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PROFIT MAXIMIZATION AND PRICE RESPONSIVENESS AMONG GUATEMALAN CORN PRODUCERS: FINDINGS AND IMPLICATIONS

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INTRODUCTION

IN this study the profit function approach introduced by Lau and Yotopoulos [21] [39] is applied to a 1974 sample of 426 Guatemalan farms to elucidate two issues: (a) the efficiency of resource utilization in the production of corn, and (b) the price responsiveness of Guatemalan corn producers. For over thirty years it has been assumed in Guatemalan official circles that the country's corn economy is unresponsive to market forces, the government's position being that "...corn has traditionally been a subsistence crop...its cultivation being determined by custom with no regard to profitability considerations..." [3]. This decades-old position is still reflected in the country's latest national development plan [30, pp. 1–38].

The above characterization of the country's corn economy is supported by Gollas-Quintero [15] who, on the basis of Cobb-Douglas production function parameter estimates and efficiency indexes, determined that *family* farms in Guatemala's traditional sector, most of which grow corn, do not use their resources efficiently.

On the other hand, concern with the price responsiveness of Guatemalan corn producers lies at the heart of an old and still unsettled controversy in development economics, as a recent article by Junankar [18] clearly shows. Here the gamut of viewpoints ranges from the "economically efficient and/or rational" stance which claims that peasant farmers in LDCs use their resources efficiently and respond to market incentives quickly and in a rational manner, to the "structuralist-institutionalist" position which suggests that structural, institutional, and cultural constraints hinder farmers' allocative ability and limit their responsiveness to price signals or incentives.[1]

This study is organized as follows. Section I reviews some salient aspects of

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1 The economic rationality position is represented by [2] [11] [34] [14] [25] [40], among others; while the "structuralist-institutionalist" view includes [5] [29] [24] [19] [10] [1] [33] [18]. Between these two polar positions lies Nakajima's subjective equilibrium theory of the farm household [27] [28]. One of the latter's most important implications is that a farmer's allocative efficiency depends critically on his participation in *both* output and input markets.

Fig. 1. Topographical Regions of Guatemala

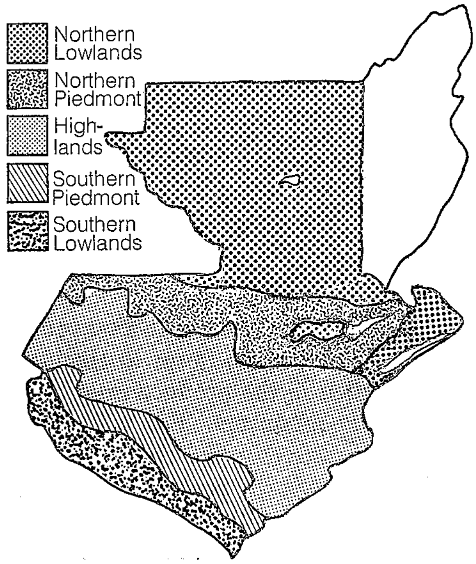
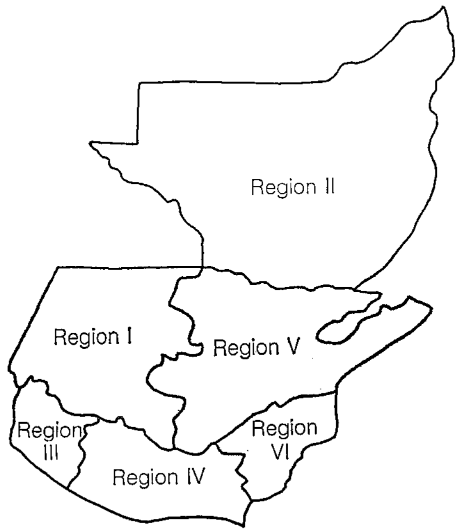


Fig. 2. Sample Regions



Source: [13, Map No. 2, p. 46].

Guatemala's corn economy. Section II discusses the profit function approach to the study of allocative efficiency and price responsiveness. Section III examines some characteristics of the corn growing farms selected for profit function estimation purposes. Sections IV and V discuss the statistical results obtained, and their implications. We conclude our analysis in the final section by pointing to new directions for further research on issues relating to allocative efficiency and price responsiveness.

I. CORN IN GUATEMALA

Corn is Guatemala's most important food crop. According to food balance sheets from FAO, Guatemala has, after Mexico, the second highest per capita consumption of corn in the world [35, p. 5]. Historically, the consumption of corn has provided approximately 53.6, 46.7, and 34.5 per cent of the population's daily intake of calories, proteins, and fats, respectively [6]. And among the poorest sectors of the population it supplies as much as 70 and 80 per cent of daily calorie and protein intake. In 1974, the year the farm sample analyzed in this study was taken, corn was the largest user of land—its cultivation accounted for almost 31 per cent of the total cultivated cropland—and the second largest generator of employment in the countryside, absorbing 13 per cent of the economically active population employed in agriculture [36, Tables 2.7 and 2.8]. Although there is no data available on the proportion of farms that grew corn in 1974, agricultural census figures reveal that, in 1964, 92.9 per cent of *all* farms in Guatemala cultivated corn [36, Table 2.6], while in 1979 a minimum of 77.9 per cent still did.[2] In Guatemala approximately 45 per cent of all corn growing farms produce only for self-consumption.[3] Subsistence farms are primarily, though not exclusively, located in the highlands (see Figure 1). Here a small farm size and a cool climate are the factors responsible for the subsistence production of corn. The severity of the land constraint is particularly acute in the highlands due to farm fragmentation caused by population growth and a poorly developed land rental market which limits access to farmland [16]. On the other hand, because of a cool climate, the growth cycle of corn in the highlands is as long as seven to eight months [17, p. 112]. This prevents farmers from growing more than two corn crops during the year. In the warm lowlands a different reason, namely, the lack of irrigation facilities, prevents the planting of two corn crops. In these areas the growth cycle of corn is as short as two to three months [17, p. 112].

II. THE MODEL

A. *The Profit Function Approach to the Study of Allocative Efficiency*

Suppose a farmer maximizes money profit, P', defined as current revenue less variable costs,

$$P'=p\cdot Q-\sum_{i=1}^{m}q_i'\cdot X_i, \tag{1}$$

where P' is the money profit, p is the unit price of output, Q is the amount of output, q_i' is the unit price of the ith variable input $(i=1,\ldots,m)$, and X_i is the amount of the ith variable input $(i=1,\ldots,m)$. Output in equation (1) is assumed to be a Cobb-Douglas function of m variable inputs and one fixed input as follows,

$$Q=A\prod_{i=1}^{m}X_i^{\alpha_i}T^{\beta}, \tag{2}$$

where T is the amount of land grown under corn, assumed to be fixed in the short run.

