Appraising Rice Production Efficiency in Taiwan under the Contract Cultivation System

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Abstract: The popularly accepted rice production system in Taiwan is contract cultivation. This paper investigates the production efficiency of rice farming under the contract cultivation system. Data obtained from the financial accounts of 60 rice-farming families are used and estimated in a translog cost function. The efficiency indicators are the elasticities of input demand combinations with respect to own- and cross-input prices and the average incremental cost. The results show that contract labour demand is the most rigid input for the adjustment of rice production efficiency. The low elasticities of input substitution and of per-unit output variable cost further prove the limited ability of rice farmers to improve efficiency except via deregulation and land policy. Some policy implications are also presented.

Introduction

Over the past three decades, several major systems of farm operation have been introduced in Taiwan's agriculture to expand the scale of farming. These are joint, contract, and cooperative operations and contract cultivation. Each system is designed to do what its name implies. The underlying policy objectives were to promote modernization and industrialization of small farms and effectively to solve family farming problems in the long run. In order to improve the efficiency of application of farm resources, programmes to expand the scale of farming were advocated and introduced. However, the performance of the various systems have shown great discrepancies. Recent reports showed that only the contract cultivation method is acceptable to general farmers.

The popularity of rice contract cultivation has been influenced by the supply of inputs and equipment from seedling centres. These centres were established after 1979 with the aim of encouraging joint planting and use of farming equipment. The major objective was to increase productivity. As a result of outflow of farm labour from the agricultural sector, continuous technology transfer, and the subsidized purchase of farm machinery, some specialized farmers have bought machines to substitute for labour. However, most small farmers have relied on contract cultivation in the form of soil management, transplanting, harvesting, and drying. As a result, contract cultivation has become the major operating system of the rice industry. Under the regulated rice supply policy, the rice price is at a comparatively low level, which focuses rice production on efficiency of resource distribution and minimum costs.

To study the performance of rice production under the contract cultivation system, a cross-sectional multi-input translog cost function was specified. A survey was carried out in September 1990 involving 60 rice farms in central Taiwan. Data on annual cost structure and output were collected to estimate the model. Neoclassical duality theory provides an approach for computing various pairwise elasticities of substitution between inputs, own-, and cross-price elasticities of demand for inputs and for computing product-specific elasticities in the short run.

Theoretical Model

The 1-output-n-input translog cost function is specified as:

$$(1) \quad \ln C_v = \alpha_0 + \alpha_y \ln Y + \sum_i \beta_i \ln P_i + \sum_i \sum_j \beta_{ij} \ln P_i \ln P_j + \sum_i \delta_i \ln Y \ln P_i$$

C_v is total variable cost, Y is rice output, and P_i is the price of input i. Technology transfer is excluded from the cross-sectional approach. Neoclassical theory further suggests a symmetric property of $\beta_{ij} = \beta_{ji}$. Any sensitive cost function must enable inputs to be homogeneous of one degree (Ray, 1982). It is assumed that the input prices of (1) are linearly

homogeneous of degree one. Thus, the quadratic approximation of the cost function implies the following $i + 1$ conditions:

(2) $\sum \beta_i = 1$, $\sum \beta_{ij} = 0$, $\sum \delta_i = 0$

By differentiating the translog cost function applying Shephard's lemma, the following variable cost share functions are obtained:

(3) $S_i = \dfrac{\partial \ln C_v}{\partial \ln P_i} = \beta_i + \sum_j \beta_{ij} \ln P_j + \delta_i \ln Y$

To coordinate with the linearly independent requirement, one of the cost share functions must be excluded from the estimation of the equation system (Christensen and Greene, 1976). The price of the excluded cost share would become the numeraire price of other inputs. Since other variable costs are minimal, they are substituted by one as a proxy price.

