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Abstract

Smallholders increasingly combine shrimp culture with the more traditional rice enterprise in regions of Thailand suitable for raising shrimps. They can exploit cost complementarities in production by combining activities in these enterprises within their farming systems. At the same time, it makes them more susceptible to on-farm negative externalities between rice and shrimp production, in both directions, causing scope diseconomies. A stochastic input distance model is estimated using data on shrimp and rice production by 52 smallholder households. Results from the estimated model are used to establish whether scope economies or diseconomies exist and whether specialisation in either shrimp or rice production significantly influences technical efficiency on the sampled smallholdings.

Significant scope economies were found to exist between the two enterprises among best-practice smallholders but they were offset by diversification inefficiencies beneath the frontier. Hence, specialisation in one of the two enterprises has two effects on productivity that operate in opposite directions. The first effect is a negative impact on productivity via loss of scope economies. The second effect is an increase in productivity by reaping specialisation efficiencies or, put another way, avoidance of diversification inefficiencies. If on-farm negative externalities between rice and shrimp production do exist, they appear to be strongly outweighed by cost complementarities on the frontier. It is likely that 'best-practice' smallholders are able to 'internalise' the negative externalities in both directions to a substantial degree. They achieve this 'internalisation' by regular use of fresh water in a semi-closed pond system of shrimp production that minimises pond contamination and protects them from the activities of surrounding producers who discharge effluent into the waterways or whose shrimp suffer from diseases.

In addition to the degree of enterprise specialisation, the level of schooling of the household head and the tenure system in shrimp and rice production were identified as variables that significantly influence technical inefficiency. As expected, higher education is associated with lower technical inefficiency. Tenancy is also associated with lower technical inefficiency. Results indicate that a small but significant level of technical inefficiency exists, which means there is limited opportunity to expand crop output without resort to greater use of factor inputs or the introduction of improved production technologies.

Key Words: scope economies, specialisation efficiencies, input distance function, Thailand, smallholders, technical efficiency

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1. Introduction

This paper reports on an analysis of scope economies and the impact of specialisation on the technical efficiency of smallholder production of shrimp and rice in Thailand. The production process within each enterprise can have an impact on the other, and the outcome of these interactions could be either productivity gains or productivity losses. On one hand, complementarities and enhanced flexibility in production could yield scope economies and efficiencies from diversifying production. On the other hand, negative externalities and the greater complexity of farm organisation brought about by enterprise diversity could cause diseconomies of scope and diversification inefficiencies (or specialisation efficiencies).

The analysis undertaken in this study is based on the results of detailed monitoring by Mekhora (2001) of Thai smallholdings predominantly engaged in shrimp and rice production. Analysis focuses on scope economies/diseconomies and specialisation efficiencies/inefficiencies in the integrated shrimp and rice sub-systems. Information is provided on the extent of technical inefficiency, and we present results of tests of the relevance of a number of factors that are expected to influence technical inefficiency in the production system as a whole.

2. Study location and data

The data used in this analysis were collected by Mekhora (2001) from 112 farmers for the production season of 1998. Farmers were selected from four provinces: Chachoengsao, Nakhon Nayok, Prachin Buri and Chainat. From the full sets of observations on shrimp and rice production, it was possible to identify 54 households that were active in both enterprises. Incomplete data on two households reduced the sample size to 52. The proportion of the total value of output derived from shrimp production by these 52 households varied from 34 per cent to 99 per cent.

Mekhora (2001, pp. 66-92) provides a detailed description of the characteristics and production technologies of the sampled farms. Shrimp production is based on the intensive cultivation of black tiger shrimp using specially formulated feed that stimulates growth and enables high stocking rates.

3. Method of analysis

3.1 Economies of scope

Coelli and Fleming (2003) observed that economies of scope are traditionally defined relative to a cost function, and gave an example of a firm producing two outputs, $y = (y_1, y_2)$, with a particular vector of fixed input quantities, z, and facing a particular vector of variable input prices, w. They defined the variable cost function of this firm as

(1) $C = c(y, z, w)$,

where $c(.)$ is a function satisfying the usual homogeneity, monotonicity and curvature properties, and observed that scope economies exist if the firm can produce y_1 and y_2 at a lower cost than two separate firms specialising in the production of the two outputs. Information on the second cross partial derivatives of an estimated cost function can be used to test for scope economies in the general case of outputs i and j as:

(2) $$\frac{\partial^2 C}{\partial y_i \partial y_j} < 0, \quad i \neq j,\ i, j = 1,...,m,$$

where C is the cost of m outputs and y_i is the i-th output variable (Deller, Chicoine and Walzer 1988).