Maximization of equation (1) is equivalent to maximization of normalized restricted profit (NRP), P,

$$P=P'/p=Q-\sum_{i=1}^{m}q_i\cdot X_i, \tag{3}$$

where $q_i=q_i'/p$ is the normalized price of the ith variable input. Normalized

2 Based on [35, Table 3.11] and [12, Table 2A].

3 Dabasi-Schweng [9] estimated that, in 1950, 47 per cent of corn gorwing farms hardly produced above subsistence needs, and thus sold little or no corn in the marketplace. Sevilla-Siero [36] using 1964 census figures estimated that 46 per cent of corn growing farms, accounting for 21 per cent of the country's output of corn, were unable to produce above the minimum consumption requirements for an average rural family of 5.7 persons,

profit in equation (3) is characterized as restricted because one of the inputs is constrained to be fixed.

Under the assumption that the producer maximizes profit *imperfectly*, maximization of equation (3) with respect to X_i $(i=1,\ldots,m)$ yields the following marginal productivity conditions,

$$\partial Q/\partial X_i = k_i \cdot q_i, \quad i=1,\ldots,m, \tag{4}$$

where $k_i > 0$. In equation (4) $k_i \cdot q_i$ may be interpreted as the *effective* normalized price of the ith variable input, and k_i may be taken to represent a behavioral rule which affects the allocation of the ith variable input. Perfect profit maximization or perfect allocative efficiency arises as a special case when $k_i = 1$ for *all* $i=1, \ldots, m$.

Equation system (4) can be solved for the actual input demands, X_i $(i=1,\ldots, m)$ as a function of $k_i \cdot q_i$ $(i=1,\ldots,m)$ and T as follows,

$$X_i = \frac{\alpha_i}{k_i q_i}\left[A \prod_{i=1}^{m}\left(\frac{\alpha_i}{k_i q_i}\right)^{\alpha i}\right] T^{\beta}, \quad i=1,\ldots, m. \tag{5}$$

Substitution of (5) into the definition of normalized restricted profit in (3) yields the actual NRP function,

$$\Pi_a = A^* \prod_{i=1}^{m} q_i^{\alpha i^*} T^{\beta^*}, \tag{6}$$

where

$$A^* \equiv A^{(1-h)^{-1}}\left[\prod_{i=1}^{m} \alpha_i^{\alpha i(1-h)^{-1}}\right]\left[\prod_{i=1}^{m} k_i^{-\alpha i(1-h)^{-1}}\right]\left[1-\sum_{i=1}^{m}\frac{\alpha_i}{k_i}\right], \tag{7}$$

$$k^* \equiv 1-\sum_{i=1}^{m}\frac{\alpha_i}{k_i}(1-h)^{-1}, \tag{8}$$

$$\alpha_i^* \equiv -\alpha_i(1-h)^{-1} < 0, \tag{9}$$

$$\beta^* \equiv \beta(1-h)^{-1} > 0, \tag{10}$$

$$h = \sum_{i=1}^{m} \alpha_i. \tag{11}$$

Note that the log-linear representation of the actual NRP function is given by

$$\ln \Pi_a = \ln A^* + \sum_{i=1}^{m} \alpha_i^* \ln q_i + \beta^* \ln T. \tag{12}$$

Using equation (6), and identities (7)–(11), the actual input demands in equation (5) may be rewritten as follows,

$$X_i = -\alpha_i^*(k_i)^{-1}(q_i)^{-1}(k^*)^{-1}\Pi_a, \qquad i=1,\ldots,m. \tag{13}$$

Rearranging terms in equation (13) yields the input share of profit equations given by

$$-\frac{q_i X_i}{\Pi_a} = (k_i)^{-1}(k^*)^{-1}\alpha_i^* \equiv \alpha_i^{*\prime}. \tag{14}$$

Note that when perfect profit maximization takes place, that is, when $k_i = 1$ for *all* $i = 1, \ldots, m$, the $\alpha_i^{*\prime}$ derived from the input share of profit equation, coincides with the corresponding α_i^* present in the actual NRP function. Hence a test of the hypothesis of perfect profit maximization can be performed by comparing the $\alpha_i^{*\prime}$ $(i = 1, \ldots, m)$ of the input share of profit equations in equation (14) with the corresponding α_i^* $(i = 1, \ldots, m)$ of the actual NRP function in equation (12), and testing simultaneously for their equality, using test statistics based on F-ratios. Thus the null hypothesis of perfect profit maximization is[4]

$$H_0 : \alpha_i^* = \alpha_i^{*\prime}. \tag{15}$$

To derive the output supply (Q^*) and input demand functions (X_i^*) from the profit function, well-known duality transformation relations shown in [21] [39] [40] were used.

B. *Stochastic Model and Estimation Procedure*

The general form of the stochastic model estimated for each of the packages examined consists of the actual NRP function and the corresponding inputs share equations,

$$\ln \Pi_a = \ln \alpha_0 + d_1 D_1 + \sum_{i=1}^{m} \alpha_i^* \ln q_i + \beta^* \ln T + e_0, \tag{16}$$

and

$$-\frac{q_i X_i}{\Pi_a} = \alpha_i^{*\prime} + e_i, \quad \text{for } i = 1, \ldots m, \tag{17}$$

where

Π_a = actual normalized profit,

[4] Two additional hypotheses were also tested: the hypothesis of constant returns to scale (CRTS) in all inputs; and the hypothesis of CRTS in all inputs *conditional* on the validity of the hypothesis of perfect profit maximization. The parameters of the actual NRP function in equation (6) can be used to test the hypothesis of constant returns to scale in all factors of the underlying production function. In this respect, it has been shown that $\beta^* = t - (t-1)\sum_{i=1}^{m}\alpha_i^*$ is a necessary and sufficient condition on the parameters of the actual NRP function in equation (6) in order for homogeneity of degree t to prevail in the underlying Cobb-Douglas production function. By virtue of the monotonicity conditions on the NRP function, $\sum_{i=1}^{m}\alpha_i^* < 0$.

Therefore, if increasing returns ($t > 1$) prevail, $\beta^* > 1$. If constant returns ($t = 1$) hold, $\beta^* = 1$. Finally, if decreasing returns ($t < 1$) exist, $\beta^* < 1$. Thus a test of the hypothesis of constant returns to scale in all factors involves the null hypothesis, $H_0 : \beta^* = 1$.

The hypothesis of constant returns to scale can also be tested conditional on the validity of the hypothesis of perfect profit maximization, and it involves testing the null hypothesis, $H_0 : \beta^* = 1$, *while* maintaining the hypothesis of perfect profit maximization.

X_i = actual demand for the ith variable input ($i = 1, \ldots, m$),
T = fixed amount of land under corn,
q_i = normalized price of ith variable input ($i = 1, \ldots, m$),
$D_1 = \begin{cases} 0 \text{ for units using traditional seed varieties,} \\ 1 \text{ for units using improved seed varieties,} \end{cases}$
e_0 = disturbance term of actual NRP function, and
e_i = disturbance term of input share equation ($i = 1, \ldots, m$).

