EMPIRICAL COST FUNCTIONS FOR LABOUR-INTENSIVE PADDY FARMS IN FORMOSA*

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This study includes an estimate of cost functions for paddy farms in Formosa. Two types of estimational techniques are used; namely regression estimates and synthesized or budgeted cost curves. Long-run and short-run regression-derived curves are estimated for rice and sweet potato farms from samples which provide the observations. Estimates are for total cost functions with average cost functions computed per hectare. From sample observations, it was possible to derive, through regression estimates, only linear total cost functions. The non-linear average cost functions have only slight (economically unimportant) slopes beyond 2·5 hectares. Hence, large farms do not seem to be an important policy imperative. However, the steep slope of the average cost functions for farms under 1·5 hectares suggest that further farm fragmentation should be prevented. The cost estimates based on synthesized functions result in conclusions paralleling those based on regression-estimated cost functions. The area at which minimum average costs occur differs among sets of fixed inputs. However, the level of costs at minimum points on the curves are similar for the numerous resource situations examined. Within the limitations of the data and results, we believe both estimational techniques imply similar policy prescriptions.

Introduction

Farm size is an intense concern of agricultural policy in many countries. Large farms provide the orientation of emphasis in Socialist countries. Small farms are the emphasis in developing countries with a dominant part of the labour force in farming. The nature of scale returns or cost economies should be important in specifying farm size policy. However, in neither of these sets of countries do we find any extent of data indicating the nature of cost functions relating to farms of different sizes.

To help fill this void and provide greater knowledge of cost economies under the technologies of developing countries, we have estimated cost functions for several samples of paddy farms in Formosa. We believe the results are relevant in policy formulation for numerous countries.

Conditions of Production

In general, farms in Formosa are small and of a non-commercial or subsistence nature. Farmers first are concerned with providing family subsistence for their families and sell only the surplus or residual in the market. Subsistence farming dominates for the following reasons.

(a) Arable land for farm expansion is very limited. (b) The population-land ratio is high and industrial development at the present

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stage is not rapid enough to absorb the excess labour from agriculture. Also, traditional inheritance laws require farmers to divide their land among all children, thus adding to the fragmentation of the cadastral structure. (c) A limited supply of capital is available to farmers. (d) Farmers lack the technological knowledge or 'know-how' to employ highly capitalized technologies. (e) They also lack knowledge of the comparative profitability of alternative enterprises. (f) They may prefer subsistence production to the uncertainty and risk of new production patterns. Subsistence farmers with very little capital or equity are reluctant to risk their equity in new ventures.

The existence of a subsistence agriculture has several implications for the structure of farming. Production is diversified among crops and animals since both types of foods are traditional in family consumption. Production factors are mainly self-provided. For example, labour is almost entirely from family supplies. Price elasticities of production supply are small in the short run. Farmers are able to make few adjustments in resources used or farm size under prevailing tenure and market conditions.

Given these conditions and the country's overall land restraints, the nature of cost functions for farms which employ mainly labour and animal technologies are important for future policy decisions which relate to the size and structure of farms. Information on cost economies also should be useful both to farmers who have some opportunity to increase farm size (but under a high price for land). It is also hoped that this study will provide a better understanding of the economics of small farms and thus provide a basis for further farm management research in other countries where these agricultural structures prevail.

Data and Procedure

Two different estimation techniques are employed in this study. First, regression estimates are made of farm cost functions from a random sample of Formosan farms [5]. Second, because of known biases for cost functions fitted in this manner [2, 4], cost functions also are synthesized in a 'budgeted manner' wherein variable and fixed costs are estimated and then incorporated directly into equations representing cost functions. In the latter method, we estimate variable costs per acre and fixed costs attached to each technique. An equation of costs then is derived with land area as the variable.

Regression estimates of cost were derived for farms using many different combinations of human labour and cow-power. They extend over all hectares and provide a type of estimate for both short-run and long-run cost functions. Actually, the regression analysis does not provide estimates precisely of short-run or long-run functions but a curve somewhat above the long-run planning curve. This relationship occurs because farmers do not typically operate at the point where their specific short-run cost curve is tangent to the long-run planning or envelope curve. Some may operate at the minimum point of the short-run curve facing them, but others operate both to the right and left of it. Some reasons for this deviation from either the tangent or low-cost points are limitations of capital, discounts growing out of risk and uncertainty and lack of knowledge and different technologies [2, Ch. 7]. However, the functions estimated do indicate the cost structure for operating farms.