The estimation involves six major steps. First, survey data are transformed into variable costs, output, variable input prices, fixed costs, and cost shares, while at the same time all variables are deflated by their geometric means. Second, a system of joint variable cost and cost share functions is jointly estimated using the iterated seemingly unrelated regression technique with the imposition of linear restrictions. Third, the estimated parameters are further investigated with tests on heteroscedasticity as well as input separability (Berndt and Christensen, 1973). Fourth, the estimated parameters are used to calculate Allen $(_aE_{ij})$, Morishima $(_mE_{ij})$, and McFadden shadow $(_sE_{ij})$ input substitution elasticities:

(4) $_aE_{ij} = \dfrac{1}{S_i S_j} \beta_{ij} + 1 = \dfrac{\beta_{ij}}{S_i^2} (\beta_{ij} + S_i^2 - S_i)$

(5) $_mE_{ij} = S_i \left({_aE_{ij}} - {_aE_{jj}} \right)$

(6) $_sE_{ij} = \dfrac{S_i S_j}{S_i + S_j} (2 {_aE_{ij}} - {_aE_{it}} - {_aE_{jt}})$

Finally, the elasticity of the average incremental cost (*AIC*) is calculated:

(7) $AIC(Y) = \dfrac{\partial \ln \dfrac{C_v}{Y}}{\partial \ln Y}$

The establishment and estimation of the model were also assisted by reference to Hanoch (1975) and Debertin and Paagoulatos (1985).

Cost Structure and Statistical Results

The cost structure of rice production in Taiwan can be explained through the production procedure. Inputs can be categorized as the fixed inputs of land and long-term capital as well as the variable inputs of contract labour, own labour, and variable capital. Long-term capital includes the discount values of farm buildings, machinery, and equipment. Land includes own- and rented-land values. Labour costs comprise the expenses resulting from soil management, transplanting, weeding, fertilizing, harvesting, and drying. Farmers are free to choose a combination of contract and own cultivation. Short-run capital involves expenditure on seeds, fertilizers, pesticides, and insecticides.

The descriptive statistics are shown in Table 1. The largest share of long-term capital (F_1) implies the intensive capitalization of rice production. The large share of the variable cost (C_v) indicates possible improvement of the cost structure. Other statistics further show that existing data have included a wide range of farm sizes. Among the variable input prices $(P_1, P_2,$ and $P_3)$, the mean price of own labour is the highest. This implies that most farmers put

a lot of time into rice production. The research thus represents not only part-time farming but rice-specialized farming.

Table 1—Descriptive Statistics of Farms under the Contract Cultivation System

Variable	Sample Mean	Standard Error	Minimum Value	Maximum Value	Geometric Mean
C_v	299,161.7	153,344.4	130,788	929,442	270,866.10
Y	19,532.25	15,579.79	1,900	89,100	14,823.87
P_1	28,618.96	12,641.64	5,600	62,636.36	25,656.18
P_2	51,030.42	36,183.52	6,893.94	204,545.45	40,078.57
P_3	25,264.04	6,447.43	17,210	48,553.33	24,580.64
F_1	935,535.70	1,305,423	20,016	9,382,500	540,660.5
F_2	56,999.53	48,761.42	5,557.50	235,188.50	40,309.21
S_1	28.54	9.90	11.06	54.62	26.76
S_2	44.37	13.94	11.63	68.89	41.80
S_3	27.08	8.75	10.11	55.00	25.64

C_v = variable costs (NT\$/year); Y = output (kg/year); P_1 = contract labour price (NT\$/acre); P_2 = own labour price (NT\$/acre); P_3 = short-run capital price (NT\$/acre); F_1 = long-run capital (NT\$); F_2 = land (NT\$); S_1 = contract labour price (percent); S_2 = own labour share (percent); and S_3 = short-run capital share (percent).

The estimated results are shown in Tables 2 and 3. The exponential of the intercept in the cost function represents total variable costs at its geometric mean. Using the estimated coefficients and linear restrictions, the coefficients of the third cost share equation are calculated.

Tests for heteroscedasticity and separability are also performed. The Glejser and Breusch-Pagan tests are applied for the former. The resulting χ^2 values are large enough for the rejection of heteroscedasticity. The test for separability is performed by taking some cost elements such as interest payments, material input costs, and meal subsidies out of the original cost categories and making them the fourth cost category. Using the χ^2 test on the results of three variable inputs and four variable inputs, the three-input case is accepted as reasonable. The estimated results are then used to calculate related elasticities.

Table 4 shows Allen, Morishima, and McFadden own- and cross-price elasticities as well as those for factor demand. Factor demand own-price elasticities are inelastic and negative in sign. Short-run capital input has the greatest variability among the three variable inputs. Own-price factor demand elasticity is also high as compared to short-run capital input. However, the price elasticity of demand for contract labour is close to zero. It represents existing conditions in the prevailing contract cultivation system. The number of aged farmers and the farm labour shortage are the main reasons for the decision of most farms to adopt contract cultivation. Such farms also have to pay for contract labourers using suitable machines in order to complete certain rice production processes.