The additive error term in the actual NRP reflects the fact that farms maximize profit subject to unknown exogenous disturbances. The additive error term in the input share equations arises from differential abilities to maximize profits. It is assumed that $E(e_0) = 0$, and $E(e_i) = 0$ for $i = 1, \ldots, m$. While the covariance of the disturbance terms of any two equations corresponding to different farms is assumed to be zero, the covariance of the errors of any two of equations for the same farm is permitted to be nonzero. Given this specification of the errors, and the fact that all variables on the left-hand side of equations (16) and (17) are jointly dependent variables, it is clear that a simultaneous system estimation method such as Zellner's [41] seemingly unrelated regression (ZEF) constitutes an asymptotically efficient method of estimation. The benefits of Zellner's method become even more apparent when the hypothesis of perfect profit maximization is tested for and not rejected. Because all variables on the right-hand side of equations (16) and (17) are predetermined, the application of OLS to equations (16) and (17) separately will yield consistent estimates. These estimates will be inefficient because each α_i^* appears both in equation (16) and in one of the input share equations in equation (17). A more efficient approach involves the simultaneous estimation of equations (16) and (17) imposing the restriction that the two estimates of each α_i^* be equal.[5]

Because of the large number of observations present in groups 1A and 1B the model estimated for these two groups was expanded to accommodate additional dummy variables that tested for the effects of literacy and age of the farm operator, and geographic location on actual normalized restricted profit.

III. SELECTION AND CHARACTERISTICS OF FARMS USED FOR PROFIT FUNCTION ESTIMATION PURPOSES

A. *Farm Selection Criteria*

For purposes of estimating the model consisting of equations (16) and (17) a total of 426 farms were selected from a 1,548 farm sample survey conducted in 1974 by institutions from Guatemala's Public Agricultural Sector (PAS) with the assistance of the U.S. Agency for International Development.[6] The farms so selected satisfied the following requirements:

[5] Kmenta and Gilbert [20] have shown that iteration of the ZEF estimation procedure (IZEF) will yield parameter estimates that will converge to the maximum likelihood estimates. Such iterations were not performed in this study. See also Ruble [32].

[6] For details on survey and sampling procedures, see [31].

TABLE I

INPUT USE BY FARM GROUP

Farm Group	Farm Group Identification Code
Labor, land	1A
Labor, fertilizer, land	1B
Labor, machinery capital, land	2
Labor, animal capital, land	3
Labor, fertilizer, machinery capital, land	4
Labor, fertilizer, animal capital, machinery capital, land	5

(i) Corn was grown on the farm. However, other crops could also be grown on the farm in addition to corn.[7]

(ii) Corn was grown *alone* rather than interplanted with other crops, such as beans.

(iii) The planting of corn took place during the March–May period.

(iv) Computed profit for the farm's corn operation was positive.

(v) Any of the input combinations or "input packages" shown in Table I, was reportedly used in the production of corn.

Items (ii) and (iii) assured, respectively, product homogeneity and concentration on the most important corn crop of the year, the planting of which takes place during the March–June period. The item (iv) is a theoretical and methodological necessity dictated by the profit function approach used in this study. Finally, the item (v) permitted the classification of farms into homogeneous groups according to the type of technology or input package used in the production of corn.

B. *Farm Characteristics*

As shown in Table II, the average farm size was 8.6 ha for all farms selected for profit function estimation purposes. No appreciable differences in farm size exist among groups: the latter varies from a minimum of 6.8 ha in group 3 to a maximum of 9.1 ha in group 1B. Average farm size in groups 1A and 1B—where machinery was not used—is larger than average farm size in groups 2, 4, and 5 where machinery was used in the production of corn. This is rather perplexing for one would expect machinery to be used primarily by large farms. The explanation for this probably lies in the poor topography of group 1A and 1B farms. According to the data, the majority of the farms in groups 1A and 1B are concentrated in regions I, V, and VI. These three regions, as shown in Figures 1 and 2, encompass the mountainous range that crosses Guatemala from northwest to southeast, as well as its northern and southern piedmonts. As a result, farms in groups 1A and 1B reported the highest percentages of steep and broken farmland, as shown in Table II. Thus an unfavorable topography apparently precludes the utilization of machinery in groups 1A and 1B. It is noteworthy that groups 1A and 1B reported

[7] This did not represent a problem as sample data permitted the identification of inputs used directly in the production of corn.

TABLE II
SELECTED FARM CHARACTERISTICS

	Group						
	1A	1B	2	3	4	5	All Farms
Crops grown:							
Aver. no. of annual crops grown[a]	1.74	2.01	2.02	1.87	2.25	2.17	1.94
Aver. no. of crops grown (all types)[b]	1.98	2.18	2.13	1.88	2.51	2.21	2.11
Size:							
Average farm size (ha)	8.87	9.17	7.95	6.88	7.84	8.03	8.59
Average area under corn (ha)	2.04	1.56	3.05	1.91	2.80	2.15	2.03
Topography:							
Percentage of farm area under:							
Flat land	29.06	18.52	79.82	33.73	60.39	60.99	34.44
Steep land	59.05	53.99	18.48	49.42	18.40	7.80	46.50
Broken land	11.89	27.49	1.70	16.85	21.21	31.21	19.06
Total	100.00	100.00	100.00	100.00	100.00	100.00	100.00
Output market participation:							
Percentage of farms with corn sales	52.4	61.5	87.5	65.6	80.0	88.2	64.7
Percentage of farms without corn sales	47.6	38.5	12.5	34.4	20.0	11.8	35.3
Total	100.0	100.0	100.0	100.0	100.0	100.0	100.0
Marketing channels:							
Percentage of output market participating farms that sold corn to:							
Middlemen	81.3	75.6	94.3	95.2	82.1	100.0	84.2
Consumers	18.7	24.4	5.7	4.8	17.9	—	15.8
Total	100.0	100.0	100.0	100.0	100.0	100.0	100.0
Labor market participation:							
Percentage of farms with hired labor	76.20	85.80	80.00	71.90	97.10	85.80	82.80
Percentage of farms without hired labor	23.80	14.20	20.00	28.10	2.90	14.20	17.20
Total	100.00	100.00	100.00	100.00	100.00	100.00	100.00

a Including corn.
b Annual and permanent crops.

the highest concentrations of *micro corn plots* (see Table III). These are corn plots so small that they cannot produce a level of corn output large enough to support a typical rural family during the year. As a result, the presence of subsistence farms (farms that did not participate at all in the output market) in groups 1A and 1B, was above the average for all farms in the six groups examined (see Table II). For those farms that *did* make corn sales, the majority sold their output

TABLE III

DISTRIBUTION OF FARMS ACCORDING TO SIZE OF CORN OPERATIONS

Distribution of Farms according to Size of Corn Operations	Input Package						All Farms
	1A	1B	2	3	4	5	
Less than 1 ha*	30.6	39.9	12.5	25.0	25.7	8.8	29.6
From 1 to less than 3 ha	53.0	51.3	52.5	62.5	40.0	73.5	53.7
From 3 to less than 5 ha	11.6	6.1	17.5	6.2	17.1	14.7	10.5
From 5 to less than 10 ha	3.4	2.7	17.5	6.2	17.1	2.9	5.7
More than 10 ha	1.4	0.0	0.0	0.0	0.0	0.0	0.5
Total	100.0	100.0	100.0	100.0[a]	100.0[a]	100.0[a]	100.0

[a] Column figures do not add up to total due to rounding errors.

