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ESTIMATING LABOR DEMAND FUNCTIONS FOR INDIAN AGRICULTURE

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INTRODUCTION

The level of employment and wage rates in the agricultural sector of developing countries in Asia is of clear policy importance. It is unlikely that substantial reduction in poverty or improvements in relative income distribution can be achieved in the absence of rapidly rising real wages for rural unskilled labor since not only the landless but also small farmers depend to a considerable extent on agricultural wages as a source of income. This is particularly true in a setting where labor supply is growing rapidly and where nonagricultural employment opportunities are not expanding rapidly.

A primary objective of studying how labor markets function is to acquire a capacity to quantitatively analyze the impact of shifts in labor demand or labor supply on the level of employment and wage rates in rural areas either ex-post or in projection analysis. Shifts in demand for agricultural labor can come from changes in output market conditions or from technical change. A rich literature exists, for example, on the direct labor demand impact of the green revolution, and of investments in irrigation or in agricultural mechanization. (For recent summaries of such studies, in the Indian context see International Labor Office, 1978, Bartsch 1977, and Binswanger 1978.) Shifts in agricultural labor supply arising from population growth or intersectoral or interregional migration have also been extensively analyzed. (Indian Government, Planning Commission, 1978).

Much of the analysis of the employment and wage effects of such shifts is based on an implication or explicit assumption of constant wages, or at least fixed technological coefficients of the alternatives considered. This is partly a legacy of early economic development literature which stressed institutionally determined wages and shared poverty mechanisms in the rural sector. But the papers presented in the earlier sections of this volume show that wages cannot be considered fixed even if they appear to be determined by institutional arrangements; the choice of institutional arrangements itself and their evolution are responsive to supply and demand changes. Thus a quantitative analysis of the impact of shifts in demand and supply on employment,wages and earnings requires knowledge of labor supply and labor demand elasticities.

Unfortunately, very few attempts have yet been made to estimate labor supply and demand relations empirically in the Asian context - again a reflection of the emphasis on institutional determinism in the area. The papers by Bardhan and Rosenzweig focus primarily on the labor supply side and our effort complements it by focussing on labor demand.

Our effort starts from the recognition - by now well supported by empirical studies - that farmers' output supply is responsive to prices and to opportunities for technological innovation. This evidence strongly supports the hypothesis that Indian farmers are cost and profit conscious. This does of course not mean that all farmers are equally efficient or that they do not make technical and economic errors. Change is always costly and takes time and experimentation. The cost consciousness of farmers can be expected to make their labor demand decision responsive to wage rates and to output prices.

In our judgement, therefore, the most appropriate methodological approach to the estimation of a labor demand function is to treat the demand for labor as part of a system of output supply and factor demand equations which takes full account of the interdependent nature of output and input decisions by farmers. The model that we employ in developing our empirical specification is based on the maximization of variable profits by farmers. We do not impose profit maximizing constraints or restrictions on our specification, however, without first statistically testing whether these restrictions are consistent with our data. Where they are not,we also present estimates of labor demand functions which do not depend on the profit maximization assumption.

We utilize data from several sets of Indian Farm Management Studies. We have individual farm data for three farm management studies, Ferozpur District in the Punjab, Muzaffarnagar District in Uttar Pradesh and Thanjavur District in Tamil Nadu. These micro data sets are suited to the estimation of short run elasticities. We also utilize data reported on an aggregated basis in a large number of Farm Management Study Reports. These studies are organized by region and are utilized to obtain estimates reflecting medium-run to long-run behavior.

SYSTEMS OF OUTPUT SUPPLY AND FACTOR DEMAND

Systems of output supply and factor demand equations can be derived from a profit function and below we will present the derivation. In later sections we will test whether this derivation is consistent with the statistical evidence. Here we note that systems of output supply and factor demand equations could exist independently of the behavioral mechanisms of profit maximization, as long as the behavior of individual agents is sufficently stable over time and can be aggregated over farmers. Therefore, the estimation equations are useful for economic analysis regardless of whether the theory restrictions of profit maximization hold. However, if profit maximization does not hold, we cannot make inferences from the supply and demand equations about the production function underlying them, since behavioral and technological relationships are then confounded in those equations.

We now adopt the following convention. There are n commodities, Y_i, of which the first m are outputs and those indexed m + 1...n are variable inputs under the control of the individual agent, i.e., we have a vector of commodities Y such that

$$Y_i \geq 0 \text{ for } i = 1...m \text{ and } Y_i \leq 0 \text{ for } i = m + 1 ...n. \quad (1)$$

These commodities have prices $P_i \geq 0$ for all i. Π is variable profits or return to fixed factors of production and $\Pi = Y'P$. Since inputs are defined as negative quantities,they subtract from revenues of the positive outputs. There are also k fixed factors of production, Z_k, k = 1...K such as fixed capital or land quality. Let t stand for time or a technology index. If a sufficiently "well-behaved" transformation function[1/] exists, g(Y,Z,t) = 0 and agents maximize variable profits Π, then a profit function exists which relates maximized profits Π^* to the prices of the variable commodities, the fixed factors and time

$$\Pi^* = \Pi^* (P,Z,t) \quad (2)$$

[1/] For the conditions which must be imposed on the transformation function see Diewert, 1978.

which has the following properties (where Π_i^* and Π_{ij}^* are derivatives and crossderivatives of the profit function with respect to the prices of the commodities i and j).