They suggest both the long-run size which gives the lowest cost and the absolute decline in costs as various sizes are attained even under different technologies.

For the cross-sectional sample data from the two farming regions, homogeneity of variance for costs was tested to allow application of appropriate statistical tests and choice of the appropriate cost-acreage functions [3]. The data were transformed, by use of the square root of the ratio of mean square errors (i.e., the ratio of the sample standard deviations) between relevant farm size groups, so that the variance of total cost in each group was homogeneous before the regression estimates were made.

The 299 farm sample included two sets of farms; those specializing in rice (135 farms) and those having a farm organization where rice and sweet potatoes were of about equal area (94 farms). Seven total cost functions were estimated for these farms. The estimates were made with total costs per hectare, *TC*, as the dependent variable and hectares or land area, *H*, as the independent variable. We use this formulation rather than the classical relation of costs to outputs because it is the form which is of interest to us. (For certain other purposes and some analysis of efficiency, cost per unit produced would be more applicable.) We are concerned with the cost per hectare as a basis for suggesting the relative advantage of farms of different sizes and mechanical-labour techniques, regardless of the biological inputs used (and the yields attained). Generally, the biological inputs affecting yield per hectare have only weak scale effects for farms which are so small and rest so heavily on labour.

The seven cost functions estimated are characterized in Table 1. The letters *R* and *S* (under the code in column 2) denote long-run and short-run cost functions, respectively. The letter subscripts on the cost function codes indicate the producing area (column 3) for which the

TABLE 1

Equation Number and Code, Type of Curve, Fixed Resources and Sample Size for the Seven Estimated Equations

Equation No.	Code	Producing area(a)	Fixed Resources		Number of farms
			Men(b)	Cows(c)	
1	L_R	Rice	none	none	135
2	S_{R-3}	Rice	3	1	50
3	S_{R-5}	Rice	5	1	34
4	L_{RS}	Rice-Sweet Potato	none	none	94
5	S_{RS-3}	Rice-Sweet Potato	3	1	33
6	L_{RRS}	Rice and Rice-Sweet Potato	none	none	229
7	$S_{RRS-1\cdot5}$	Rice and Rice-Sweet Potato	1·5	1	37

(a) Major commodity produced in the area sampled.
(b) Man years at which human labour force is "fixed".
(c) "Fixed" cow numbers for short-run functions.

function is estimated. The numerical subscript on the cost function codes indicate the 'fixed' number of men (column 4) to which the short-run functions refer. Hence, L_{RS} (equation 4) indicates a long-run cost function estimated for the rice-sweet potato area while S_{RS-3} (equation 5) indicates a short-run cost function for the rice-sweet potato area when man years is fixed at 3. The size of the sample for each cost function estimate is given in the last column of Table 1. (The number of cows for each short-run cost function is 'fixed' at 1.) Equations 1 (L_R) and 4 (L_{RS}) are long-run cost functions estimated separately for the rice and rice-sweet potato area, respectively. Equation 6 (L_{RRS}) is a long-run cost function estimated when data from these two producing regions are pooled. (See later discussion for reasons that the two samples were pooled.) After data were pooled for the two regions, a 37-farm sample of farms with 1·5 labour was available. Hence, a short-run cost function ($S_{RRS-1.5}$ in equation 7) was estimated for this strata of observations.

Regression Analysis

In estimating total costs, three algebraic functions were tried:

$$TC = k + aH + bH^2 + cH^3,$$
$$TC = k + aH + bH^2 \text{ and}$$
$$TC = k + aH,$$

where H is land area in hectares; k is a constant expressing fixed costs and a, b and c are statistics expressing the effect of variable costs in the functions. In all cases, the R^2 value and the regression coefficient for H in linear form were significant at the 1 per cent level of probability. In no case, for either short-run or long-run functions, were the coefficients for H^2 and H^3 significant at an acceptable level of probability. The analysis of variance statistics for the long-run rice function (similar analyses with equivalent results prevailing for all functions) are presented in Table 2.