* Micro corn plots.

directly to middlemen more than they did to consumers, 84.2 per cent vs. 15.8 per cent (Table II).[8] From the point of view of participation in the labor market, Table II shows that the percentage of farms that used hired labor was relatively high across groups.

IV. STATISTICAL TESTS AND ESTIMATION RESULTS

A. *Results of Statistical Tests*

The computed and the critical F statistics associated with the profit maximization and constant returns to scale tests are shown in Table IV. On the other hand,

[8] Although the farm sample examined does not contain information on the market distribution chains used by the farms under examination, we know—based on information supplied by Rodolfo Estrada, minister of agriculture of Guatemala during 1986–89—that corn is marketed in three different ways. First, some corn producers, particularly those located in the highlands and piedmont areas usually market their produce directly to consumers: they rent a pickup truck or use other means of rural transportation to bring their produce (unhusked corn) to the neighboring town where it is sold directly to consumers in market fairs that meet in the town plaza once, and sometimes, twice a week. Not unexpectedly, groups 1A and 1B which reported the highest percentage of farms located in the highlands and piedmont areas, also reported the highest percentage of farms that sold directly to consumers. Second, in the Peten area (region II) and along the Pacific coastland (the low flatlands of regions III and IV), truck-driving intermediaries buy shelled corn directly from the producers. The price they pay to the latter is based on a spot price the truckers agree upon among themselves before they contact the producers. Appropriate discounts from this spot price are made by the truckers based on deficiencies and the degree of humidity present in the grain. Truckers sell their corn to other intermediaries and wholesalers in the towns or in Guatemala City, and to manufacturers of chicken feed. The latter have purchase points in strategically-located road intersections outside Guatemala City. And third, the Instituto de Comercialización Agropecuaria, INDECA (Agricultural Marketing Institute), the government's grain marketing organization, also buys corn from producers at support prices announced at the beginning of the planting season. Though INDECA has more than twenty purchase outlets throughout the country, due to a chronic lack of funds, it is often incapable of implementing guaranteed prices effectively. INDECA buys at various pre-established prices only corn that satisfies certain quality standards. If the latter are not met INDECA will not effect a purchase.

TABLE IV

STATISTICAL HYPOTHESES TESTED BY FARM GROUP

Farm Group	Input Composition	Maintained Hypothesis	Tested Hypothesis H_0	Computed F Statistics	Critical F Statistics at Various Levels of Significance				Test Results
					0.05	0.01	0.005	0.001	
1A	L, T		$\alpha_i^* = \alpha_i^{*\prime}$	$F_{(1,282)} = 91.82$	3.84	6.63	7.88	10.83	Rejected
			$\beta^* = 1$	$F_{(1,282)} = 11.26$	3.84	6.63	7.88	10.83	Rejected
1B	L, F, T		$\alpha_i^* = \alpha_i^{*\prime}$	$F_{(2,430)} = 35.60$	3.00	4.61	5.30	6.91	Rejected
			$\beta^* = 1$	$F_{(1,430)} = 8.93$	3.84	6.63	7.88	10.83	Sig. at 0.001
2	L, K_m, T		$\alpha_i^* = \alpha_i^{*\prime}$	$F_{(2,113)} = 2.94$	3.07	4.79	5.54	7.32	Sig. at 0.001
			$\beta^* = 1$	$F_{(1,113)} = 23.39$	3.92	6.85	8.18	11.38	Rejected
		$\alpha_i^* = \alpha_i^{*\prime}$	$\beta^* = 1$	$F_{(3,113)} = 8.12$	2.68	3.95	4.50	5.79	Rejected
3	L, K_a, T		$\alpha_i^* = \alpha_i^{*\prime}$	$F_{(2,89)} = 6.08$	3.11	4.90	5.30	6.91	Sig. at 0.001
			$\beta^* = 1$	$F_{(1,89)} = 0.38$	3.96	6.95	8.33	11.68	Sig. at 0.001
		$\alpha_i^* = \alpha_i^{*\prime}$	$\beta^* = 1$	$F_{(3,89)} = 4.39$	2.75	4.10	4.28	5.42	Sig. at 0.001
4	L, F, K_m, T		$\alpha_i^* = \alpha_i^{*\prime}$	$F_{(3,131)} = 3.06$	2.68	3.95	4.50	5.79	Sig. at 0.001
			$\beta^* = 1$	$F_{(1,131)} = 11.64$	3.92	6.63	8.18	10.83	Rejected
5	L, F, K_a, K_m, T		$\alpha_i^* = \alpha_i^{*\prime}$	$F_{(4,159)} = 2.67$	2.37	2.79	3.72	4.63	Sig. at 0.001
			$\beta^* = 1$	$F_{(1,159)} = 0.01$	3.84	6.63	7.88	10.83	Sig. at 0.001

TABLE V

COBB-DOUGLAS PROFIT AND FACTOR DEMAND FUNCTIONS FOR FARM GROUP 1A

Profit Function	Variable (1)	Parameter (2)	Zellner's Efficient Estimation: No Restrictions (3)
Intercept	Constant	$\ln A^*$	5.426* (16.02)
Normalized wage	$\ln q_l$	α_1^*	0.5057* (3.134)
Land	$\ln T$	β^*	0.8147* (14.27)
Seed variety dummy	D_1	d_1	0.1675 (1.292)
Education dummy	D_2	d_2	0.03533 (0.3648)
Age dummy	D_3	d_3	0.02471 (0.2732)
Tech. assist. dummy	D_4	d_4	−0.02573 (−0.2409)
Region III dummy	G_1	g_1	−0.08552 (−0.3633)
Region IV dummy	G_2	g_2	−0.1858 (−1.129)
Region V dummy	G_3	g_3	−0.2392* (−1.749)
Region VI dummy	G_4	g_4	−0.05542 (−0.3426)
Labor share equation		$\alpha_1^{*\prime}$	−1.176* (−14.21)

* Statistically significant at the 0.05 level.

Tables V–X report both the unrestricted estimation results as well as the restricted ones supported by the statistical tests.

The restrictions implied by the hypothesis of perfect profit maximization were rejected at all levels of significance in groups 1A and 1B. Contrary to theoretical expectations the coefficient of the normalized wage in group 1A was positive and statistically significant (Table V, column 3), whereas in group 1B the coefficients of the normalized wage and the normalized price of fertilizer lacked statistical significance.

