683
a	1.845569	0.09049	2.03356	0.824
B1	0.3016697***	0.22147	0.14611	4.263
B2	1.270878***	0.67605	0.29520	18.535
S1	-2.282277***	-0.34358	0.78790	8.391
S2	0.1726691	0.04060	0.45769	0.142
Z1	-1.461695	-0.22639	1.24923	1.369
Z2	-2.298348***	-0.53372	1.24415	3.413
Z3	-1.789796**	-0.32915	1.21091	2.185
Z4	-2.591728***	-0.17799	1.57626	2.703
Z5	-0.7144126	-0.15489	1.32495	0.291
Z6	-3.111008***	-0.19538	1.67055	3.468
C	-0.1506395	-0.02660	0.48312	0.097
I	0.3640682	0.07215	0.48864	0.555
E1	0.6298642	0.05805	0.75255	0.701
E2	1.288730***	0.14765	0.64724	3.965
E3	-2.417963***	-0.28543	0.78439	9.502
(CONSTANT)	0.8928502			

Source: Dominican Republic Sector Analysis Survey 1976

Notes: The estimating equation is

$$\ln \Pi = \text{constant} + C + I + \sum_{i=1}^{2} S_i F_i + \sum_{i=1}^{2} Z_i D_i + \sum_{i=1}^{4} E_i N_i + a \ln W + B_1 \ln K + B_2 \ln T$$

T = land in rice production
K = 10% of fixed capital plus depreciation
All other variables are the same as those in Table 25.
The definitions of the asterisks are the same as those in Table 21.

significant. The coefficients for capital and land are positive and significant at a probability level over 99.9%. The coefficient of the land variable is now over one, which is considerably higher than the coefficient of land from the regressions run on all farms. This is not surprising because rice revenue and profit are more closely related to the land in rice than total revenue is related to cultivable land or various proportions of all land on the farm.

The coefficients of the farm size dummy variables are similar to those from the other regressions run. The coefficient of large farms is negative and significant and that of medium farms is positive but small and insignificant. This implies, once again, that large farms are not as economically efficient as small and medium farms.

The coefficients of the regional dummy variables differ from those from the regressions run on all farms, because the sample size is much smaller. The fact that all regions have negative coefficients tells us only that they are not as profitable as Region 7. Since Region 7 has only one rice farm, this means very little. However, since the coefficients for Regions 1 and 5 are the smallest and are not significant, the implication is that Regions 1, 5, and 7 are more efficient than Regions 2, 4 and 6, which have larger negative coefficients which are significant at a level over 95%.

The coefficients of the credit and irrigation dummy variables are not significant. Once again, however, the sample size and distribution of observations among groups diminishes

the relevance of such information, because most of the rice farms have irrigation and credit. In fact, only 10 of the 109 observations have no irrigated land and only 18 have no credit.

The coefficients of the tenancy-type dummy variables show that sharecroppers are more profitable than farmers who own their own land and farms with most of their land from agrarian reform are less profitable. The same problems with sample size are present, so such results should not be over-emphasized.

Since rice is responsible for most of the revenue and costs on these farms, the revenue and expenditures for the livestock and processed products enterprises are not as important as they were when the profit function was applied to all farms with positive values for revenue and labor. The farms are therefore much less heterogeneous and a larger proportion of the variation in profit among them is explained by the profit function. The R^2 is .599, which is almost double the size of the R^2s for the profit functions applied to all farms. (Compare Table 27 to Tables 21 through 26.)

Another aspect of the homogeneity among rice farms is that most of them hire labor and purchase inputs so when additional prices of inputs are included as independent variables the problem of imputing a large number of prices and cost of inputs is diminished. Table 28 presents the results of the regression equation when the prices (or rental rates) of animal use, machinery use, seeds, fertilizer, and irrigation are included as independent variables. Once again, none of