(i) The profit function is monotonically increasing in P_i if i is an output and monotonically decreasing in P_i if i is an input. The output supply and factor demand curves are

$$Y_i = \Pi_i^* (P,Z,t) \begin{array}{l} \geq 0 \quad i = 1,\ldots m \\ \leq 0 \quad i = m+1,\ldots n \end{array} \tag{3}$$

(ii) The profit function is symmetric, i.e.,

$$\Pi_{ij} = \Pi_{ji} \tag{4}$$

(iii) The profit function is convex, i.e., the (singular) matrix of its cross derivatives Π_{ij} is <u>positive semi-definite</u> or all its characteristic roots are positive or zero.

(iv) The profit function is homogeneous of degree one and the supply and demand equations are homogeneous of degree zero. The matrix

$\left[\eta_{ij}\right] = \left[\frac{\partial Y_i}{\partial P_j} \frac{P_j}{Y_i}\right]$ defines the factor demand and output supply elasticities

and the following constraint on these elasticities holds:

$$\sum_{j=1}^{n} \eta_{ij} = 0 \qquad i = 1, \ldots\ldots, n. \tag{5}$$

We will consider two alternative functional forms for equation (2) in our empirical work. The first, the Generalized Leontief, is written as

$$\Pi^* = \sum_{ij}\sum b_{ij} P_i^{1/2} P_j^{1/2} + \sum_{ik}\sum b_{ik} P_i Z_k + \sum_i b_{it} P_i t \tag{6}$$

The corresponding factor demand and output supply system is given in panel (a) of Table 1. All n equations can be estimated jointly but the profit

Table 1. Output Supply and Factor Demand Formulae and Restrictions.

	(a) Generalized Leontief	(b) Normalized Quadratic
Form of Factor Demand and Output Supply Equations	$Y_i = b_{ii} + \sum_{j \neq i} b_{ij} \left(\frac{P_j}{P_i}\right)^{1/2} + \sum_k b_{ik} Z_k + b_{it}\, t$ for $i = 1, ..n.$	$Y_i = a_i + \sum_{j=1}^{n-1} b_{ij} \frac{P_j}{P_n} + \sum_k b_{ik} Z_k + b_{it}\, t$ for $i = 1, ... n-1$; $Y_n = a_o - \frac{1}{2} \sum_{i-1}^{n-1} \sum_{j-1}^{n-1} b_{ij} q_i q_j$
Homogeneity Constraint	Imposed not testable	Imposed not testable
Symmetry Constraint	$b_{ij} = b_{ji} \quad i \neq j$	$b_{ij} = b_{ji} \quad i,j \neq n$ and including the b_{ij} of equation n.
<u>Elasticities</u>		
Cross price	$\eta_{ij} = \frac{b_{ij}}{2Y_i} \left(\frac{P_j}{P_i}\right)^{1/2}$	$\eta_{ij} = b_{ij} \frac{P_j}{Y_i} \quad i \neq n$; $\eta_{nj} = \frac{P_j}{P_n^2 Y_n} \sum_{i=1}^{n-1} b_{ij} P_i \quad j = 1, ..., n-1$
Own price	$\eta_{ii} = \sum_{j \neq i} \frac{b_{ij}}{2Y_i} \left(\frac{P_j}{P_i}\right)^{1/2}$	$\eta_{ii} = b_{ii} \frac{P_i}{Y_i} \quad i \neq j, n$; $\eta_{nn} = - \sum_{j=1}^{n-1} \eta_{nj}$

function (6) is not linearly independent since it is the linear combination $\sum_{i-1}^{n} Y_i P_i$ of the individual equations. Note that in this system, homogeneity is not testable since for each equation η_{ii} is estimated residually and we have no other independent estimates of it. This characteristic is also a serious liability when data sets are not complete.

The second functional form is derived from the Normalized Quadratic profit function. (For a discussion of normalized profit functions see Lau, 1977). A normalized profit function is derived by stating the initial profit maximizing problem in terms of normalized prices $q_i = \frac{P_i}{P_n}$ where all prices and profits are divided by the price of the n'th commodity. Normalized profits then are written as

$$\tilde{\Pi} = \frac{\Pi}{P_n} = \sum_{i=1}^{n-1} Y_i q_i + Y_n \qquad (7)$$

Shephard's Lemma then reads that $\frac{\partial\tilde{\Pi}}{\partial q_i} = Y_i$. The quadratic normalized profit function is written as

$$\tilde{\Pi} = a_o + \sum_{i=1}^{n-1} a_i q_i + \frac{1}{2} \sum_{i=1}^{n-1} \sum_{j=1}^{n-1} b_{ij} q_i q_j + \sum_{i=1}^{n-1} \sum_{k} b_{ik} q_i Z_k + \sum_{i=1}^{n-1} b_{ik} q_i \qquad (8)$$

The output supply and factor demand curves for the first n-1 outputs and factors are given in panel b of Table 1, written in terms of the original prices. Homogeneity of degree zero is imposed on the equations and cannot be tested. Symmetry is tested in the usual way. Note that in this system we do not have the n'th commodity equation which has to be derived from equation (8) and the commodity equations

$$Y_i = a_i + \sum_{j=1}^{n-1} b_{ij} q_j + \sum_k b_{ik} Z_k + b_i t. \qquad (9)$$

