FACTOR DEMANDS OF LOUISIANA RICE PRODUCERS: AN ECONOMETRIC INVESTIGATION

Patricia E. McLean-Meyinsse and Albert Ade. Okunade

Abstract

A Diewert-flexible (dual) cost function was used to derive a system of conditional factor demand equations for Louisiana rice producers. Generalized Leontief cost and factor share equations were fitted for the 1955-87 period using Zellner's SURE system estimation procedure. The Aitken parameter estimates reveal that: (1) the optimal input mix of rice farmers varies with production scale, (2) the factor-augmenting technical change is labor and chemical saving but seed using, (3) pairwise input substitutions are limited, and (4) factor demands are own-price inelastic. An implication is that Louisiana rice farmers will not appreciably alter their factor utilizations when relative input prices change.

Key words: rice production, conditional factor demands, dual cost function, flexible functional specification, factor-augmenting technical change, factor substitution possibilities, nonhomothetic production technology.

The weak performance of the Louisiana state economy during recent years is partly due to depressed activities in its traditionally strong energy, tourism, and agricultural sectors. Yet, in spite of low capacity utilization in agriculture, rice production has remained an important source of farm revenue for Louisiana. In recent years, cash receipts from Louisiana rice ranked third in the U.S. after Arkansas and California (USDA, 1986).

This paper employs neoclassical duality between cost and production functions to derive and estimate a set of factor input demand functions using data on Louisiana rice farms. The demand for rice inputs is derived from the output demand for rice. Because rice farmers tend to select the least-cost mix of inputs for a given level of output, their derived demand for factor inputs depends on the level of downstream demand for rice output, market-determined relative prices of all inputs, and the substitution possibilities among inputs allowed by the production technology in use. Elasticity of substitution in factor space is a pure number which indicates the shape of an isoquant. As the substitution elasticity approaches zero, the isoquants become nearly right angled, and substitution among inputs is nearly impossible. As the substitution elasticity increases, factors substitute more easily in the production process, and the downwardly sloping isoquants are convex to the origin. Finally, a negatively-sloped isoquant with a constant slope will allow for perfect factor substitution given a constant marginal rate of substitution. The shape of these curves are estimated in this paper.

First, the conditional factor demand equations are derived based on the assumption of cost minimization for rice farmers. These derived-demand functions are then tested for integrability and homotheticity of the production process, and hence for constant returns to scale. Estimates of own-price elasticities of factor demand, the Allen-Uzawa partial elasticities of factor substitution, and technical progress are reported. The effects of technical change on the structure of input demands on rice farms are discussed. Finally, the implications of the study findings for policy making and resource employment on

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The authors acknowledge partial support for this work by the Department of Agricultural Economics and Agribusiness at Southern University, Dillard University, and The Avron & Robert Fogelman College of Business and Economics at Memphis State University. They also acknowledge the helpful comments and suggestions of Mark Cochran, Bruce L. Dixon, Richard Evans, Thomas J. Lareau, Robert Premus, Howard Tuckman, and three anonymous *Journal* referees and the editors. However, the authors assume full responsibility for errors.

Louisiana rice farms are examined.

METHODOLOGY AND HYPOTHESES

The duality between production and cost functions was first demonstrated by Shephard, who argued that a well-behaved cost function is necessarily an economic summary of a production technology. Duality models of production processes have particularly benefited from the recently discovered class of flexible functional forms. Chalfant; Guilkey, Knox, and Sickles; Okunade; Pope; and others have demonstrated that Diewert-flexible functional approximations of costs and technologies asymptotically reduce model misspecification because they do not impose *a priori* restrictions on the Allen-Uzawa partial elasticities of factor substitution and other parameters of the production technology. The generalized Leontief and flexible translog functional forms can be interpreted as second order numeric or differential local approximations to an unspecified true underlying (cost, production, or profit) function (Barnett, Lee, and Wolfe). These unrestrictive models have proven superior to the celebrated Cobb-Douglas (C-D) and Constant Elasticity of Substitution (CES) specifications when modelling production technologies involving multiple inputs or outputs. The CES and self-dual C-D models are *a priori* restrictive by providing only first order approximations to the true underlying function, and the resulting factor substitutions are constant for pairs of inputs.