Rejection of the hypothesis of profit maximization in 1A and 1B is likely to be due to a number of causes. Foremost among these is model misspecification bias caused by the high percentage of subsistence farms present in these two groups vis-à-vis the other groups (see Table II). According to Nakajima's subjective

TABLE VI

COBB-DOUGLAS PROFIT AND FACTOR DEMAND FUNCTIONS FOR FARM GROUP 1B

Profit Function	Variable (1)	Parameter (2)	Zellner's Efficient Estimation	
			No Restrictions (3)	$\beta^*=1$ (4)
Intercept	Constant	$\ln A^*$	6.57* (21.72)	6.569* (21.14)
Normalized wage	$\ln q_l$	α_1^*	0.1136 (0.7545)	0.1294 (0.08366)
Normalized price of fertilizer	$\ln q_{fr}$	α_2^*	0.1796 (0.9277)	0.2284 (1.133)
Land	$\ln T$	β^*	0.8242* (13.58)	1.000* (.2147D 10)
Seed variety dummy	D_1	d_1	−0.01007 (−0.1009)	−0.02897 (−0.2830)
Education dummy	D_2	d_2	−0.1195 (−1.253)	−0.1017 (−1.038)
Age dummy	D_3	d_3	−0.02428 (−0.2894)	−0.06525 (−0.7682)
Tech. assist. dummy	D_4	d_4	0.2162* (2.419)	0.2611* (2.886)
Region III dummy	G_1	g_1	0.1681 (0.3503)	−0.07022 (−0.1446)
Region IV dummy	G_2	g_2	0.05493 (0.3225)	−0.1529 (−0.9642)
Region V dummy	G_3	g_3	−0.1271 (−0.972)	−0.2558* (−2.026)
Region VI dummy	G_4	g_4	−0.3291* (−2.788)	−0.4373* (−3.805)
Labor share equation		$\alpha_1^{*\prime}$	−0.8749* (−13.76)	−0.8749* (−13.76)
Fertilizer share equation		$\alpha_2^{*\prime}$	−0.3775* (−11.26)	−0.3775* (−11.26)

* Statistically significant at the 0.05 level.

equilibrium theory of the farm household [27] [28], whenever the latter does not participate in either the labor market or the output market or both, its production choices become intertwined with its consumption choices. As a result, the typical marginal productivity conditions associated with profit maximization are not met and, in addition, a profit function such as equation (6) can no longer be defined, much less estimated, for the subsistence unit.[9]

[9] Other sources of specification bias may be affecting group 1A and 1B results. First, these two groups reported the highest percentages of farms that sold directly to consumers. These farms, unlike those that sell directly to truckers at the farm gate, transport their corn to

TABLE VII

COBB-DOUGLAS PROFIT AND FACTOR DEMAND FUNCTIONS FOR FARM GROUP 2

Profit Function	Variable (1)	Parameter (2)	Zellner's Efficient Estimation: No Restrictions (3)	Zellner's Efficient Estimation: $\alpha_i^* = \alpha_i^{*\prime}$ (4)
Intercept	Constant	$\ln A^*$	7.350* (5.997)	9.665* (14.73)
Normalized wage	$\ln q_l$	α_1^*	−0.1739 (−0.6131)	−0.6654* (−4.432)
Normalized price of machinery capital services	$\ln q_{km}$	α_2^*	−0.04102 (0.1522)	−0.2803* (−2.395)
Land	$\ln T$	β^*	0.4674* (4.077)	0.5369* (4.583)
Seed variety dummy	D_1	d_1	−0.01707 (0.1045)	−0.02038 (−0.1161)
Labor share equation		$\alpha_1^{*\prime}$	−0.8722* (−4.897)	−0.6654* (−4.432)
Machine-hours share equation		$\alpha_2^{*\prime}$	−0.4212* (−3.115)	−0.2903* (−2.395)

* Statistically significant at the 0.05 level.

the marketplace and thus incur transportation and marketing costs that were not taken into account in the computation of their profit. The exclusion of this category of costs has the effect of overstating the profit generated by farms that sell directly to consumers or what is the same, of overstating the net effective price (net of marketing costs) received by the farm.

Another source of misspecification is the possibility that farms in groups 1A and 1B, where the prevalence of micro corn plots and production for self-consumption is highest, may be subject to an input expenditure or credit constraint. In this case the approach used by Lee and Chambers [22], relying on the estimation of an expenditure-constrained generalized Leontieff profit function, may be more appropriate. This approach permits testing for the hypothesis of expenditure-constrained, as opposed to unconstrained, profit maximization.

Model misspecification may also arise if producers in groups 1A and 1B, because of the low profits they generate, segment their family labor from the rest of the labor market, and charge the former a discriminatory wage that is below the market wage rate. Sevilla-Siero [37] has shown that labor and/or output market segmentation are legitimate strategies that a farmer may use to defend or augment farm profit in the face of declining prices for farm output and/or increasing wage rates for labor. The possibility of segmentation implies that the wage rate and/or output price used by the farmer in estimating profit are not completely exogenous, as required by the NRP function approach.

Also our use of a Cobb-Douglas specification reflects untested constraints on input substitutability and separability which may result in biased estimates of the marginal products. In this regard Marsh et al. [23] have found evidence suggesting that the relevant technology for one of the groups examined in our study may be of the translog type. Finally, the imputation of a price to the output of farms that did not sell any corn at all may have led to problems due to errors in variables. Clearly the clarification of these matters necessitates an amount of additional research that is beyond the scope of this study.

TABLE VIII

COBB-DOUGLAS PROFIT AND FACTOR DEMAND FUNCTIONS FOR FARM GROUP 3

Profit Function	Variable (1)	Parameter (2)	Zellner's Efficient Estimation: No Restrictions (3)	Zellner's Efficient Estimation: $\alpha_i^*=\alpha_i^{*\prime}$, $\beta^*=1$ (4)
Intercept	Constant	$\ln A^*$	5.946* (7.452)	8.347* (36.40)
Normalized wage	$\ln q_l$	α_1^*	0.2685 (0.7977)	−0.6768* (−5.401)
Normalized price of animal capital services	$\ln q_{ka}$	α_2^*	0.007672 (0.02719)	−0.1614* (−4.513)
Land	$\ln T$	β^*	0.9346* (8.769)	1.000* (.1074 10)
Seed variety dummy	D_1	d_1	−0.2590 (−1.231)	−0.1738 (−0.6901)
Labor share equation		$\alpha_1^{*\prime}$	−0.8152* (−6.11)	−0.6768* (−5.401)
Animal-days share equation		$\alpha_2^{*\prime}$	−0.1827* (−5.133)	−0.1614* (−4.513)

* Statistically significant at the 0.05 level.