From equation (7) we can compute $Y_n^* = \tilde{\Pi}^* - \sum_{i=1}^{n-1} Y_i^* q_i$. By substituting into this expression the equations (8) for $\bar{\Pi}^*$ and the commodity equations (9) for Y_i^* we can derive

$$\bar{Y}_n = a_o - 1/2 \sum_{i=1}^{n-1} \sum_{j=1}^{n-1} b_{ij} q_i q_j \qquad (10)$$

The derivatives of this equation with respect to individual prices are

$$\frac{\partial Y_n}{\partial P_j} = -\sum_{i=1}^{n-1} b_{ij} \frac{P_i}{P_n^2} \qquad j < n \qquad (11)$$

from which we can compute the elasticities for the n'th equation as

$$\eta_{nj} = \frac{\partial Y_n}{\partial P_j} \cdot \frac{P_j}{Y_n} = -\frac{P_j}{P_n^2 Y_n} \sum_{i=1}^{n-1} b_{ij} P_i \qquad (12)$$

Finally, η_{nn} can be determined residually via equation (5) as $\eta_{nn} = -\sum_{j=1}^{n-1} \eta_{nj}$. Note that one could include equation (6) in the estimation process or leave it out and estimate the elasticities of the n'th equation residually.

The estimation technique for these equations is as follows. In a first step each equation is estimated by Ordinary Least Squares region dummy variables to clear out region effects. In a second step, all equations are estimated jointly by Generalized Least Squares, taking account of error interdependence across equations (Zellner, 1963). Restrictions across equations are then tested via F tests, and the system is reestimated with the full set of constraints. Finally elasticities are then computed using the formulae of Table 1 and predicted values of those dependent variables which appear in the equations. The standard errors of the elasticities reported are approximations since they only take account of the variance of the coefficients in the formulae and not of the predicted values.

THE DATA AND DEFINITIONS OF VARIABLES

The Indian Farm Management Studies have provided a valuable data base for a number of studies of Indian agriculture. They were conducted in selected districts throughout India from 1954-55 to 1971-72 when they were discontinued. Summary reports have now been published for 26 or more studies conducted in 22 different districts in 14 states. These studies utilized relatively standardized statistical designs and data collection methods and concepts. The typical statistical design of the studies was to first randomly select 10 or 15 sample villages in the district. Then a random sample of 10 to 15 farms stratified by acreage farmed was selected in each village. Data on production, inputs, prices and costs were carefully collected from the 150 sample farms for 3 consecutive years.

In several districts studies were conducted in the 1950's and again in the 1960's. The study reports provide data for the average farm in an aggregated group. A typical report would provide all of the relevant data for farms in 5 to 7 size groups and 2 or 3 regions. Table 2 summarizes the districts studied. We have allocated these districts to 3 major agricultural regions in India.

In addition to these grouped data, we were able to obtain data on individual farms for three of the Farm Management Studies: Ferozepur District, Punjab (1966-67, 1967-68, 1969-70); Muzaffarnagar District, Uttar Pradesh (1965-66, 1966-67, 1967-68); and Thanjavur District, Tamil Nadu (1967-68, 1968-69). (Permission to use these data was granted by the Directorate of Economics and Statistics several years ago. Access to most of the valuable individual data sets has not been granted to researchers on a wide basis, however.)

We are thus able to report estimates for three micro or farm level data sets and three grouped data sets. Table 2 provides a data summary and dictionary of variables for each data set. The dependent variables reflect the structure of the systems of equations estimated. Equations for output, bullock labor,

Table 2: Dictionary of Variables and their Means

	Micro-Data Sets			Grouped Data Sets		
	Ferozepur	Mazaffarnagar	Thanjavur	Northern Wheat	Eastern Rice	Coastal Rice
1. Dependent Variables						
Output: Value in constant prices of main product plus by-product per farm	139.66	227.36	52.12	1.124	.950	1.02
Bullock Labor: Days used, hired and owned per farm	270.96	171.34	210.64	469.89	147.78	164.60
Human Labor: Days worked, family, permanent, casual workers per farm	614.16	634.08	539.91	610.65	343.03	1392.65
Fertilizer and Manure: Value of N,P,K, and manure deflated by fertilizer price index, per farm	15.31	2.77	4.88	na	na	na
Land: Operated Area (ha)	14.12	6.56	3.08	8.39	3.31	4.88
2. Independent Variables						
High Yielding Varieties: Proportion of land planted to high yielding varieties of wheat, rice and sorghum	na	na	na	3.06	.15	9.47
Irrigation Intensity: Gross Irrigated Area/Land	1.09	1.35	1.52	.74	.125	.569
Fragmentation: # of Fragments/ Land	.37	.58	4.34	1.59	4.46	3.55
Major Implements: Value	2310	416	861	3465	650	3270
Minor Implements: Value	229					
Price of Output	70.69	100.38	103.08	1.12	.95	1.12
Price - Bullock Labor	1.72	12.52	2.67	6.24	2.13	5.79
Price - Human Labor	3.66	2.67	3.01	2.076	2.068	1.73
Price - Fertilizer	60.73	131.93	115.24	na	na	"
Price - Land (annual rental value)				237.6	270.39	433.1