A dual generalized Leontief cost specification is adopted in this study to model input demand functions for rice growers in Louisiana. Binswanger postulated several advantages to using this methodological approach rather than the direct production function specification when estimating dual production parameters. For example, dual cost functions are homogeneous of degree one in factor prices in order to be consistent with basic theory, regardless of the homogeneity status of the underlying production function with respect to the factor quantities. The linear homogeneity of the cost function ensures that relative, not absolute, prices determine the least-cost surface. Moreover, a dual cost function model mitigates multicollinearity problems among the regressors because factor prices are rarely collinear compared to factor quantities of the primal production function model. Also, under conditions approximating perfect competition in factor markets, input prices are truly exogenous arguments in the dual cost model, thereby reducing misspecification of the regression model.

Diewert has shown that if there exists a continuous from above (concave), twice differentiable production function $Q = F(x)$, there exists a corresponding minimum cost function frontier $C = c(w; Q)$, such that:

$$(1) \quad C(w;\ Q) \equiv \underset{x}{\text{Min.}}\ \{w'x\colon F\ (x) \geq Q\},$$

where w is a vector of exogenously determined factor prices, x represents a vector of factor demands, F defines a known transformation function, and Q is the level of output produced. The dual cost function $C(w;Q)$ is well behaved if it is twice-continuously differentiable, concave, non-decreasing, and homogeneous of degree one in input prices. To the neoclassical production technology implied by $C(w;Q)$ corresponds a set of conditional derived demand equations that are homogeneous of degree zero in w when the substitution matrix of second partial derivatives of $C(w;Q)$ with respect to each input price is negative semidefinite. This condition guarantees that the cross-price effects are symmetric and the own-price effects are negative. Therefore, the conditional factor demands are downwardly sloped; and the isoquant surface lies above, and is tangent to, the isocost curve at the cost minimization point for that output at given factor prices.

Consequently, this paper postulates the existence of a twice-continuously differentiable, strictly monotonic, and quasi-concave aggregate production function which transforms the flow services of Capital (K), Labor (L), Seeds (S), Fertilizer (F), and Chemicals (C) inputs to the output flow of rice. A generalized second-order Leontief cost function of the form

$$(2) \quad C(w;\ Q,\ t) = Q\bullet\sum_i \sum_j \beta_{ij} w_i^{1/2}\ w_j^{\ 1/2} + Q^2 \bullet \sum_i \alpha_i w_i + Q\bullet t\bullet \sum_i \gamma_i w_i + \hat{\xi}_c$$

is assumed flexible enough to describe the economic dimension corresponding to the production process. The w_i's are input prices ($i = K,L,S,F,C$), t stands for time, and the $\hat{\xi}_c$ term of the functional specification truncates higher than second-order terms to a stochastic disturbance for the underlying Taylor series approximation.

The local point of expansion for the generalized Leontief functional specification is the arithmetic mean. As a test of the sensitivity of the choice of expansion point (Zadeh), each of the first and last data observations were also experimented with as alternative points of approximation. The model results were not found to be hypersensitive to the choice of an expansion point; therefore, the cost function model retains the arithmetic mean as the expansion point in this study.

The system of derived demand functions for inputs is obtained using Shephard's lemma

(3) $\partial C^*(w; Q, t)/\partial w_i = x_i^*$, where

(4) $x_i^* = \sum_{j=1} \beta_{ij} (w_j/w_i)^{1/2} \bullet Q + \alpha_i Q^2 + \gamma_i Q \bullet t + \hat{\xi}_i,$

where, by the envelope theorem, C^* is minimum cost (frontier) for producing Q level of output, and x_i^* is optimal factor employment of i-th input given its factor price w_i. Thus, given optimization behavior by rice farmers, the derived demands for factor inputs are determined by relative factor prices, output level, and the substitution possibilities among inputs given the production technology. The error term $\hat{\xi}_i$ [different from that in equation (2)] appearing in each cost share equation (4) reflects possible errors by farmers in optimal input choice decisions. These errors are typically known to be contemporaneously and serially correlated (Johnston).