TABLE 2

Analysis of Variance for Linear, Squared and Cubed Values of H in Long-run Function for Rice Farms

Source	d.f.	Sum Squares (million)	Mean Square (million)	F Ratio
Overall regression	4	122,312	—	—
Regression of H	1	18,657	18,657	437·52
Added for H^2	1	106	106	2·70
Added for H^3	1	2	2	·05
Deviation from regression	131	5,162	39	—
Mean	1	103,545	—	—
TOTAL	135	127,474	—	—

Hence, from the sample data, we were able to estimate statistically significant long-run cost functions (in the context explained) of linear form. We were not able to estimate non-linear cost functions which give rise to U-shaped short-run cost functions from the sample data and regression techniques. However, the average cost functions, A, derived from the long-run functions are non-linear but monotonically decreasing.

Even though the latter is true, we are interested in the changing slope of the average cost functions as an indication of the 'degree' of cost economies among the farms sampled. If the slope of the A function is great over the sample range of H, we consider that an advantage prevails in larger farms. However, if the slope of A becomes small i.e., the average cost function becomes relatively flat) at small values of H, we consider that farms of sizes within the sample have fairly attained available cost economies under the technologies in use.

The estimated statistics of the seven cost functions are presented in Table 3. (The codes in column 2 identify the producing areas and the amount of 'fixed' man labour inputs.) In the equations, k and a (the two numerical coefficients, respectively, in the equations) are expressed in N.T. dollars. The R^2 value of each statistically estimated total cost function is given at the right. (See Table 2 for added detail on rice farms.)

TABLE 3

Estimated Long-run and Short-run Total Cost Functions from Sample Data

Equation No.	Code	Estimated Statistics		
		k	a	R^2
1	L_R	5,504	17,070	0·959
2	S_{R-3}	5,576	15,205	0·965
3	S_{R-5}	5,877	17,004	0·973
4	L_{RS}	5,493	17,891	0·960
5	S_{RS-3}	3,911	17,933	0·971
6	L_{RRS}	5,752	17,126	0·971
7	$S_{RRS-1\cdot 5}$	4,853	20,213	0·962

The statistics representing predicted slopes and constants of the regression equations do not differ significantly between the long-run total cost functions for the rice (L_R) and the rice-sweet potato (L_{RS}) areas. Hence, the pooled long-run total cost function has an average cost function with approximately the same configuration as the separate rice and rice-sweet potato average (long-run) functions. Similarly, statistically significant differences do not prevail among the slopes and constants of the short-run total cost functions. The average cost functions are dominated by the variable costs represented by the regression coefficient of H (i.e., by the cropping costs represented in seed, fertilizer, insecticides, etc.). Hence, it is reasonable to expect that, from the type and magnitude of variance encountered in a cross-sectional sample of farms, statistically significant differences might not be established among the different sets of cost curves.

Figure 1 includes the regression-estimated long-run total cost and the average cost functions (both sets of costs expressed as functions of land area) for rice farms. The sharp decline in the average cost function is for land area up to 1·5 hectares. Thereafter, the curve declines moderately up to 4 hectares and becomes quite flat for larger areas. Per hectare cost declines by about 22 per cent between 0·5 and 1·5 hectares, but by only 1·5 per cent between 4·0 and 5·0 hectares. The decline is 9 per cent between 1·5 and 2·5 hectares but only 4 per cent between 2·5 and 4·0 hectares. The small decline in average costs, a general con-