Farm Management Studies Included in Each Group:

Northern Wheat: UP: Meerut (54,55,56), Mazaffarnagar (66,67,68), Punjab: Amritsar and Ferozepur (55,56,57), Ferozepur (67,68,69), Karmal, Rothak, Jind (61,62,63)

Eastern Rice: Assam: Nowgong (68,69), Bihar, Shahadabad (60,61,62), Orissa: Sambalpur (57,58, 59) West Bengal:(Hooghly) (54,55,56)

Coastal Rice: A.P.:West Godavari (57,58,59), Kerala: Aleppy & Quilon (62,63,64), Orissa: Cuttack (67,68,69), Tamil Nadu, Thanjavur (67,68,69) human labor and fertilizer were estimated for the micro data sets. The independent variables in each equation were prices for each variable output and factor and quantities of "fixed" factors. Note that we are treating land as a fixed factor in the micro short-run data sets but we consider it to be a variable factor in the grouped data set regressions. This is partly for reasons of data quality. Rental prices for land for individual farms were generally incomplete, while for the grouped data the average rental value of land was always available. Our practice is also consistent with the short-run and medium-run interpretation that we wish to use for these data. Land can be reasonably treated as fixed in the short-run.

It may also be noted that while we had reasonably reliable fertilizer price data for the micro-data sets which were conducted in the late 1960's, we were not able to construct a consistent fertilizer price for the grouped data sets, which were conducted over longer periods of time.

We have treated irrigation intensity and fragmentation as fixed factors in both data sets. We have also treated buildings and implements as a fixed capital stock. This treatment may not be fully consistent with reality, but in view of the nature of the market for credit and for major implements where some quantity rationing takes place, we believe this treatment to be justified. We did differentiate between major implements (tractors and pumpsets) and other implements in the Ferozepur micro data set.

We do not have consistent data on farm operator characteristics such as experience and schooling and were unable to include these as fixed factors.

ESTIMATES

We first estimated the equation systems for each data set in unrestricted and restricted form and performed a test for the compatibility of the restrictions imposed by variable profit maximizing behavior with the data. This is a test comparing the weighted mean square error for the system with and without restrictions. These test results are reported in Table 3. Values of computed F's for which one would reject the hypothesis that mean square errors are not significantly higher in the presence of restrictions are roughly 2.1 or greater at the .05 probability level and 2.9 at the .01 level.

Table 3: Summary of Symmetry Restriction Tests

Data Sets	Generalized Leontief		Normalized Quadratic		
	Bullock and Labor Demand Symmetry Only	Full System Symmetry	Bullock and Labor Demand Symmetry Only	Full System Excluding nth Equation Restrictions	Full System Including nth Equation Restrictions
I. Grouped Data Sets Treating Land as a Variable Factor					
Northern Wheat	2.8	11.7	.1	2.5	1.0
Eastern Rainfed Rice	10.7	10.1	3.7	1.6	5.2
Coastal Irrigated Rice	26.1	7.4	16.0	6.8	5.7
II. Grouped Data Sets Treating Land as a Fixed Factor					
Northern Wheat	1.5	6.8	.5	.5	7.4
Eastern Rainfed Rice	2.6	10.6	.3	.4	7.2
Coastal Irrigated Rice	20.1	10.6	14.7	14.4	6.8
III. Micro Data Sets Treating Land as a Fixed Factor					
Ferozepur - Punjab	3.2	3.1	.3	5.2	3.4
Muzaffarnagar - U.P.	1.4	3.7	6.9	9.8	8.6
Thanjavur - T.N.	2.5	12.7	.7	2.1	5.7

As Table 3 indicates, symmetry restrictions imposed under the Generalized Leontief functional forms were rejected by the data in almost all cases. Even the relatively weak Bullock-Labor demand symmetry restrictions were rejected in most cases. These test results combined with the fact that the own price elasticities are computed residually and may therefore be subject to severe error from left-out variable factors. This led us to concentrate on the results of the Normalized Quadratic function.

The Normalized Quadratic form is considerably more compatible with the symmetry restrictions. In Table 3 we report test results for one partial system including only the labor and bullock demand equation and for two sets of full system results. The first of these is for a system where the n'th equation (equation 10) is estimated residually. In the second full system the n'th equation is estimated as part of the system and all symmetry restrictions including those for the n'th equation are imposed. We first note that for the micro data sets (Table III) the restrictions on the full system are not compatible with the data, except for the case of Tanjavur when the restrictions for the n'th equation are left out. However, the single bullock to labor restriction is acceptable in the case of Ferozepur and Tanjavur.

For the grouped data sets the full set of restrictions is also not acceptable. The weaker set of restrictions, excluding those on the n'th equation, are, however, acceptable, except in the case of coastal rice. Note that in the coastal rice region not even the single bullock to labor symmetry constraint is acceptable.

On the basis of these results we conclude that we should proceed to report two sets of estimates for each data set. In Table 4 for the grouped data sets we report the restricted estimates for the Normalized Quadratic form where the n'th equation is estimated residually for all but the Coastal Irrigated Rice set. For the micro data sets (Table 5) we report the restricted estimates where only symmetry across the bullock and labor demand equations is imposed. For all data sets, we also report unrestricted results for the full system for comparative purposes. These estimates are reported in elasticity form in the text. Appendix Tables 1, 2, 3 and 4 report actual parameter estimates.