TABLE 28.--Profit function with prices of other inputs run on rice farms

NUMBER OF OBS.	109
MULTIPLE R	0.65950
R SQUARE	0.43494
ADJUSTED R SQUARE	0.33667
STANDARD ERROR	2.40548
F STATISTIC	4.4

PARAMETER	B	BETA	STD ERROR B	F
Z6	-2.244649	-0.09933	2.59527	0.748
a1	-2.227931	-0.07697	3.35998	0.440
a2	0.13202570-01	0.03029	0.04337	0.093
a3	-0.17151430-01	-0.03449	0.04931	0.121
a4	-0.12476690-01	-0.01957	0.07908	0.025
a5	0.46979090-01	0.08660	0.06631	0.502
a6	0.1484055	0.03186	0.40889	0.132
B1	0.6504050***	0.33646	0.25099	6.715
B2	0.6251094*	0.23431	0.46208	1.830
S1	-4.854095***	-0.51491	1.12811	18.515
S2	0.6875096	0.11391	0.70593	0.948
Z1	-0.3373002	-0.03681	2.13345	0.025
Z2	-0.8874002	-0.14520	2.01329	0.194
Z3	-0.5306423	-0.06876	2.13057	0.062
Z4	-3.174381	-0.15361	2.55924	1.538
Z5	0.75625740-01	0.01155	2.27868	0.001
(CONSTANT)	3.945161			

Source: Dominican Republic Sector Analysis Survey 1976

Notes: The estimating equation is

$$\ln \Pi = \text{constant} + \sum_{i=1}^{4} S_i F_i + \sum_{i=1}^{6} Z_i D_i + a_1 \ln W + a_2 \ln A + a_3 \ln M + a_4 \ln PRF + a_5 \ln I + a_6 \ln SD + B_1 \ln K + B_2 \ln T$$

T = land in rice production
K = 10% of fixed capital plus depreciation
All other variables are the same as those in Table 24.
The definitions of the asterisks are the same as those in Table 21.

their coefficients are significant, which suggests that prices are not important factors affecting profit.

Because prices of other variable inputs were included in the regression, the cost of the relevant inputs were deducted from revenue. Given the new definition of revenue, there is no significant difference in the coefficients of the regional dummy variables. The coefficients of the farm size dummy variables are similar to those of Table 27, with the coefficient of the large farm category both larger and more significant than that of Table 27.

Although prices seem to have no effect on profit, the use of certain inputs may. Therefore, in the final regression run on rice farms, dummy variables were given a value of one for machinery use (M), fertilizer use (F), pesticide use (P), irrigation (I), and the use of improved or hybrid seeds (SD). A value of zero was given to the farms which did not use each of these inputs.

Table 29 shows that only the coefficient for irrigation is positive and significant. The coefficients for machinery use and the use of improved or hybrid seeds are negative but insignificant while those for the use of fertilizer and pesticides are positive and insignificant. It must be pointed out that most farms have irrigation, and use fertilizer and machinery. Of the 109 observations, only 10, 12, and 17 use no irrigation, fertilizer, or machinery respectively.

The results with respect to the use of improved or hybrid seed are surprising in that the coefficient is negative and

TABLE 29.--Profit function with dummy variables for input use run on rice farms

NUMBER OF OBS.	109
MULTIPLE R	0.63670
R SQUARE	0.40539
ADJUSTED R SQUARE	0.34471
STANDARD ERROR	2.39086
F STATISTIC	6.7

PARAMETER	B	BETA	STD ERROR B	F
S2	0.8581436	0.14218	0.64184	1.788
a	-3.419363	-0.11813	2.72527	1.574
M	-0.3993196	-0.05468	0.64979	0.378
FT	0.1131570	0.01459	0.81671	0.019
P	0.1893170	0.02589	0.63645	0.088
SD	-0.93276640-01	-0.01544	0.53336	0.031
I	1.209785 **	0.16894	0.76999	2.469
B1	0.7618250 ***	0.39409	0.22108	11.874
B2	0.4645749	0.17414	0.41720	1.240
S1	-4.684328 ***	-0.49690	1.07131	19.119
(CONSTANT)	2.873762			

Source: Dominican Republic Sector Analysis Survey 1976

Notes: The estimating equation is

$$II = \text{constant} + M + FT + P + SD + I + \sum_{i=1}^{2} S_i F_i + a\ln W + B_1 \ln K + B_2 \ln T$$

M = dummy variable for machinery use with a value of one for use and zero for no use
FT = dummy variable for fertilizer use with a value of one for use and zero for no use
P = dummy variable for use of pesticides with a value of one for use and zero for no use
SD = dummy variable for seeds with a value of one for hybrid or improved seed and zero for criollo
I = dummy variable for irrigation with a value of one for use and zero for no use
All other variables are the same as those in Table 28.
The definitions of the asterisks are the same as those in Table 21.

insignificant. More than half of the farms use them (57%), so the sample size is large for both values of the dummy variable.

With this formulation of the regression equation, the coefficient of the wage rate is now negative and just barely significant at the 90% level. The land variable no longer has a statistically significant coefficient.