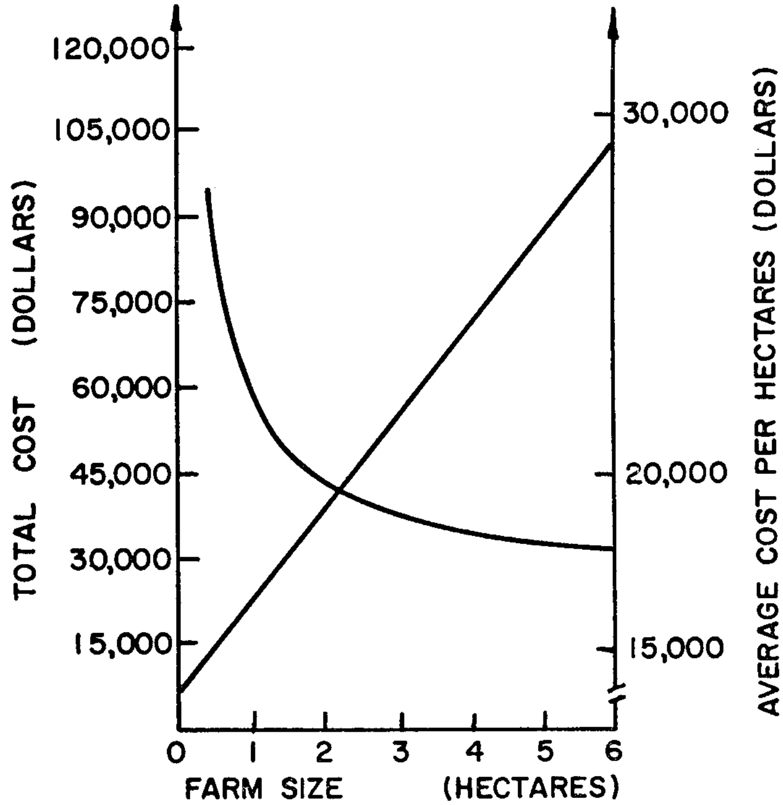

FIG. 1—Long-run cost-acreage functions for farm sample in rice producing region.

dition for both the estimated short-run and long-run functions, for areas over 2·5 hectares results from the dominance of cropping costs (a function of the area cultivated).

Cost economies appear unimportant for farms greater than 4·0 hectares (or even 2·5 hectares) in size. However, the majority of farms in Formosa are smaller than 2·5 hectares; the present inheritance system encourages further fragmentation. There are, of course, objectives other than cost efficiency which relate to farm size and are important in determining the production possibilities expressing the marginal rate of substitution among goals for which societies must make choices [1. ch. 12]. Objectives, other than farm and resource efficiency generated by larger farms, include productive employment of labour in economies where great underemployment would prevail, social and political stability engendered as more families are engaged in self-directed employment and equity in the distribution of income and wealth. Under constant scale returns, more of the latter objectives can be attained with more small farms at no sacrifice in resource efficiency. Under increasing scale returns (decreasing long-run costs), attainment of these alternative objectives require sacrifice in resource efficiency, if farms are to be larger in number and smaller in size. Decision on optimal farm size then can be determined only in light of the social welfare function.

Synthesized Cost Functions

Because of the difficulties in interpreting regression-estimated cost functions from sample data, we also synthesized cost functions from the survey and other technological data available [1, 6]. We propose that the long-run cost functions estimated by regression methods will lie above an actual long-run planning or envelope curve but have comparable slopes for a given output (land area in this case) and a minimum point at comparable magnitudes. Yet while these similarities may exist between a statistically-estimated long-run cost functions based on cross-sectional data and an actual long-run cost envelope curve, we believe that other techniques may (because of heterogeneity in technologies and other combinations) give better indications of cost economies for farms of different areas. More important, sample farms engage in a range of technologies which cannot be adequately stratified in samples of the size available to us. Consequently, the cost functions estimated from such samples may be 'hybrids', drawn from different but specific families of cost functions. Hence, as a possible check on this prevalence, but more to be able to derive cost functions which represent given technologies, we turn to synthesized (budgeted) cost functions. (As indicated later, both types of estimates indicate scale or cost economies to extend only over a relatively small land area for the technologies concerned.)

In the synthesis of cost functions, we divided fixed and variable costs into two categories; 'long-run' is simply used to denote that no input was specified as fixed. In the short-run cost functions, labour is fixed at the levels specified (Table 1) while land area (hectares) is varied according to observations in the sample. In the long-run cost functions, labour (man and cow) as well as land are varied according to sample observations. The fixed costs in the short-run functions represent the annual value of man labour (on a man equivalent of family labour) and the costs of one cow and all related mechanical equipment. They include housing depreciation, annual cow depreciation, the opportunity wage rate of man labour, interest on cow feed and investment and specific costs which are fixed regardless of farm size or are fixed in ratio to man and cow labour (i.e., equipment for this labour combination). The variable costs for the short-run curves include fertilizer, seed, insecticides and all other materials where the usage is a function of land area. In the long-run cost functions, man labour and cow costs (and costs associated with labour) are treated as variable costs, along with seed and other inputs which are a function of land area cultivated. Costs related to acreage as a variable include land tax, rental value of land, cropping costs (seed, fertilizer, insecticides, twine, etc.), irrigation fees, variable depreciation on small equipment, interest on variable capital and similar items.