The above considerations strongly suggest that the NRP function models estimated for groups 1A and 1B are seriously biased, and that better results would have been obtained if subsistence farms had been excluded from the estimation sample.[10] This, however, would have seriously weakened the test for perfect profit maximization among group 1A and 1B farms by excluding from the analysis those units whose presence would have made rejection of the hypothesis of perfect allocative efficiency less likely. Because of all of the above considerations, rejection of profit maximization in 1A and 1B should not be interpreted as representing the average production behavior of *market participants* in these two groups.[11]

[10] This, however, invalidates the application of classical statistical procedures because it introduces a systematic nonrandom factor into the sample selection process as if only those samples that fit the data extremely well were used. In this regard, see [7, p. 8].

[11] Given the various theoretical arguments that make profit maximization on the part of purely or quasi-subsistence farms highly unlikely, an explanation is in order at this point as to why I chose not to exclude subsistence units present in 1A and 1B in testing for the hypothesis of perfect profit maximization in these two groups. The reason is that the hypothesis of perfect profit maximization is a composite one: it transcends mere price taking and the equalization of the value marginal productivity of each input with its corresponding market price. It also implies that farmers impute to each farmer-owned or supplied input its corresponding market opportunity cost. Because of this consideration, purely subsistence and quasi-subsistence farms should not, in principle, be excluded from any rigorous test of the hypothesis of perfect profit maximization.

TABLE IX

COBB-DOUGLAS PROFIT AND FACTOR DEMAND FUNCTIONS FOR FARM GROUP 4

Profit Function	Variable (1)	Parameter (2)	Zellner's Efficient Estimation: No Restrictions (3)	Zellner's Efficient Estimation: $\alpha_i^* = \alpha_i^{*\prime}$ (4)
Intercept	Constant	$\ln A^*$	7.015* (5.217)	9.452* (34.31)
Normalized wage	$\ln q_l$	α_1^*	0.2543 (0.6055)	−0.6559* (−7.157)
Normalized price of fertilizer	$\ln q_{fr}$	α_2^*	−0.08644 (−0.1621)	−0.2923* (−5.196)
Normalized price of machinery capital services	$\ln q_{km}$	α_3^*	−0.1277 (−0.5543)	−0.2494* (−5.377)
Land	$\ln T$	β^*	0.6470* (5.997)	0.6573* (6.429)
Seed variety dummy	D_1	d_1	0.03068 (0.1522)	0.3048* (1.731)
Labor share equation		$\alpha_1^{*\prime}$	−0.7189* (−7.546)	−0.6559* (−7.157)
Fertilizer share equation		$\alpha_2^{*\prime}$	−0.3233* (−5.612)	−0.2923* (−5.196)
Machine-hours share equation		$\alpha_3^{*\prime}$	−0.2751* (−5.707)	−0.2494* (−5.377)

* Statistically significant at the 0.05 level.

On the other hand, in groups 2, 3, 4, and 5 the F statistics presented in Table IV suggest that the restrictions implied by the hypothesis of perfect profit maximization are valid. This is not an unexpected result, in view of the considerable proportion of output market participants present in these four groups, a minimum of 66 per cent in group 3, and a maximum of 88 per cent in group 5.

The hypothesis of constant returns to scale was not rejected in groups 1B, 3, and 5, implying the existence of diminishing returns to scale in production units in groups 1A, 2, and 4.

B. *Restricted Estimation Results*

The results of the profit maximization and the constant returns to scale tests were used to obtain efficient parameter estimates of the NRP function and input share equation models for farm groups 1B, 2, 3, 4, and 5. This was achieved by incorporating into the estimation procedure applied to each group the restrictions supported by such tests: the CRTS restriction in group 1B; the profit maximization restrictions in groups 2 and 4; and the profit maximization and CRTS restrictions in groups 3 and 5. The restricted estimates so obtained are shown in column (4) of Tables VI–X.

TABLE X

COBB-DOUGLAS PROFIT AND FACTOR DEMAND FUNCTIONS FOR FARM GROUP 5

Profit Function	Variable (1)	Parameter (2)	Zellner's Efficient Estimation: No Restrictions (3)	Zellner's Efficient Estimation: $\alpha_i^*=\alpha_i^{*\prime}$, $\beta^*=1$ (4)
Intercept	Constant	$\ln A^*$	6.935*	8.312*
			(5.511)	(24.63)
Normalized wage	$\ln q_l$	α_1^*	−0.2789	−0.3780*
			(−1.087)	(−4.612)
Normalized price of fertilizer	$\ln q_{fr}$	α_2^*	0.7717*	−0.2325*
			(1.879)	(−4.844)
Normalized price of animal capital services	$\ln q_{ka}$	α_3^*	0.2482	−0.05076*
			(0.8724)	(−5.401)
Normalized price of machinery capital services	$\ln q_{km}$	α_4^*	−0.09025	−0.1373*
			(−0.3335)	(−3.618)
Land	$\ln T$	β^*	0.9778*	1.0*
			(5.019)	(5.492)
Seed variety dummy	D_1	d_1	0.2466	0.2132
			(1.185)	(0.9455)
Labor share equation		$\alpha_1^{*\prime}$	−0.4596*	−0.3780*
			(−5.132)	(−4.612)
Fertilizer share equation		$\alpha_2^{*\prime}$	−0.2775*	−0.2325*
			(−5.517)	(−4.844)
Animal-days share equation		$\alpha_3^{*\prime}$	−0.05791*	−0.05076*
			(−5.87)	(−5.401)
Machine-hours share equation		$\alpha_4^{*\prime}$	−0.1738*	−0.1373*
			(−4.232)	(−3.618)

* Statistically significant at the 0.05 level.

In groups 2, 3, 4, and 5, imposition of the constraints implied by the profit maximization hypothesis and, where applicable, by the constant returns to scale hypothesis improved dramatically the statistical significance of the estimated parameters. The restricted profit functions estimated for these four groups all conform to theoretical expectations. They are decreasing and convex in the normalized prices of the variable inputs in accordance with the theory of profit functions due to the negative coefficients estimated for these prices. The convexity assumption can also be confirmed by looking at the positive sign associated with the second derivatives of the normalized profit functions with respect to the relevant normalized input prices as shown in Table XI.

All of the second derivatives shown in Table XI are greater than zero since $\Pi > 0$ and, hence, $\Pi^* > 0$ for the units under examination. Also, as predicted by theory, the NRP function is increasing with respect to the fixed factor of production, land.