The coefficients of the farm size dummy variables are similar to those of Tables 27 and 28, supporting once again the implication that large farms are the least economically efficient and that medium farms are the most efficient group. This is of particular interest because when applying the profit function to rice farms only, it is safer to say that the difference in the coefficients is due to economic efficiency rather than to the difference in profitability of crop (small) farms and cattle (large) farms. This is true because small farms in the sample as a whole have 78% of their land in crops, while large farms have only 23% of their land in crops. Controlling the land-use factor by using only rice farms is therefore important for the interpretation of the results.

3.5 Summary of Conclusions Drawn from the Application of the Profit Function to Data from the Dominican Republic

The results of Section 3 of this chapter permit some conclusions to be drawn concerning farm policy in the Dominican Republic. Both land and capital have positive and statistically significant coefficients for all definitions of these variables.

Thus, profit increases when more fixed inputs are employed. The coefficient of the wage rate is not statistically significant nor are the coefficients for the other prices and rental rates of variable inputs which are available from the survey. This is primarily due to the use of imputed prices for inputs which were not purchased, and to the fact that the variable inputs accounted for make up only a proportion of the total variable inputs employed on the farms.

The results from the use of the farm size dummy variables are somewhat ambiguous because they tend to change when the definition of the other variables in the equation are changed. However, there is some evidence that large farms (more than 77 acres) are less efficient than small and medium farms, and that medium farms (12 to 77 acres) are the most efficient group. When the small farms (less than 12 acres) are considered alone, there is no evidence of a significant difference in efficiency when they are disaggregated into three farm size categories.

All of this indicates that farms of 12 to 77 acres are of optimal size with respect to economic efficiency. This suggests that land reform should focus on the distribution of land from large to small farms. Given the low per capita income of the small farms, such a policy would help by releasing the land constraint from their income producing potential.

The availability of credit also seems to have an effect upon profit. The positive coefficient for the credit dummy variable indicates that those farms with credit are more profitable than those without credit. The same can be said for

irrigation which also has a positive coefficient for the dummy variable.

The results from the tenancy dummy variables support the implementation of land reform. Farms with fifty percent or more of their land from agrarian reform are more profitable than those with fifty percent or more of their land owned. Sharecroppers also are more profitable than farmers who own their own land, perhaps because they do not own their own capital and therefore expend less for production. Farms which have fifty percent or more of their land held without title are the only group which is less efficient than farms with owned land. This may be because such land is used for livestock, which is not as productive as crops.

The R^2 for most of the regressions run ranges from .15 to .28, which indicates that the profit functions as defined do not explain most of the variation in profits among farms. This is not surprising, given the heterogeneous nature of the farms in the survey. When rice farms alone are selected for applications of the profit function, the R^2 almost doubles, which indicates that its application should be limited to farms which are somewhat similar with respect to sources of revenue and input use.

CHAPTER IV

SUMMARY OF FINDINGS

The main purpose of this paper was to study the economic efficiency of farms in the Dominican Republic with special reference to variables which are related to policies which affect the economic welfare of the poorest farm families (target group).

The paper began by showing some proof that farmers in the Dominican Republic are profit maximizers. This was done by applying a test developed by John Wise and Pan Yotopoulos which estimates an index of economic rationality based upon the product-moment correlation of capital and labor use. The value of the coefficient represents the systematic profit maximizing behavior of the farms. The value was found to be .7174 for all farms. According to the test this means that 72% of the variance in the natural logs of capital and labor is due to systematic profit maximizing behavior.

The second step in the study was to identify the target group (or those farms with the lowest per capita gross income) in terms of geographical location and farm size. It was found that the average gross farm per capita income on small farms (less than 12 acres) is DR$140. With the addition of non-farm income it is DR$195. In comparison, the average gross farm

income per capita is DR$354 on medium farms (12 to 77 acres) and DR$1162 on large farms (greater than 77 acres). This indicates that even before costs are deducted, the income producing capacity of small farms is inadequate. Furthermore, the Gini coefficients showed large disparities in both gross farm income and land distribution among farms. The correlation between the amount of land and income which pertains to each defined farm-size category was also found to be very high.

The alternative means of improving the per capita income on small farms are the following: (1) increase non-farm income by making more work available off the farm, (2) increase farm revenue by making more of the basic factors of production available, and (3) increase farm revenue by increasing the economic efficiency of the farms. The study of economic efficiency is therefore more than just an academic exercise, because it is important for identifying policies which may improve the income and welfare of the poorest farm families in the country.