In dual cost models of production processes involving more than two inputs, the concept of partial elasticity of factor substitution becomes relevant. Uzawa has shown that if the behavioral model assumed for an economic agent is profit maximization, Allen's partial elasticity of factor substitution σ_{ij}, can be computed from the parent cost function, C^*, as

(5) $\sigma_{ij} = C^* \bullet C_{ij}/C_i \bullet C_j = \sigma_{ji}, i \neq j,$

where $C_i = \partial C^*(w;Q)/\partial w_i$, $C_j = \partial C^*(w;Q)/\partial w_j$, $C_{ij} = \partial^2 C^*(w;Q)/\partial w_i \bullet \partial w_j$ (= C_{ji}), and C^* is minimum cost at output level Q (Diewert). The estimate of σ_{ij} given in equation (5) follows from Young's theorem on the invariance of the cross-partial derivatives $\partial^2 C^*(w; Q)/\partial w_i \partial w_j$ and $\partial^2 C^*(w;Q)/\partial w_j \partial w_i$ to the order of differentiation. The estimated $\hat{\sigma}_{ij}(Q; w)$ between two inputs i and j, given their respective prices w_i and w_j, permits the producer to alter the usage of inputs other than i and j when relative prices (w_i/w_j) change, holding constant all other input prices and the output level. While the cross-price elasticities of factor demand between two inputs can be conventionally calculated as

(6) $\eta_{ij} = \partial x_i/x_i \bullet w_j/\partial w_j$ ($\neq \eta_{ji}$, generally),

Binswanger suggested that $\hat{\sigma}_{ij}(= \hat{\sigma}_{ji})$ be used for inferences on pairwise factor substitutions. One of the advantages of the flexible cost model of this study is that the estimated $\sigma_{ij}(w; Q)$ values are allowed to vary from one observation to another, depending on the value of cost shares, S_i, for input factors (Okunade).

Own-price elasticities of factor demand are computed as

(7) $\eta_{ii} = \partial x_i/x_i \bullet w_i/\partial w_i$.

Alternatively, the own-price and cross-price elasticities of factor demand can also be calculated, respectively, as

(8) $\eta_{ii} = S_i \bullet \hat{\sigma}_{ii}$, and

(9) $\eta_{ij} = S_j \bullet \hat{\sigma}_{ij}, i \neq j,$

where the i-th input expenditure share of the total cost is $S_i = w_i x_i^*/C^*$, σ_{ij} is as previously given in equation (5), and σ_{ii} is obtained as in equation (5) by replacing C_{ij} with $C_{ii} = \partial^2 C^*(w;Q)/\partial w_i^2$. Finally, because all of the factors of production (hence, total produc tion costs) are only approximately accounted for in empirical studies, the resulting elasticities are best regarded as static partial equilibrium values.

To test for constant returns to scale (CRS) in the technology of rice production, it must be possible to decompose the cost function as

(10) $C(w; Q) = Q\lambda^{i} \bullet (w),$

where $\lambda(w)$ is a unit cost function. This derivation obtains if the estimated parameter α_i (i=K,L,S,F,C) is zero in equations where it appears. The cost function $C(w; Q)$ will correspond to a homothetic technology if it can be expressed as a multiplicatively separable function of input prices w and a scalar output level Q. That is, $C(w;Q) = g(Q) \cdot f(w)$ would imply that the production function is homothetic (with homogeneous cost function); hence, the factor cost shares do not contain output as an argument. Consequently, all factor shares are due to factor substitution and/or factor augmenting technical change, expansion paths are linear (rays from the origin), and the factor cost shares are invariant to changes in the scales of production for homothetic technologies. The direction and magnitude of disembodied technological change are derived from parameter γ_i in equations containing time as an argument. If $\gamma_i = 0$ (i = K,L,S,F,C), then the technology structure is time-invariant given observed data.

THE DATA AND STATISTICAL ESTIMATION

Annual time series data for the 1955-87 period were collected on five major factors of rice production: capital (K), labor (L), seeds (S), fertilizer (F), and chemicals (C); and on the output of rice. The data used in the final estimation were the price and quantity indexes for each input and the output index for rice.