Table 4: Labor Demand Elasticities Grouped Data Sets Normalized Quadratic Form [1/]

Estimated Labor Demand Elasticity with Respect to:	Northern Wheat				Eastern Rice				Coastal Rice	
	Restricted System		Unrestricted System		Restricted System		Unrestricted System		Unrestricted System	
	LF [2/]	LV [2/]	LF	LV	LF	LV	LF	LV	LF	LV
Wage Rates	-.242 (3.12) [3]	-.236 (3.08)	-.239 (3.08)	-.105 (.94)	-.339 (10.27)	-.289 (6.13)	-.310 (3.64)	-.500 (4.72)	-.173 (1.22)	-.278 (1.84)
Bullock Prices	.003 (.13)	.009 (.34)	.0217 (.45)	.066 (.99)	.387 (9.64)	.331 (7.28)	.149 (5.77)	.288 (4.27)	-.226 (2.15)	-.370 (3.10)
Land Prices		.050 (1.40)		-.138 (1.63)		-.043 (1.33)		-.036 (.36)		.897 (2.32)
Output Prices	.403 (3.12)	.214 (1.65)	.217 (3.50)	.176 (1.76)	.168 (3.39)	.264 (4.78)	.161 (4.54)	.248 (3.68)	.399 (2.34)	-.249 (.66)
Operated Area	.415 (11.18)	-	.414 (11.31)	-	.896 (15.65)	-	.899 (15.31)	-	.386 (4.43)	-
Irrigation Intensity	.066 (.91)	-.133 (1.36)	.068 (.93)	-.199 (1.09)	.072 (3.38)	.088 (2.31)	.073 (3.31)	.071 (1.83)	-.604 (2.41)	-.562 (2.07)
Fragmentation	-.344 (6.60)	-.664 (10.65)	-.343 (6.54)	-.701 (11.06)	-.021 (1.27)	-.763 (7.38)	-.019 (.24)	-.741 (6.43)	-.318 (1.73)	-.512 (2.54)
Capital Stock	.065 (2.30)	.235 (7.26)	.060 (2.11)	.217 (6.30)	.034 (.99)	.276 (4.52)	.036 (.99)	.270 (4.68)	.070 (.70)	.257 (3.22)
High Yielding Varieties	.005 (.465)	.012 (.80)	-	-	-.010 (1.53)	-.005 (.14)	-	-		

1/ See Appendix Tables 1, 2 and 3 for Coefficient Estimates.

2/ LF: Land treated as a fixed factor. LV: Land treated as a Variable factor

3/ t ratios in parentheses.

Table 5: Labor Demand Elasticity Estimates: Micro Data Sets 1/

Labor Demand Elasticities (computed at sample means) with respect to:	Ferozepur		Muzzafarnagur		Thanjavur	
	Restricted 2-equation	Unrestricted System	Restricted 2-equation	Unrestricted System	Restricted 2-equation	Unrestricted System
Wage rates	-.166 (2.55) 2/	-.148 (2.35)	.060 (1.51)	-.009 (.21)	.003 (.02)	-.046 (.31)
Bullock prices	-.006 (.53)	-.030 (.85)	.137 (4.32)	-.228 (5.40)	.009 (1.82)	.009 1.88
Fertilizer prices	.711 (4.67)	.682 (4.185)	-.668 (4.13)	-.665 (4.15)	1.95 (2.79)	1.94 2.77
Output prices	-.538 (3.54)	-.504 (3.38)	.867 (5.27)	.902 (5.51)	-1.97 (2.79)	-1.91 2.69
Land	.195 (4.60)	.196 (4.61)	.683 (24.8)	.663 (24.6)	.481 (6.31)	.373 (5.01)
Irrigation intensity	.266 (1.82)	.263 (1.87)	.500 (7.12)	.479 (7.03)	-.475 (.94)	-.884 (1.76)
Fragmentation	-.110 (2.95)	-.105 (2.73)	.021 (1.56)	-.008 (.51)	-.234 (2.23)	-.356 (3.48)
Major implements stock	.080 (7.0)	.080 (7.0)	.015 (.74)	.025 (1.22)	.023 (2.61)	.029 (3.35)
Minor Implements stock	.142 (3.13)	.143 (3.16)				

1/ For actual coefficients see Appendix Tables.

2/ "t" ratios in parentheses.

DISCUSSION OF THE RESULTS

Tables 4 and 5 report estimates which differ in two major respects. The first is between grouped and micro data. The second is in terms of the treatment of the land variable. A comparison of Tables 4 and 5 will quickly show that the grouped data sets provide estimates of the price elasticities which are more consistent with a priori expections. We expect on a priori grounds that the own price or wage elasticity of the demand for labor will be negative and that the output price elasticity will be positive. These results are obtained in all three grouped data sets and are not highly sensitive to the treatment of land or generally to the restrictions. The wage elasticity is generally negative in the micro-data sets but it is also lower in magnitude. The output price effects have the wrong signs in two of the micro-data sets.

We believe that the inconsistent results from the micro-data sets are due to the limited price variation in these sets. With data from only two or three years, output prices will tend to vary little and much of the variation observed may be due to measurement errors. Thus, we believe it appropriate to concentrate our discussion on the grouped data results.