The methodology employed to study economic efficiency was the "Unit Output Price" profit function developed by Pan A. Yotopoulos and Lawrence Lau. The results of the application of the profit function to farms in the Dominican Republic showed that large farms are less efficient than small and medium farms, and that medium farms are the most efficient group. When the small farms were considered alone and disaggregated further into three small farm size categories, there

was no evidence of a significant difference in economic efficiency. This implies that the optimal farm size is greater than 12 acres.

Given the low per capita income of the small farms, it is apparent that the redistribution of land to small farms would release the land constraint from their income producing potential. The study of land tenancy through the inclusion of dummy variables in the profit function confirmed the importance of land redistribution. Farms with fifty percent or more of their land from agrarian reform are more profitable than farms with fifty percent or more of their land owned.

The availability of both credit and irrigation is also important. Farms which have access to them are more efficient than those which do not. Therefore, any policy which promotes small-farmer credit and the construction of irrigation systems should increase both the efficiency of small farms and the income and welfare of small-farm families.

APPENDIX A

DESCRIPTION OF THE UNIVERSE AND THE SAMPLE FROM THE 1976 DOMINICAN REPUBLIC COST OF PRODUCTION SURVEY

The universe of the population consists of all farming operations with eight or more tareas (.5 hectares or more), excluding colono sugar farms and all other farms growing only sugar cane; land controlled by the State Sugar Council (CEA); large agri-business enterprises; farms and lands managed centrally by the Dominican Agrarian Institute; and experimental farms. "Micro farms" of less than eight tareas are excluded because they are not considered to be viable economic units, and all large centrally managed farms are excluded because they are managed in a way completely different from the smaller, multi-activity farms that are the focus of the survey.

The sample of 1,800 farms was based upon an area frame in which the land was pre-stratified according to five land-use strata. Each stratum was divided into areas of equal size, and a listing was made of the areas. A systematic selection of the areas was then chosen based upon the number of segments desired for the sample. A listing was then made of every farmer in the chosen segment and from this listing a post-stratification was done by region and farm size. Finally, a sub-sample was selected (also systematically) after farms with certain crops were selected with certainty to ensure that there would be enough

observations of such crops for analysis. The sample is, therefore, a probability sample (not self weighting), so the most reliable results are those obtained from observations which are weighted by the inverse of their probability of being sampled.

TABLE 30.--Unweighted number of observations

Region 1	375
Region 2	304
Region 3	231
Region 4	239
Region 5	234
Region 6	236
Region 7	183
Farm Size 8-79 Tareas	989
Farm Size 80-499 Tareas	606
Farm Size 500+ Tareas	207

Source: Dominican Republic Sector Analysis Survey 1976

APPENDIX B

THE CALCULATION OF GROSS FARM INCOME AND NON FARM INCOME

1. Gross Farm Income[1]

Gross farm income is the total value of production from all crops, livestock, and processed products produced on the farm.

The total value of crop production is computed by multiplying the farm-gate price per unit of each crop by the total production of the crop. The farm-gate price used to compute the total value of production of each crop was derived by dividing the total value of sales by the total quantity of the crop sold on the farm. When sales transactions did not take place on a farm, the price used will be the average farm-gate price computed for all sales transacted for that crop in the sample.

The total revenue from livestock production includes the total value of sales of animals on the hoof, slaughtered animals, and animal products, the imputed value of all such production used on the farm, and the imputed value of net inventory changes.

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[1]For a thorough discussion of the calculation of gross farm and non-farm income, consult Methodological Working Document Number Five, Procedures for Developing Additional Data Cells, by Sandra Rowland, U.S. Agency for International Development, Bureau for Latin America, Sector Analysis Division, Washington, D.C., August 1977, pp. 34-94.

A net increase in livestock inventory will be counted as an addition to gross revenue, and a decrease will be counted as a deduction from gross revenue.

Since most processing is done with raw material produced on the farm, the revenue from processed products represents only the gross value added in processing. In other words, the imputed value of farm-produced inputs is deducted from the gross value of processed products production.

2. Non-farm Income[1]

Income acquired from non-farm sources is made up of revenue from non-agricultural work on the farm and off farm revenue. Specifically, it is comprised of cash and revenue in kind from artisan work, interest and dividends, agricultural work on other farms, work in other sectors, transfers of income from emigrants and all other sources not specified.

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[1]Ibid.

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