TABLE XI

SECOND DERIVATIVES OF NRP FUNCTIONS WITH RESPECT TO NORMALIZED PRICES OF VARIABLE FACTORS IN THE PROFIT-MAXIMIZING GROUPS

Farm Group	$\partial^2\Pi^*/\partial q_l^2$	$\partial^2\Pi^*/\partial q_{km}^2$	$\partial^2\Pi^*/\partial q_{fr}^2$	$\partial^2\Pi^*/\partial q_{ka}^2$
2	$-0.6654(-1.6654)\Pi^*/q_l^2$	$-0.2803(-1.2803)\Pi^*/q_{km}^2$		
3	$-0.6768(-1.6768)\Pi^*/q_l^2$			$-0.1614(-1.1614)\Pi^*/q_{ka}^2$
4	$-0.6559(-1.6559)\Pi^*/q_l^2$	$-0.2494(-1.2494)\Pi^*/q_{km}^2$	$-0.2923(-1.2923)\Pi^*/q_{fr}^2$	
5	$-0.3780(-1.3780)\Pi^*/q_l^2$	$-0.1373(-1.1373)\Pi^*/q_{km}^2$	$-0.2325(-1.2325)\Pi^*/q_{fr}^2$	$-0.0507(-1.0507)\Pi^*/q_{ka}^2$

TABLE XII

COMPUTED ELASTICITIES OF OUTPUT SUPPLY IN FARM GROUPS 1A, 1B, 2, 3, 4, AND 5

Farm Group	Output Price	Elasticity of Output Supply with Respect to:				
		Wage Rate	Fertilizer Price	Machine-Hour Price	Animal-Day Price	Land
1A	−0.5057	0.5057				0.8147
1B	−0.3578	0.1294	0.2284			1.0
2	0.9457	−0.6654		−0.2803		0.536
3	0.8382	−0.6768			−0.1614	1.0
4	1.1976	−0.6559	−0.2923	−0.2494		0.657
5	0.7985	−0.3780	−0.2325	−0.1373	−0.0507	1.0

TABLE XIII

COMPUTED ELASTICITIES OF LABOR DEMAND IN FARM GROUPS 1A, 1B, 2, 3, 4, AND 5

Farm Group	Output Price	Elasticity of Labor Demand with Respect to:				
		Wage Rate	Fertilizer Price	Machine-Hour Price	Animal-Day Price	Land
1A	0.4943	−0.4943				0.8147
1B	0.6422	−0.8706	0.2284			1.0
2	1.9457	−1.6654		−0.2803		0.5369
3	1.8382	−1.6768			−0.1614	1.0
4	2.1976	−1.6559	−0.2923	−0.2494		0.657
5	1.7985	−1.3780	−0.2325	−0.1373	−0.0507	1.0

On the other hand, the CRTS-restricted estimates obtained for package 1B, shown in column (4) of Table VI, yielded theoretically incorrect coefficients for the normalized prices of the variable inputs of production. As suggested above, this reflects the impact of misspecification in the stochastic model estimated for 1B due to the presence of a large proportion of subsistence units.

V. PRICE RESPONSIVENESS OF OUTPUT SUPPLY AND INPUT DEMANDS

The unrestricted estimates in column (3) of Table V, and the restricted estimates in column (4) of Tables VI–X are used in this section to derive the output supply and factor demand price response parameters corresponding to groups 1A, 1B, 2, 3, 4, and 5. For this purpose, well-known duality transformation relations are utilized [21] [39]. Tables XII–XVI report all the relevant information supplied by these functions in each of the groups studied.

A. *Supply Responsiveness*

On the basis of Table XII figures, the range of supply responsiveness exhibited by corn producers in Guatemala is rather wide, contrary to official expectations:

TABLE XIV

COMPUTED ELASTICITIES OF DEMAND FOR MACHINE-HOURS IN FARM GROUPS 2, 4, AND 5

Farm Group	Output Price	Elasticity of Machine-Hours Demand with Respect to:				
		Wage Rate	Fertilizer Price	Machine-Hour Price	Animal-Day Price	Land
2	1.9457	−0.6654		−1.2803		0.5369
4	2.1976	−0.6559	−0.2923	−1.2494		0.6573
5	1.7985	−0.3780	−0.2325	−1.1373	−0.0507	1.0

TABLE XV

COMPUTED ELASTICITIES OF FERTILIZER DEMAND IN FARM GROUPS 1B, 4, AND 5

Farm Group	Output Price	Elasticity of Fertilizer Demand with Respect to:				
		Wage Rate	Fertilizer Price	Machine-Hour Price	Animal-Day Price	Land
1B	0.6422	0.1294	−0.7716			1.0
4	2.1976	−0.6559	−1.2923	−0.2494		0.6573
5	1.7985	−0.3780	−1.2325	−0.1373	−0.0507	1.0

TABLE XVI

COMPUTED ELASTICITIES OF DEMAND FOR ANIMAL-DAYS IN FARM GROUPS 3 AND 5

Farm Group	Output Price	Elasticity of Animal-Days Demand with Respect to:				
		Wage Rate	Fertilizer Price	Machine-Hour Price	Animal-Day Price	Land
3	1.8382	−0.6768			−1.1614	1.0
5	1.7985	−0.3780	−0.2325	−0.1373	−1.0507	1.0

it varies from a minimum of −0.51 in group 1A to a maximum of 1.19 in group 4. No special significance should be attached to the negative price elasticities of output supply corresponding to 1A and 1B as they were derived from stochastic NRP function models afflicted by misspecification bias caused by the presence of a large percentage of subsistence farms in these two packages.

Thus, while no definitive statement can be made concerning the output price elasticity of supply in 1A and 1B, the discussion in the preceding sections strongly suggests that such elasticity is negligible, if not zero, for nonparticipants, but positive, although unspecified, for market participants.

Unlike 1A and 1B, the output price elasticities of supply derived for groups 2, 3, 4, and 5 are all positive and range from 0.79 to 1.19. This is in accord with a priori theoretical expectations and attests to the supply responsiveness of market-participating, corn-producing farmers in Guatemala.

Examination of the cross-price elasticities shown in Table XII reveals that the supply of corn at the farm level is negatively related to input prices in profit-maximizing packages 2, 3, 4, and 5, unlike in groups 1A and 1B, the nonmaximizing groups, where output supply is positively related to input prices. These positively-signed cross-elasticities in 1A and 1B should be taken with strong reservations for they are a reflection of, and result directly from, the theoretically unsound NRP function parameters estimated for these two farm groups, as discussed above.

B. *The Price Responsiveness of Input Demand*

In accordance with a priori theoretical expectations, the wage elasticity of labor demand is negative in all the groups under examination. The magnitude of such elasticity, as shown in Table XIII, differs significantly between the profit-maximizing groups and the non-profit-maximizing groups. In the former, it takes an average value of −1.59, whereas in the latter it reports an average value of only −0.66.[12]

A similar situation prevails for the elasticity of labor demand with respect to the price of output. The value of this parameter is very high in groups 2, 3, 4, and 5, where it ranges from 1.79 to 2.19, and low in groups 1A and 1B, where it varies from 0.49 to 0.64. The marked differences in response elasticities observed between the profit-maximizing groups and the nonmaximizers reflect, no doubt, underlying differences in the proportion of output market participants present among them.

A significant result reported in the above table is the negative cross-elasticity of labor demand with respect to the price of machinery and of animal capital services. This implies that labor and capital are complements in the market-oriented production of rainfed corn in Guatemala. This finding is in agreement with the partial elasticity of the substitution estimates obtained by Marsh, Jameson, and Phillips [23], showing that labor and capital are complements in the production of corn in Guatemala.