Capital costs encompassed expenditures on tractor purchase price amortized over useful life, repair cost, and expenditures for fuel and lubrication; airplane costs for seeding and pesticide spraying; and rice field irrigation costs of water, wells, pumps, ditches, and flood gates. These costs were compiled from *Agricultural Statistics* (USDA); Paxton and Lavergne; Paxton et al.; and Zacharias and McManus. Labor expenditure, measured as the minimum wage augmented by allowances for social security and workmen's compensation, was compiled from Paxton et al. and *Agricultural Statistics.* Costs data on nitrogen, phosphate, and potassium comprised the fertilizer category and were obtained from Paxton et al.; *Fertilizer Use and Price Statistics 1960-1985* (USDA); and *Agricultural Statistics.* Expenditures on chemical input were those of herbicides and insecticides taken directly from Paxton et al. and *Agricultural Statistics.* Seed prices were also compiled from Paxton et al. and *Agricultural Statistics.* Data on rice prices and output levels were collected from Paxton et al.; Fielder and Nelson; USDA's *Rice Outlook and Situation;* and USDA's *Rice Background for 1985 Farm Legislation.* The total cost of rice production comprised expenditures on all the factor inputs.

The factor cost share of each input, $S_i = w_i x_i / C(w;Q)$, was the dependent variable in the estimation of the input demand functions given by equation (4). In the dual cost system, input prices were used as arguments in the model specification, rather than the physical quantities of a production function specification. A linear time trend variable was included as a proxy regressor in equations (2) and (4) to capture the possible effects of technical progress on the production cost, assuming that technical change is highly correlated with time and occurs smoothly over time.

Since the units of measurement were not the same for all inputs, Divisia price and quantity indices were constructed. The Divisia price indexes are of the form

$$(11) \quad w_2 = w_1 \left[\sum_{i=1}^{n} S_i \left(\frac{\dot{w}_i}{w_i} \right) \right] + 1,$$

where S_i is cost share of input i in aggregation, w_i is price of i-th input, $\dot{w}_i$ is change in price of input i from year 1 to year 2, and w_1 is the first price index value and is set equal to 1 (Bishop et al.). Divisia quantity indexes were similarly derived. All prices were indexed to 1967, the typical base period for many of the statistics published by the U.S. Department of Agriculture and others.

The five equations comprising the system of derived demand for inputs [equation (4)] are linear in the unknown parameters, and thus linear regression techniques may be used to obtain parameter estimates. Preliminary Ordinary Least Squares (OLS) estimates of the individual equations (with Hicks symmetry restrictions $\beta_{ij} = \beta_{ji}$ imposed) yielded serially and contemporaneously autocorrelated residuals and heteroscedastic error variance. Therefore, the unbiased and consistent OLS estimates were no longer efficient. The presence of non-spherical disturbances made the generalized least-squares (GLS) estimation technique a feasible alternative procedure.

Letting k represent the number of factor share equations, econometric considerations would dictate that only (k-1) or 4 of the 5 factor share equations are linearly independent due to the homogeneity of degree one in input prices contraint. The arbitrarily selected n-th factor share equation is redundant, hence is dropped from estimation. Second, all factor shares have the same exogenous regressors and are seemingly unrelated in the Zellner sense. Third, because the regressors of the (k-1) share equations are the same variables, cross-equation restrictions must be imposed on their parameters to ensure that the resulting estimates are invariant from one share equation to another. Fourth, it is more efficient to estimate the system of (k-1) share equations with the parent cost function (Diewert).

The application of three-stage least-squares (3SLS) estimation method showed the sensitivity of parameter estimates to the omission of a specific k-th redundant factor share equation (Okunade). Therefore, the (k-1) system of factor equations and the cost function were jointly estimated using Zellner's iterative 3SLS (I3SLS) system estimation. The feasible GLS estimation procedure iterated on both the estimated residual covariance matrix and parameter estimates until stable convergence was obtained. The resulting parameter estimates are invariant to the deletion of any particular share equation, and the asymptotically normal coefficients are maximum likelihood estimates.

Parks has argued that the residual variances in factor share equations are distri buted as $Q_n^2 \cdot \sigma_i^2$. Therefore, the share equations for estimation were heteroscedasticity-adjusted by expressing factor demand equations as input-output ratios

$$(12) \quad x_{in}/Q_n = \sum_i \beta_{ij}\,(w_{jn}/w_{in})^{1/2} + \alpha_i Q_n + \gamma_i t + \Psi_{in},$$

where $\Psi_{in} = \xi_{in}/Q_n$; $\underset{n\to\infty}{E}(\Psi_{in}) = 0$; $\underset{n\to\infty}{V}(\Psi_{in}) = \sigma^2$,

and n indicates a specific observation. Notice that ξ_i is the disturbance term associated with equation (4), while Ψ_{in} is the transformed residual for equation (12).