It is of interest to note in the grouped data that the treatment of land as a fixed or variable factor does not generally affect the estimates of the wage and bullock price elasticities (particularly not in the restriced estimates). Treating land as a variable factor does appear to have an influence on the output effect. Its major effect, however, is on the fixed factors. When land is a variable factor, the capital stock elasticities are increased by a factor of 3 or so in all data sets. Fragmentation has a more severe negative effect when land is variable and in the northern wheat and coastal rice region the irrigation elasticity is reduced.

In general, the restricted and unrestricted estimates do not differ greatly.

We now go to a discussion of each elasticity:

a) Wage Elasticities:

The wage elasticity is the most important estimate of this study from the point of view of understanding labor markets. Our estimates of the wage elasticity are generally highly significant and insensitive to changes in the treatment of the land variable. We believe that we can claim these to be well estimated. It is quite clear that the demand for labor is quite wage inelastic. A 10 percent increase in the wage farmers have to pay will lead them to reduce employment by 2-1/2 - 3-1/2 percent according to most of our estimates. The micro-data results show more inelasticity.

b) Output Price Elasticities:

The effect of output price changes on the demand for labor is also of obvious importance. In the grouped data sets we have identified this elasticity to be positive and approximately in the .2 to .4 range. The micro-data do not yield a consistent estimate of this elasticity for reasons discussed above.

c) Bullock Price Cross-Elasticities

It is not a priori clear whether bullock labor is a net substitute for human labor or a complement to human labor. Our data show little relationship in the northern wheat (and Ferozepur) region. In the northeastern rice region we identify a significant substitute relationship. When bullock prices rise, farmers hire more labor. The opposite appears to be the case in the coastal rice regions.

d) Fertilizer Price Elasticities

Since we have fertilizer prices only for the micro-data sets. we are limited by data quality in assessing our results. They do show fertilizer to be a good substitute for labor in the two data sets where fertilizer use is significant.

e) Land and Irrigated Land Elasticities

When land is treated as a fixed factor, its elasticity ranges from .4 to .8. As a variable factor, it has a low price elasticity except in the coastal rice zone where a rise in the land price induces substitution of labor for land. However, when land is treated as a variable factor, irrigation intensity elasticities are lower. This indicates that when rental prices are held constant instead of land area operated, higher irrigation intensities are associated with lower, even negative, effects on the demand for labor. The inclusion of both a rental price and an irrigation intensity in the equation is inconsistent if the rental price is not strictly for unirrigated land. Holding the rental price constant while changing irrigation will then pick up effects of irrigation quality. In the coastal irrigated rice region, irrigation intensities appear to have a negative impact on labor demand.

f) Fragmentation Elasticities

Our results show a very consistent negative impact of land fragmentation on the demand for labor. They show similar impacts on output supply and suggest that land consolidation may have a relatively high pay-off.

g) Capital Stock Elasticities

Here again we obtain consistent positive imputs of the capital stock on the demand for labor. They are sensitive to the treatment of land. When land is treated as a variable factor, the capital stock elasticities are much higher.

CONCLUSIONS

The systems approach used in the estimation specification in the paper is quite demanding of data. Farmer behavior must be observed under substantial price variation for all factors of production used. This generally requires observations over several years. There are alternative procedures for estimating labor demand functions which are less demanding of data. With linear programming for example, a minimum of data is required. One could also estimate a production function from quantity data and proceed to infer, or calculate, a labor demand function by supposing profit maximizing behavior. Our approach has been to (1) estimate the labor demand function directly, and (2) to avoid the imposition of behavioral restrictions which are inconsistent with the data. Accordingly, we have reported estimates from a restricted system where the restrictions are compatible, in a statistical sense with our data and a full unrestricted system.

We believe that our estimates for the three grouped data sets are of sufficient quality to bear some policy discussion. Our major findings were:

a) The elasticity of demand for labor with respect to the wage rate facing farm employers is low - in the 0.25 to 0.4 range.

b) The elasticity of demand for labor with respect to output prices is also in the 0.2 to 0.4 range.

c) Animal power appears to be a good substitute for labor only in the northeastern region.

Other findings were:

d) Fertilizer appears to be a substitute for labor.

e) Land is a substitute for labor in only one of the regions.

f) Fragmentation reduces the demand for labor.

g) Growth in the fixed capital stock is associated with increased employment.

The picture that emerges is thus one of a labor market which is relatively inelastic to wage changes. A rightward shift in the supply function of labor to the agricultural sector will not be absorbed with only a small decrease in wages. Conversely, a leftward shift could result in a significant increase in wage rates. Migration policies, for example, which would be designed to reduce migration out of a rural area are likely to have severe wage effects for those remaining in rural areas. And, of course, policies inducing more migration would have the reverse effects. Policymakers should not presume that the agricultural system is flexible enough to absorb labor easily. Nor can policy be based on an assumption that output prices matter little for the demand for labor. Our estimates show an inelastic, but statistically significant, response to output prices.

We have not in these estimates been able to obtain direct evidence regarding the substitutability of labor and tractor power. Our data suggest that animal power is generally not a very close substitute for labor in at least some regions. Fertilizer is probably a good substitute for land.