With the exception of group 1B[13] the information presented in Tables XIII and XV also suggests that labor and fertilizer are complements in the production of corn. Fertilizer use, by raising yields, also increases labor requirements at harvest time. The positive cross-elasticity of labor demand with respect to fertilizer price reported in group 1B, suggesting that labor and fertilizer are substitutes, is rather odd. Actually, this cross-elasticity reflects the positive and theoretically incorrect coefficient estimated for $\ln q_l$ in the misspecified NRP function model estimated for 1B.

Keeping in mind the qualifications made with regard to the NRP function results obtained for group 1B and the price elasticity parameters derived therefrom, the information presented in Tables XIII, XIV, and XV further confirms the com-

[12] For the reasons set forth in Section V.B, the price elasticities of input demand derived from the misspecified NRP functions of groups 1A and 1B, shown in Tables XIII and XV, must be accepted with reservations.

[13] The usual reservations are made regarding the positive cross-elasticity of group 1B labor demand with respect to fertilizer price (see Table XIII), and the positive cross-elasticity of group 1B fertilizer demand with respect to the wage rate (see Table XV).

plementarity among variable inputs in the production of corn in Guatemala. Particularly noteworthy are the high own-price elasticities of fertilizer and of machinery services demand: their absolute values are both greater than 1.0. This implies that fertilizer and machinery application levels among corn producers (in the applicable groups) are very sensitive to prices thus underscoring the potential of an input prices policy to influence output and yields.

CONCLUSIONS

Of the six groups of Guatemalan corn-producing farms examined in this study, the hypothesis of profit maximization was rejected at all levels of significance in 1A and 1B. These two groups reported, on the average, the highest concentrations of farms that did not participate in the output market at all. In groups 2, 3, 4, and 5 the hypothesis of profit maximization was not rejected at low levels of significance. In the context of the profit function approach used in this study rejection of the hypothesis of perfect allocative efficiency in 1A and 1B appears to be due to various sorts of model misspecifications including, but not restricted to, interdepence of consumption and production decisions caused by nonparticipation in output and/or input markets. Thus the results obtained in groups 1A and 1B, though inconclusive, point to the need for better specified models, and for more focused research on the influence that market participation has on farmers' ability to maximize profit. Another important finding is that the production of corn in Guatemala exhibits a significant range of price responsiveness, the latter being negligible for subsistence farms, and positive for market participating units.

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APPENDIX

Nakajima's subjective equilibrium theory of the farm household [27] can be used to prove that the latter's production and consumption decisions become interdependent whenever the household does not participate in either the product or the labor market or both. Consider first the case of a farm household that, due to the absence of a product and a labor market, is self-sufficient in both consumption and labor use. The farm household's single-output production function is given by

$$Q = F(L, T), \tag{A.1}$$

where Q = amount of output, L = amount of family labor used on the farm, T = fixed amount of land, $F_L > 0$, and $F_{LL} < 0$. The farm household's utility function is given by

$$U = U(L, Q), \tag{A.2}$$

where U exhibits the usual properties. Maximization of (A.2) subject to (A.1) requires that

$$-U_L/U_Q = F_L. \tag{A.3}$$

Condition (A.3) requires that the marginal subjective valuation of family labor in terms of Q be equated with the marginal physical product of family labor. Note that by virtue of (A.3) the farm household's consumption *and* production decisions are inextricably linked and cannot be undertaken independently of one another. Satisfaction of (A.3) determines *simultaneously* the amount of family labor used, and the amount of output consumed which in turn coincides with the amount of output produced via (A.1).

Consider now the case of a farm household that, because of the existence of a labor market, both hires non-family labor *and* sells family labor to the outside. However, due to the lack of an output market it must produce all the output that it consumes. The farm's production function is

$$Q = F(L', T), \tag{A.4}$$

where $Q =$ amount of farm output, $L' =$ amount of labor used on the farm, $T =$ fixed amount of land, and F is a well-behaved production function. The farm household's money income, derived from the sale of family labor to the outside, is given by

$$M = w(L - L'), \tag{A.5}$$

where $M =$ money income, $w =$ market wage rate, $L =$ total amount of family labor supplied to both on-farm and off-farm activities, $(L - L') =$ net amount of family labor supplied to off-farm activities. The farm household's utility function is given by

$$U = U(L, Q, M), \tag{A.6}$$

where $U_L < 0$, $U_Q > 0$, and $U_M > 0$. Maximization of (A.6) subject to (A.4) and (A.5) yields the following conditions:

$$-(U_L/U_M) = w, \tag{A.7}$$

$$U_M \cdot w = U_Q \cdot (\delta Q/\delta L'). \tag{A.8}$$

Condition (A.7), governing the utilization of L, tells us that the marginal valuation of family labor must be equated to the market wage rate; (A.8) tells us that the optimum amount of labor applied to the farm is determined by equating the increment in utility associated with unit-wage income with the increment in utility associated with the application of one more labor unit to the farm. Using (A.7), (A.8) may be rewritten as follows,

$$-U_L = U_Q \cdot (\delta Q/\delta L'). \tag{A.9}$$

(A.9) yields a more intuitively clear interpretation of the equilibrium condition governing the utilization of labor on the farm: labor should be applied to the farm up to the point where the marginal utility brought about by the application of an additional unit of labor to the farm is equal to the marginal disutility of household labor. Note that (A.7) and (A.8) or (A.9) form a simultaneous system of equations that jointly determine the amount of labor applied to the farm, the amount of household labor utilized, the amount of output produced and consumed, the net amount of family labor supplied to off-farm activities, and the amount of money (wage) income earned. Clearly nonparticipation in the output market on the part of the farm household, even though it participates in the labor market, results in interdependent production and consumption decisions.

Consider, finally, the case of a pure commercial farm that participates in both the output *and* the labor market. Here the farm household maximizes household utility given by

$$U = U(L, M), \tag{A.10}$$

subject to the following money income constraint,

$$M = P \cdot F(L', T) + w(L - L'), \tag{A.11}$$

where $P =$ unit price of farm output, and all other variables and functions are as described above. Maximization of (A.10) subject to (A.11) yields the following conditions,

$$P \cdot (\delta Q/\delta L') = w, \tag{A.12}$$

$$-(U_L/U_M) = w, \tag{A.13}$$

and (A.11). Note that (A.11), (A.12), and (A.13) are not simultaneous equations. First, the profit-maximizing amount of labor used on the farm, L', is determined by (A.12) alone. Determination of L' also implies the determination of the profit maximizing supply of output via the farm's production function. Next, by simultaneous equations (A.11) and (A.13), both L' and M are determined. In other words, when the farm household participates fully in both the output and the labor market, the subjective equilibrium model of the farm household is determined in a block-recursive fashion: first, and independently from the consumption, the farm's production decision variables are determined. Subsequently, once the production block has been determined, the farm household proceeds to maximize utility subject to the income constraint. Clearly, in this instance it is possible to define a profit function for the farm.