The Goldfeld-Quandt F test and Breusch-Pagan chi-square test (Johnston) for detecting classical and mixed representations of heteroscedasticity indicated that the residuals of the system were homoscedastic. The absence of residual autocorrelation was indicated by the estimated (weighted) Durbin-Watson statistic for detecting first order autoregressive error process. Nonautocorrelated and homoscedastic errors gave reasonable assurance that the estimated model was not misspecified.

EMPIRICAL RESULTS

It is important to ascertain that the generalized Leontief system being estimated satisfied the sufficient conditions for the existence of a well-behaved cost function. The fulfillment of these conditions would give reasonable confidence that the postulated cost function and its derivatives exist. The requirements that $C(w;Q,t)$ is concave in input prices and that the factor demand functions are strictly positive are tested at the local point of expansion. The fitted cost function is not expected to satisfy these conditions globally (Barnett et al.). The concavity test, based on the Aitken (GLS) parameter estimates, confirmed the negative semidefiniteness of the Hessian matrix. The price monotonicity condition is satisfied if $\partial C^*/\partial w_i > 0$ for all i (i = K,L,S,F,C). By using the unrestricted model parameter estimates and substituting each observation, it was found that the derived demands are strictly positive. Given that the symmetry condition (i.e., $\beta_{ij} = \beta_{ji}$; $i \neq j$) is satisfied, the estimated demand functions are integrable. Therefore, aggregate cost and production functions that are dual to each other exist because the cost function is generally well-behaved for the observed data period.

The off-diagonal entries in Table 1 are the estimated cross-price elasticities of factor demand. In this regard, labor and capital tend to be good substitutes in Louisiana rice production. This finding is consistent with previous (dual) translog cost models of U.S. agricultural production by Ray, Binswanger, and others. In addition, seeds and fertilizer are substitutes for hired farm labor. Ray has argued that the tendency for labor and fertilizer to substitute in U.S. agricultural production seems consistent with the steady decline in labor use and steep increase in fertilizer use. However, Binswanger reports significant complementarity between labor and fertilizer, implying that increasing fertilizer use calls forth increased use of hired labor. There is very poor (and statistically insignificant) substitution between labor and chemicals, and between fertilizer and farm capital in Louisiana rice production. The relationship between fertilizer and capital previously reported for U.S. agricultural production is mixed (for example, see Ray and Binswanger). Moreover, chemicals and seeds seem to complement capital poorly in rice cultivation. Finally, seeds and fertilizer are

TABLE 1. ELASTICITY ESTIMATES OF THE DERIVED DEMAND EQUATIONS SYSTEM (SYMMETRY RESTRICTIONS IMPOSED) FOR LOUISIANA RICE PRODUCERS[a] (TAYLOR SERIES EXPANSION AT SAMPLE MEANS)

	Regressors							
Factor	Price of Labor	Price of Capital	Price of Chemicals	Price of Seeds	Price of Fertilizer	Price of Miscellaneous[c]	Output	Time Trend
Share of Labor	-0.383***[b]	0.441***	0.131	0.234**	0.510*	-0.933	-0.126	-0.450***
	(-3.080)	(2.616)	(0.544)	(1.867)	(1.785)		(-0.244)	(-4.127)
Share of Capital		-0.214***	-0.053	-0.025	0.142	-0.291	-0.991***	-0.035
		(-2.640)	(-0.476)	(-0.430)	(1.076)		(-4.118)	(-0.687)
Share of Chemicals			-0.087	-0.364	-2.127	2.500	-1.282***	-1.159**
			(-0.920)	(-0.516)	(-1.220)		(-4.082)	(-2.056)
Share of Seeds				-0.026	0.109	0.072	-0.491	0.248**
				(-0.520)	(0.432)		(-1.041)	(2.881)
Share of Fertilizer					-0.531***	1.897	-1.783*	0.159
		Symmetric			(-2.790)		(-1.740)	(0.923)
Share of Miscellaneous						-3.245		

[a] Asymptotic t-values are in parentheses.