Total cost functions of the linear form were derived for farms with different 'fixed' labour quantities, plus other costs per farm unassociated with area and output. The fixed costs were accumulated to form the constant, k, of each synthesized equation. Then, all per hectare costs of crop production (seed, fertilizer, insecticides, etc.) were summed to provide the coefficient, a, of the linear total cost function. Dividing each of these total cost functions by H, hectares, an average total cost function was derived for each labour-cow combination. We derived such short-run cost functions for these 'fixed' labour combinations: (a) 5 labourers and 2 cows, (b) 5 labourers and 1 cow, (c) 3·5 labourers and no cows, (d) 3 labourers and 1 cow, (e) 1·5 labourers and 1 cow and (f) 1·5 labourers and no cows. Cost curves for these six combinations of 'fixed' labour were computed for both rice farms and rice-sweet potato farms. However, since the results were so highly similar between the two types of farms, we present only those for rice farms. We also present only the average cost curves derived from the synthesized total cost functions.

The labour combinations above provide the 'fixed' resources for different sets of short-run cost functions. Labour, with the majority coming typically from the family, cow power and the associated small equipment usually serve as the fixed collection of resources while land area and cropping costs serve as the 'variable resources' defining different sizes of units and outputs.

Per hectare costs with no yield loss

The curves of average cost per hectare for the six labour-cow combinations are presented in Figure 2. Without considering yield reduction due to 'untimeliness' as farm size in area is increased against each of these combinations, the curves decline sharply at the outset as the fixed component of cost is divided by a growing value of H. However, the constant variable cropping costs per hectare dominate as land area increases and the curves all become quite flat. Considering all of the labour-cow combinations, the curves become relatively flat between 2·5 and 4·5 hectares, depending on the curve. The per hectare cost curves become flat for small farms or areas because the fixed costs of labour and cow power are relatively small in comparison with the capital costs of materials used in crop production. Even without considering yield and revenue losses per hectare due to 'untimeliness', farms larger than six hectares evidently have no important cost economies for the technologies considered.

Costs considering 'untimeliness'

The functions in Figure 2 for costs per hectare are somewhat unrealistic. If land area were increased continuously against given labour and cow inputs, slightly lower per hectare costs would occur but yield and revenue per hectare would decline. Accordingly, we have used data on time of operations, labour requirements and yield relationships to compute per hectare costs when yields are held at constant levels for farms of all areas and labour-cow combinations. To maintain constant yield (avoid yield losses) and revenue, we allow added labour to be hired at different peak periods in the production process. As the number of hectares increased for a given labour-cow combination, hired labour increasingly must be added (if yield losses are avoided) at times when help is in greatest demand and seasonal wages are highest. The resulting per hectare cost functions for each fixed labour-cow combination are presented in Figure 3. These short-run cost functions each attain a minimum and then increase slowly. The farm size in hectares at each labour-cow combination is given in Table 4, along with the per hectare