Own labour has very little substitution effect on the contract labour price, with a cross elasticity of only 0.0967; i.e., a 0.967-percent increase in own labour demand is expected in response to a 10-percent increase in the contract labour price. When the own labour price is increased, farmers may start thinking of some substitution away from contract labour and short-run capital. If own-labour price increases by 10 percent, the demands for contract labour and short-run capital are anticipated to increase by 1.504 and 3.405 percent, respectively. Short-run capital is the preferred choice in such a situation. Short-run capital may be partially substitutable for contract input, and vice versa. In the short run, both contract and

own labour may be substitutable for capital. As a result, farmers may choose variable substitutes while factor prices, except for contract labour, change, but would not take such action in the short run.

Table 2—Estimated Parameters of the Translog Variable Cost *F*unction

Variable	Estimated Coefficient	*t*-value
Constant	−0.057755**	−2.91
ln Y	0.743668**	12.35
ln P_1	0.285571**	172.83
ln P_2	0.443337**	217.98
ln P_3	0.271093**	140.91
ln P_1 ln P_1	0.091472**	50.79
ln P_1 ln P_2	−0.083706**	−26.15
ln P_1 ln P_3	−0.007766*	−2.51
ln P_2 ln P_2	0.111653**	36.15
ln P_2 ln P_3	−0.027947**	−7.61
ln P_3 ln P_3	−0.023121	−1.45
ln F_1	−0.015458	−0.84
ln F_2	0.224017**	4.41
ln F_1 ln F_1	0.030887*	1.98
ln F_1 ln F_2	0.143247*	2.11
ln F_2 ln F_2	−0.220992*	−2.35
ln Y ln P_1	0.038127**	12.29
ln Y ln P_2	0.019036**	3.47
ln Y ln P_3	−0.057163**	−10.39
ln Y ln F_1	−0.058386	−0.81
ln Y ln F_2	0.171398	1.58
ln P_1 ln F_1	0.079078	1.70
ln P_1 ln F_2	−0.120905*	−2.43
ln P_2 ln F_1	0.187154*	2.06
ln P_2 ln F_2	−0.149429	−1.83
ln P_3 ln F_1	0.005382	0.08
ln P_3 ln F_2	0.242092*	2.41

$R^2 = 0.953$, $DW = 1.638$, $D.F. = 33$
*Significance level is 0.025.
**Significance level is 0.005.

Table 3—Estimated Coefficients of the Share Functions

	Estimated Coefficient	*t*-value
S_1: Constant	0.2855706	172.83
P_1	0.1829436	50.79
P_2	−0.08370554	−26.15
P_3	−0.007766269	−2.51
Y	0.03812664	12.29
S_2: Constant	0.4433368	217.98
P_1	−0.08370554	−26.15
P_2	0.2233054	36.15
P_3	−0.02794714	−7.60
Y	0.01903598	3.47
S_2: Constant	0.2710926	
P_1	−0.007766269	
P_2	−0.02794714	
P_3	−0.0462416	
Y	−0.05716262	

The Allen elasticity considers the effects of relative factor price movement on factor substitution. The own-price elasticities of own labour and short-run capital are elastic and negative in sign. The own-price elasticity of contract labour input is also very inelastic. For cross-price elasticity in the short run, own labour and contract labour possess very inelastic substitutability. However, short-run capital is considered as a near perfect substitute for both contract and own labour.

The Morishima elasticity takes own elasticity into account weighted by own cost share. Since the own-price elasticities of own labour and short-run capital are high in value, the Morishima elasticities are mostly near one for these two inputs. Here, contract labour shows greater substitutability for own labour than that in Allen's. The substitutability of own labour and short-run capital for contract labour is very inelastic. The low own-price Allen's elasticity of contract labour depresses the substitutability of short-run capital for contract labour. In the short run, these results better capture the reality.

Table 4—Own- and Cross-Price Elasticities

Inputs	P_1	P_2	P_3
Factor demand:			
Contract labour	−0.0735923	0.1504082	0.2435884
Own labour	0.0967467	−0.7449533	0.2078136
Short–run capital	0.2567213	0.3404981	−0.8145803
Allen elasticity:			
Contract labour	−0.2578567	0.3389862	0.899514
Own labour		−1.6789571	0.7674062
Short–run capital			−3.0080513
Morishima elasticity:			
Contract labour	0	0.8953614	1.0581686
Own labour	0.1703389	0	1.0223938
Short–run capital	0.3303135	1.0854513	0
Shadow (McFadden) elasticity:			
Contract labour	0	0.4541423	0.7037936
Own labour		0	1.0462924
Short–run capital			0

P_1 = per acre price of contract cultivation; P_2 = per acre price of own cultivation; and P_3 = per acre price of short-run capital input.