The findings of Rosenzweig and Bardhan reported in the preceeding chapters imply low labor supply elasticities of labor resident in a particular village or region. Inelastic supply and demand for agricultural labor together imply a substantial sensitivity of rural wage rates to shifts in labor demand or supply or to policies which induce them. This is in sharp contrast to the earlier theoretical literature on rural labor markets which stressed institutional wages fixities and income sharing mechanisms which would jointly imply a capacity of agriculture to absorb additional labor, without substantial deterioration of rural wages or standards of living.

Appendix Table 1: Normalized Quadratic Estimates: Northern Wheat Zone

Independent Variables	Restricted, Excluding n'th Equation							Unrestricted, Including n'th Equation							
	Land as a Fixed Factor			Land as a Variable Factor				Land as a Fixed Factor			Land as a Variable Factor				
	Labor	Bullock Labor	Output	Labor	Bullock Labor	Land	Output	Labor	Bullock Labor	Output 1/	Labor	Bullock Labor	Land	Output 1/
Fixed Factors														
Land	-30.21 (2.67) 2/	-30.77 (3.02)	363.49 (73.85)					-30.16 (2.66)	-31.74 (3.62)	324.61 (71.49)				
Irrigation Intensity	-54.42 (60.19)	157.02 66.27	-789.19 (1662)	109.70 (80.90)	325.06 (84.48)	9.52 (1.90)	-3526 (1693)	-56.11 (59.80)	196.96 (81.39)	329.28 (1591)	90.15 (82.07)	327.16 (97.66)	9.275 (1.964)	-1645 (1789)
Fragment Intensity	132.25 20.34	-7.63 (22.96)	-2502. (561.)	255.58 (24.01)	119.62 (25.12)	4.69 (.57)	-3526 (500)	132.51 (20.26)	-14.25 (27.53)	-2815 (540)	269.11 (24.11)	143.12 (28.93)	5.036 (.581)	-4084 (514)
Capital Stock	-.0115 (.005)	-.0104 (.0052)	1.386 (.140)	-.0414 (.0057)	-.0411 (.0057)	-.0011 (.0001)	1.805 (.1230)	-.0107 (0050)	-.0116 (.0007)	1.219 (.138)	-.0383 (.006)	-.0387 (.007)	-.0010 (.0001)	1.493 (.142)
High Yielding Varieties	.93 (2.03)	16.96 (2.23)	36.08 (56.01)	2.30 (2.85)	18.16 (2.97)	.045 (.067)	-12.85 (59.29)							
Price Terms 3/														
P_B/P_O	91.16 (27.83)	-3.08 (5.63)	1787.8 (765)	85.76 (27.10)	-6.26 (6.43)	-.185 (.208)	790.62 (736.52)	-2.42 (5.70)	-21.29 (7.89)	-15.50 (17.45)	-7.39 (7.82)	-26.37 (9.46)	-.226 .190	-6.86 (28.75)
P_L/P_O	-3.08 (5.08)	-19.85 (5.25)	319.34 (157.7)	-6.26 (6.43)	-23.95 (5.98)	-.1165 (.125)	375.16 151.70	79.93 (27.19)	21.58 (38.00)	-15.59 (389.5)	34.98 (39.49)	-58.22 (48.28)	-1.081 .972	-372.99 (366.94)
P_{Ha}/P_O				-.186 (.208)	-.117 (.125)	.0011 (0045)	24.25 (5.09)			245.48 (155.6)	.404 (.263)	1.061 (.323)	.015 (.006)	.00263 (.0663)
														207.84
														164.65
														-.466 (844)

1/ The functional form differs for the output equation in the full system. See Table I.

2/ Standard errors in parentheses.

3/ P_B, P_O, P_L, and P_{ha} are the prices of bullocks, output, labor and land respectively.

Appendix Table 2: Normalized Quadratic Estimates: Winter Rice

Independent Variables	Restricted, Excluding nth Equation							Unrestricted, Including nth Equation						
	Land as a Fixed Factor			Land as a Variable Factor				Land as a Fixed Factor			Land as a Variable Factor			
	Labor	Bullock Labor	Output	Labor	Bullock Labor	Land	Output 1/	Land	Bullock Labor	Output	Labor	Bullock Labor	Land	Output 1/
Fixed Factors														
Land	-92.92 (5.93) 2/	-42.22 (2.94)	352.42 (29.87)					-93.20 (6.08)	-42.26 (3.01)	354.32 (31.59				
Irrigation Intensity	-200.92 (59.37)	-58.05 (29.40)	247.37 (297.7)	-243.59 (105.25)	-81.43 (49.39)	-.91 (.99)	312.93 (425.57)	-202.13 (60.62)	-57.54 (30.05)	272.46 (306.64)	-195.63 (106.65)	-58.31 (50.01)	.495 (1.00)	225.1 (429.2)
Fragment Intensity	1.67 (6.14)	-.344 (3.03)	-12.55 (30.54)	58.71 (8.80)	26.26 (4.13)	.61 (.08)	-218.80 (35.54)	1.47 (6.19)	-.471 (3.07)	-7.80 (31.49)	57.06 (8.86)	25.41 (4.15)	.602 (.083)	-217.2 (36.2)
Capital Stock	-.018 (.018)	-.0004 (.0092)	.081 (.092)	-.146 (.032)	-.063 (.014)	-.0013 (.0003)	.507 (.122)	-.019 (.019)	-.0006 (0094)	.0887 (0961)	-.143 (.030)	-.0616 (.0142)	-.0013 (.0003)	.539 (.122)
High Yielding Varieties	21.47 (14.02)	13.078 (6.93)	213.6 (69.4)	13.17 (24.97)	7.70 (11.70)	-.0339 (.2356)	233.27 (700.36)							
Price Terms 3/														
P_B/P_O	-26.24 (2.88)	30.06 (2.16)	-93.24 (32.24)	-22.53 (3.28)	33.78 (2.14)	-.078 (.027)	-56.24 (29.20)	-23.24 (6.64)	31.10 (3.28)	-5.71 (5.02)	-45.37 (11.27)	22.99 (5.28)	-.289 (.102)	2.85 (5.28)
P_L/P_O	55.24 (5.56)	-26.24 (2.88)	149.88 (44.71)	46.28 (7.86)	-22.54 (3.28)	.079 (.060)	233:17 49.38	49.66 (9.25)	-28.95 (4.58)	22.13 (11.30)	80.97 18.39	-6.14 (8.62)	.450 (.167)	-4.029 (27.16)
P_{ha}/P_O				.079 (.060)	-.078 (.028)	.0016 (.0006)	-1.49 (.42)			-11.77 (13.71)	.045 (.129)	-.093 (.060)	.0001 (.0001)	-.0017 (.0017) -7.08 (21.78) .0050 (.185) .2592 (.4492)