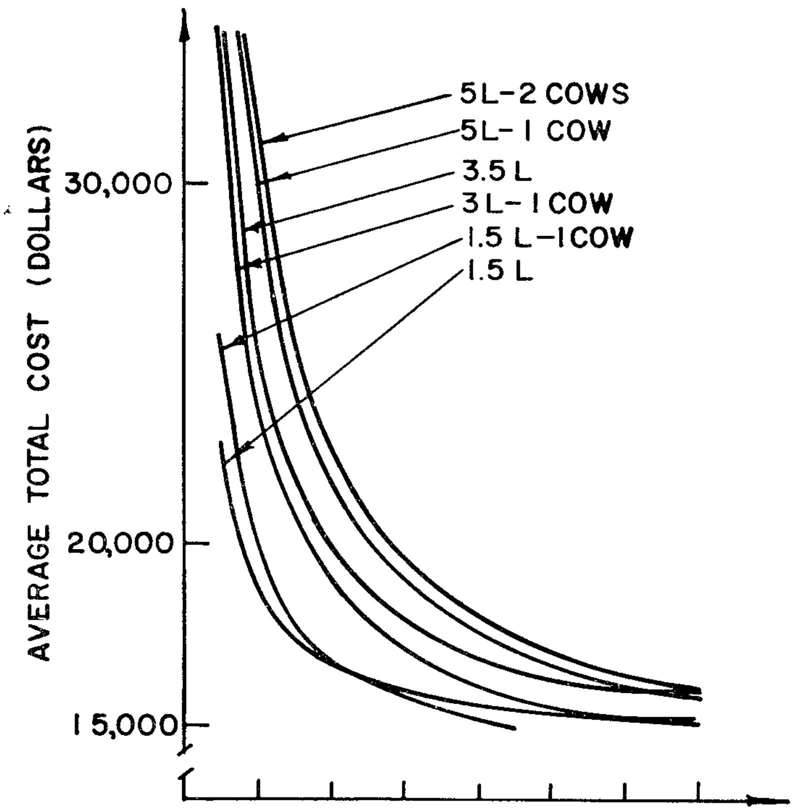

FIG. 2—Average total cost per hectare from budgeting estimation with no yield losses in rice.

TABLE 4

Cost per Hectare for Six Labour-cow Combinations on Rice Farms from Budgeted Cost Functions Including Untimeliness

Labour-Cow Combination	Farm Size for Minimum per Hectare Cost (ha.)	Minimum Average Cost per Hectare (N.T. $)
1·5 *L*–0 cow	1·6	17,456
1·5 *L*–1 cow	1·8	17,662
3·0 *L*–1 cow	3·4	17,091
3·5 *L*–0 cow	4·2	17,366
5·0 *L*–1 cow	4·6	17,168
5·0 *L*–2 cow	5·7	17,126

cost at this size. The corresponding short-run cost functions are presented in Figure 3.

The difference between the functions in Table 4 and Figure 3 at the minimum costs averages less than 1 per cent. Hence, for all practical purposes, a farm with a combination of 1·5 labour, 1 cow and 1·6 hectares appears highly competitive from a cost standpoint, with one having a combination of five labourers, two cows and 5·7 hectares (and vice versa). Of course, the larger farm will have a larger net income for

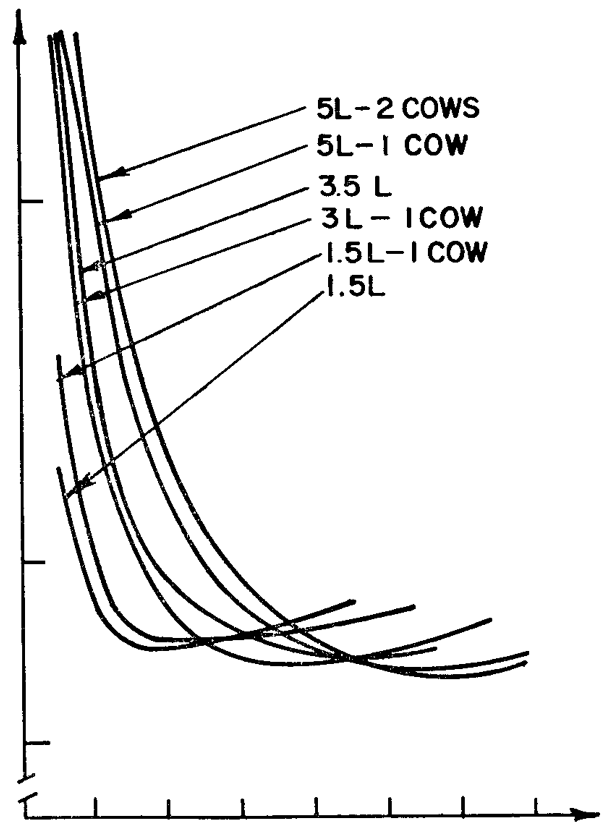

FIG. 3—Average total cost per hectare from budgeting estimation with yield losses in rice.

the family, but its cost per unit of production is not importantly different. In terms of our computations, a farm with three labourers, one cow and 3·4 hectares has the lowest average cost ($17,091) per hectare (an amount also quite comparable to the minima posed for the regression-estimated short-run cost functions). However, the minimum cost for this combination differs so little from the minima for other combinations examined that we might consider them equal. (Oversights or errors in cost items included might account for the 3·3 per cent difference, Table 4, between this combination and the one with the highest minimum cost, $17,662.)