[b] Statistical significance of the parameter estimates at the .01, .05, and .10 levels are indicated by ***, **, and *, respectively. The weighted system adjusted $R^2 = 0.88$.

[c] Implied estimates computed using the homogeneity of degree one in input prices condition. Therefore, their respective t-ratios are unknown.

poor substitutes, and these two inputs do not appear to complement the chemical input strongly on Louisiana rice farms.

The pattern of factor substitution relationships in Table 1 is further reinforced by the Allen-Uzawa partial elasticities of factor substitution entries in Table 2. However, the numerical magnitude of the Allen-Uzawa estimates are slightly lower in absolute values. The highest degree of (statistically significant) factor substitutions seems to be between labor and each of capital and fertilizer (see Tables 1 and 2). This, along with the finding that seeds and fertilizer are good substitutes for labor, appears reasonable. The "miscellaneous" input category lumps together those remaining factors of rice production not explicitly measured. The elasticities of factor substitution between miscellaneous input and other inputs given in Table 1 are the estimates implied by imposing the homogeneity of degree one (HD1) in input prices condition on the generalized Leontief cost model parameters. The HD1 condition guarantees that, for a fixed output level, total costs must vary proportionately when all input prices change proportionally. Although the exact composition of the residual category of inputs is unknown, it substitutes in various degrees for chemicals, seeds, and fertilizer, but complements labor and capital in Louisiana rice production.

The diagonal entries in Table 1 are direct price elasticities of factor demands. They have the proper signs and are own-price inelastic. However, only labor, capital, and fertilizer are statistically significant at the .10 level or better. The miscellaneous input demand category is own-price elastic and has the correct sign.

The joint multiple parameter hypotheses F-tests (Morrison), which are asymptotically equivalent to the multivariate Neyman-Pearson likelihood ratio tests or Wilk's lambda tests, were used to test for constant returns technology (CRS), homotheticity, and zero augmenting technical change hypotheses. If the production process is consistent with the constant returns to scale technology structure, then the α_i coefficients should vanish from those equations in which they appear. Table 1 shows that this is not the case for the derived demand equations for capital, chemical, and fertilizer inputs. The high t values would suggest a rejection of the null hypothesis. Joint F-tests between the restricted and unrestricted equations further reinforce this conclusion. Rejection of CRS hypothesis implies that factor proportions can be expected to change with output expansion.

The trend coefficient in Table 1 is significantly different from zero at the .05 level or better in the labor, chemicals, and seeds demand equations, indicating that the null hypothesis of zero-augmenting technical change is rejected. The results indicate that technical change is not Hicks-neutral in

TABLE 2. ALLEN-UZAWA PARTIAL ELASTICITIES OF SUBSTITUTION BETWEEN INPUT PAIRS (CALCULATED AT SAMPLE MEANS)

$\hat{\sigma}_{LK}$	=	0.253***[a] (8.724)	$\hat{\sigma}_{KS}$	=	-0.013 (-0.016)
$\hat{\sigma}_{LC}$	=	0.075 (0.131)	$\hat{\sigma}_{KF}$	=	0.076 (1.407)
$\hat{\sigma}_{LS}$	=	0.134 (0.192)	$\hat{\sigma}_{CS}$	=	-0.055 (-0.066)
$\hat{\sigma}_{LF}$	=	0.292*** (2.703)	$\hat{\sigma}_{CF}$	=	-0.324 (-0.131)
$\hat{\sigma}_{KC}$	=	-0.028 (-.021)	$\hat{\sigma}_{SF}$	=	0.617 (0.689)

[a] The parenthesized t-ratios are calculated from respective standard errors, $SE(\hat{\sigma}_{ij}) = SE(\beta_{ij})/S_i \cdot S_j$, where S_i and S_j are cost shares of inputs i and j, respectively. Computational formula used for SE $(\hat{\sigma}_{ij})$ is given in Binswanger. The asterisked $\hat{\sigma}_{ij}$ values are statistically significant at the .01 level.