1/ The function form differs for the output equation in the full system. See Table I.

2/ Standard errors in parentheses.

Appendix Table 3: Normalized Quadratic Estimates: Coastal Rice

Independent Variables	Unrestricted, Including n'th Equation						
	Land as a Fixed Factor			Land as a Variable Factor			
	Labor	Bullock Labor	Output 1/	Labor	Bullock Labor	Land	Output 1/
Fixed Factors							
Land	-112.09	-27.06	858.66				
	(25.29) 2/	(2.25)	(48.00)				
Irrigation Intensity	1478.9	-70.30	4689.9	1376.7	-159.84	-3.105	6872
	611.4	(54.51)	(1156.5)	(663.0)	(88.75)	(2.477)	(2338)
Fragment Intensity	125.25	-5.31	-59.24	201.4	4.33	.569	-461.8
	72.28	(6.44)	(134.59)	(79.2)	(10.49)	(.293)	(282.8)
Capital Stock	-.0300	-.0088	-.297	-.1098	-.0402	-.0012	.723
	(.043)	(.0038)	(.082)	(.034)	(.0045)	(.0001)	(.121)
Price Terms 3/							
P_B/P_O	63.26	-.228	-.946	98.51	3.51	.225	-16.21
	(30.71)	(2.72)	(2.21)	(33.69	(4.30)	(.120)	(8.93)
P_L/P_O	161.07	-63.194	-128.00	246.48	-56.37	.551	-314.02
	(140.95)	(12.54)	(427.8)	(153.07)	(20.07)	(.560)	(70.37)
P_{HA}/P_O			425.99	-3.194	-.078	-.0097	-.0063
			115.86	(1.44)	(.184)	(.0051)	(.0074)
							238.86
							(167.91)
							.785
							(.544)
							5.567
							(1.888)

/ The functional form differs from the output equation in the full system. See Table 1.

/ Standard errors in parentheses.

/ As in last Table.

Appendix Table 4: Normalized Quadratic System Estimates of Labor Demand Function: Micro Data Sets

Independent Variables	Ferozepur: Restricted Excluding n'th Equation	Ferozepur: Unrestricted Excluding n'th Equation	Muzzafarnagar: Restricted Excluding n'th Equation	Muzzafarnagar: Unrestricted Excluding n'th Equation	Thanjavur: Restricted Excluding n'th Equation	Thanjavur: Unrestricted Excluding n'th Equatio
Price Terms[1/]						
P_B/P_0	187.71	987.1	(112.9)	-1160.6	-192.58	-493.93
	(357.5)[2/]	(1170.1)	(219.3)	(218.0)	(107.14)	(96.60)
P_L/P_0	2190	2051	(91.8)	211.5	-57.44	-748.49
	(871)	(891)	(1456)	(1038)	(26.6)	(2574)
P_F/P_0	-611.4	-614.7	260.6	-317.4	-945.22	-152.29
	(130.2)	(129.9)	(118.6)	(76.8)	(342.93)	(58.02)
Land	-8.51	-8.54	66.2	-64.11	-84.38	-65.52
	(1.85)	(1.85)	(2.67)	(2.61)	(13.36)	(13.06)
Irrigation Intensity	-150.1	-154.5	-235.2	-225.5	169.06	316.53
	(81.9)	(82.2)	(33.0)	(31.7)	(180.11)	(178.84)
Fragment Intensity	183.5	175.0	25.53	8.29	29.20	44.652
	(62.7)	(63.8)	(16.28)	(16.33)	(13.55)	(12.79)
Major Impl.	-.021	-.021	-.253	-.039	-.0144	-.0181
	(.003)	(.003)	(.0340)	(.0322)	(.0055)	(.0054
Minor Impl.	-.382	-.386				
	(.122)	(.122)				

[1/] As in last table

[2/] Standard errors in parentheses

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