'Long-run' synthesized cost function

By selecting tangent and minimum points of the short-run per hectare functions for the various labour-cow cost curves in Figure 3, we have developed the envelope or 'long-run' cost function in Figure 4. It declines sharply over small land areas, as do all of the short-run functions in Figures 2 and 3. It then 'flattens out' while declining slightly to its minimum point at 3·5 hectares. It then increases at a slow rate. The 'long-run' cost per hectare curve is nearly 'flat' over an area ranging from 1·5 to 5·0 (or more) hectares. The per hectare costs at 1·5 and 5·0 hectares differ by less than 5 per cent. The 'flatness' of the 'long-run' curve is consistent with the general configurations of the short-run functions in both Figures 2 and 3. It also is highly consistent in slopes, although the height differs considerably, from the regression-estimated long-run (monotonically decreasing) curve in Figure 1. At least, all evidence indicates that major cost economies have been attained for the technologies involved at a small hectare value; and economies or diseconomies thereafter are very slight and perhaps unimportant from an efficiency standpoint.

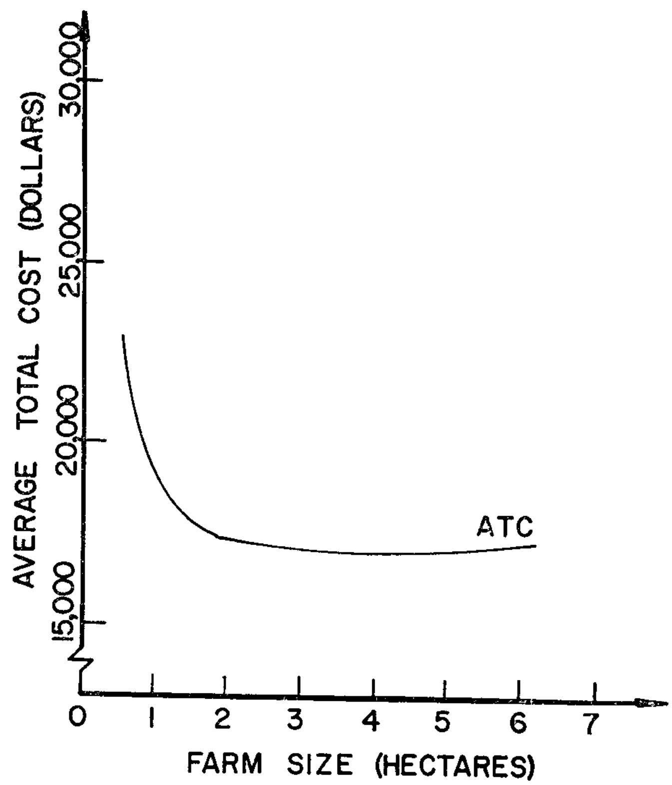

FIG. 4—Long-run total cost-acreage function from budgeting estimation with yield losses in rice producing region.

Conclusions

Rice farms in the sample averaged 1·75 hectares, 3·45 labour units and 0·87 cows. (Obviously, few farms have a fraction of a cow, but the typical farm had one cow and 3·5 labour units.) Farms of this size evidently are of a scale and have a resource mix which would allow them to attain the main cost economies which seem to prevail under the technological conditions examined. The sample did include about a third of the farms with less than one hectare. These units are too small to have attained the main cost efficiencies, when the value of family labour is considered, even though major cost efficiencies (a) are attained with a rather small land area and (b) do not increase appreciably up to five hectares.

The 'flat bottom' of the cost function in Figure 4 suggests that there is no great policy imperative in increasing farm size beyond the average of the sample or of several typical existing sizes ranging from 1·5 to 5·0 hectares; but there is need to see that inheritance laws and customs do not lead to continued fragmentation into mini-farms. Of course, these statements apply as long as an economic era prevails wherein human and cow labour have relative costs or prices which favour them over mechanical power and associated equipment. The cost functions estimated suggest also, technologies remaining constant, that a different social organization of farms (e.g., farming co-operatives) would not necessarily bring greater farming efficiency. This statement applies in terms of scale or cost economies internal to the farm. (Marketing co-operatives are still implied if this sector possesses important internal or external scale economies.)

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