Louisiana rice production in the 1955-87 study period. The highly significant trend coefficients of -1.159 and -0.450 in the chemical and labor share equations indicate that technological progress is both chemical and labor saving. A similar finding by Lianos suggests that the observed decline in labor's relative share arises from an increasing capital-labor ratio and higher productivity growth of capital relative to labor in U.S. agriculture. Moreover, Kako's study of rice input demand using Japanese data attributes the decline in labor input utilization mainly to technical change; while the labor-saving effect of factor substitution along an isoquant and the output level effect are relatively minimal. The finding of chemical-saving technical progress in this study may reflect the success of environmentalists in pushing for less chemical use in Louisiana. As a result, technological progress in Louisiana rice production involves significant usage of fertilizer and seed. This result is consistent with the work of Fielder and Osagie and a recent USDA (1984) rice study reporting strong relationships between increased rice production, rising fertilizer use, and the farmer's adoption of high-yield rice seed varieties.

SUMMARY, IMPLICATIONS, AND CONCLUSIONS

The primary purpose of this study was to utilize neoclassical duality between cost and production functions to derive and estimate a set of factor input demand functions using Louisiana rice production and cost data. Maximum likelihood parameter estimates of the joint generalized least squares regression of the factor shares and flexible Leontief cost equations were obtained.

The results show that the output-constrained factor demands are integrable; therefore, the production function is recoverable from the (well-behaved) dual cost specification; the structure of Louisiana rice production is inconsistent with the hypotheses of technological homotheticity and constant returns to scale production; technical progress is not Hicks-neutral, but is labor and capital saving, and seeds using. Moreover, labor appears to substitute for capital, seeds, and fertilizer. Finally, input demands for capital, labor, chemicals, seeds, and fertilizer are own-price inelastic while that for the miscellaneous input category is own-price elastic.

The observed results suggest several interesting insights. First, the significant substitution of capital, seeds, and fertilizer for hired farm labor on rice farms may moderate the threat of prolonged labor strikes and dampen the wage bargaining power of organized farm labor. That is, job attrition among hired rice farm workers would worsen if labor costs rise relative to those of competing inputs.

Second, during the present period of low capacity utilization and high unemployment on Louisiana farms, policies that increase real interest rates for financing farm capital or those that escalate the cost of fertilizer use (such as environmental legislations restricting fertilizer water run-offs pollution, etc.) relative to farm wage rates will increase labor input use in rice production. However, the observations above must be tempered by the limited substitution relationships among the factors of rice production. Moreover, a fall in the price of one input will tend to enhance both its use and those of complementary factors, *ceteris paribus.*

Third, the presence of limited factor substitutions suggests that certain minimum threshold levels of each input are required to produce rice on a typical Louisiana farm. This condition would tend to retard the optimal input mix adjustment by farmers to changing relative factor prices. For example, when relative factor prices rise and expansion paths shift, restricted factor substitutions may prevent farmers from making swift, cost-minimizing movements to re-establish optimal factor employments along a given isoquant. Therefore, production costs will increase, *ceteris paribus.* This may eventually cause the farmer to abandon the high cost-of-production technology in search of an alternative production technology that allows swifter factor substitutions.

Fourth, the small numerical magnitudes of direct price and cross-price elasticities of factor demands generally suggest that rice farms cannot be relied upon to improve the employment of labor, capital, fertilizer, seeds, and chemical inputs in Louisiana's agricultural sector. Finally, since technical change is significantly seed using, new varieties of rice strains should find ready market on Louisiana rice farms.

There are limitations to this study. First, family-supplied farm labor was excluded. This implicitly assumes the existence of functional separability of the cost function and other inputs from family-supplied labor (Berndt and Christensen). Second, it is desirable to disaggregate the miscellaneous input category into distinct component factors of production to permit a more meaningful interpretation of their relationships with other explicitly measured factors of rice production. Finally, a need exists for future researchers to correct for and assess the efficiency differences that typically exist among different vintages of farm capital and how these differences impact on factor demands and the measured rates and direction of technical progress. Although data limitations prevented implementing such a procedure in this study, it would be beneficial for researchers and farm policy decision makers to recognize and analyze the apportionment of total technical change between that which progresses smoothly with time (i.e., disembodied) and those that are explicitly embodied in the vintage and quality of farm inputs.

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