The McFadden elasticity considers own-price elasticity and relative cost share more than the Morishima elasticity and becomes symmetrical. As a result, the cross relationships among the three short-run inputs are similar to Allen's except for the substitution between own labour and short-run capital. Own labour and short-run capital turn out to have elastic substitution while the variables remain inelastic. This results from the high values of both own elasticities.

The result of average incremental cost (AIC) is 10.39, which indicates an inefficient production system. As rice output increases by 1 percent, the per-unit variable cost increases nearly tenfold. Under conditions of rising labour wages and other input costs, a low productivity growth rate would be detrimental to rice production efficiency. Such an inefficient production situation could be highly correlated to government programmes on land ownership, mechanized farming, and crop conversion.

Conclusion

This research uses 1990 sample cost data from 60 rice farmers to analyse cost structure and production efficiency in Taiwanese rice production. The translog cost function associated with cost share equations is estimated using the seemingly unrelated regression technique. The estimated results are collected to calculate short-run own- and cross-input price elasticities and the average incremental variable cost. The calculated elasticities are then analysed to evaluate of rice production efficiency in Taiwan.

Own- and cross-price elasticities and the average incremental costs well capture rice farmers' production characteristics in Taiwan. Farmers are concerned about own labour and short-run capital price changes but not about contract labour. The rigidity of adjusting contract cultivation under conditions of labour shortage is evident in rice production. It turns out that only own labour and short-run capital can be substituted elastically. Some farmers may still be able to substitute short-run capital for contract labour while substitution between

own labour and contract labour is limited. As a result, rice farmers have a very limited ability to perform short-run cost minimization and thus improve production efficiency. Moreover, the elasticity of per unit output variable cost gives little hope of improving rice production efficiency without deregulation.

The results may provide some policy implications for the rice programme in Taiwan. The variability of short-run capital input prices must be maintained within a certain range under the contract cultivation system for the possible improvement of the cost structure and thus production efficiency. Since there is little substitutability of contract cultivation for other variable inputs, the extension programme to organize contract cultivation for efficient operation may be important for the improvement of overall production efficiency. Finally, the high cost share of own labour may imply failure of programmes to mechanize rice production and need re-evaluation.

Note

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Discussion Opening—*Bradley J. McDonald* (US Department of Agriculture)

Lo and Hwang use a translog cost function approach to estimate econometrically input relationships for rice production in Taiwan. The study uses data from a cross-section of 60 Taiwanese rice farms, apparently all using a system of contract cultivation. The parameter estimates from the translog cost function are used to draw conclusions about the production efficiency of the contract cultivation system for rice in Taiwan and for Taiwanese rice policy.

My first concern with the paper is that its stated objective is to investigate production efficiency, but this is not actually done. Instead, the econometric estimation in the paper relates to the measurement of optimal input relationships.

The type of exercise conducted in this paper is, nevertheless, valuable. Among many potential applications is the use of the estimated parameters in calibration studies, such as applied general equilibrium models. The authors of this paper are to be congratulated for the thorough reporting of results. For example, they not only present the Allen elasticity of substitution matrix resulting from their estimation but also the Morishima and McFadden substitution elasticities and the price elasticities. They point out important differences

between these measures and, although these could be derived by the reader, it is convenient to have them reported in the paper.

A second concern is that, unfortunately, the integrity of the results can be called into question by the apparent failure of some parameter restrictions, suggested by microeconomic theory, to hold. For example, in Equation (2), it is noted that the sum over i of β_{ij} should equal zero. The restriction seems to have been applied for the first two inputs but not for the third (see Table 2). The Euler condition on the Allen elasticity of substitution matrix, which requires the row sum of Allen elasticities, when weighted by cost shares, to equal zero, is therefore violated (see Table 4 and the cost shares in Table 1).

These two concerns lead me to believe that the conclusions drawn in the paper regarding efficiency of rice production in Taiwan may not be valid.

If the authors' interest lies in the comparison of production efficiency under the contract cultivation system with that of other systems in Taiwan (such as joint management or cooperative operation), it may be desirable to use another approach.