Following Coelli and Fleming (2003), we diverge from this standard approach by estimating an input distance function instead of a cost function on the premise that the cost minimisation assumption is unlikely to be applicable to Thai smallholders. We also allow for the possibility of inefficiency in production. Coelli, Rao and Battese (1998, p. 64) defined the input distance function as:

(3) $d(x,y) = \{D: (x/D) \in L(y)\}$,

where $L(y)$ represents the set of all input vectors, x, that can produce the output vector, y. The expression, $d(x,y)$, is non-decreasing in the input vector, x, and increasing in the output vector, y, and linearly homogeneous and concave in x. The value of the distance function is equal to or greater than one if x is an element of the feasible input set, $L(y)$. That is, $d(x,y) \geq 1$ if $x \in L(y)$. It is equal to one if x is located on the inner boundary of the input set. That is, it equals one if the firm is technically efficient and exceeds one if the firm is technically inefficient, which is the inverse of the traditional input-oriented technical efficiency measure defined by Farrell (1957) (Coelli and Fleming 2003).

We now define a measure of economies of scope relative to an input distance function. A negative first partial derivative of the input distance with respect to the *i*-th output indicates that an extra unit of output reduces the amount needed to deflate the input vector to put the observation onto the efficient frontier, other variables held constant. The second cross partial derivative would need to be positive to provide evidence of scope economies (Coelli and Fleming 2003):

(4) $$\frac{\partial^2 D}{\partial Y_i \partial Y_j} > 0, \qquad i \neq j,\ i, j = 1,..., m.$$

Whether the degree of specialisation in either shrimp or rice production leads to scope economies or diseconomies among 'best-practice' producers (those operating on the production frontier) is problematic because there are factors favouring both enterprise specialisation and enterprise diversification. On one hand, enterprise specialisation enables members of the farm household to apportion their labour and management resources to take advantage of specialist skills and knowledge, achieve product-specific scale economies and limit the need to switch between production tasks.

There are also the potential scope diseconomies caused by on-farm negative externalities between the two enterprises, caused primarily by the effluent produced by each of the two sub-systems. Negative externalities are traditionally defined as costs imposed on a third party without any compensation to the injured party. In this study, we consider externalities at two levels by distinguishing on-farm externalities from off-farm externalities. The latter take on the normal meaning of the term. In respect of the former, the shrimp and rice enterprises are regarded as separate parties for identifying on-farm negative externalities. On-farm external costs of rice cultivation emanate from deterioration in water quality with the application of fertilisers and chemicals that adversely affect shrimp culture. Those of shrimp culture arise from the disposal of waste from cultivated ponds, which have a negative impact on rice yields (Mekhora 2001, p. 26).

Offsetting potential on-farm negative externalities are the advantages of diversification through the opportunity for farmers to exploit complementarity in the use of resources in the production processes of the two enterprises. Labour, management skills and water resources used in both enterprises offer the potential to save on costs that would be incurred if the two enterprises were to be conducted on separate farms. These diversification advantages should augment the effects of any diminishing returns to inputs that normally yield a convex production possibilities frontier.

3.2 Specialisation efficiencies

While scope economies (diseconomies) refer to the technical advantages of diversification (specialisation) for producers operating on the frontier, specialisation efficiencies describe how firms with different output shares are distributed underneath the production possibilities frontier. Specialisation efficiencies occur when increased specialisation among outputs leads to lower technical inefficiency. Conversely, diversification efficiencies occur when technical inefficiency is reduced by allocating resources to various activities that have outcomes that are not closely related (Coelli and Fleming 2003).

Smallholders with diversified farming systems risk technical efficiency losses from having to devote their management skills and labour resources to a more complex farming system. The challenge to manage this complexity is made more acute by the need to avoid the negative externalities between enterprises noted in the previous section. The ability of smallholders to avoid these losses when undertaking diversified enterprises depends on how well established and understood the production practices of the different enterprises are. Mekhora (2001, pp. 10-24, 77-78) reported the strong history of rice and shrimp production in Thailand, and the effective adoption of low-salt shrimp culture within a semi-closed recycling system. Smallholders, he observed, are well versed in the requirements of these two enterprises and have successfully integrated them into their farming systems. He pinpointed three reasons why the operation of a more complex diversified farming system might not result in greater technical inefficiencies. First, the semi-closed low-salt recycling system employed to raise black tiger shrimp has proved suitable to the circumstances of smallholders. Second, management skills have improved as farmers have become more experienced in shrimp culture. Third, the new inland culture areas that were developed, and from which the sample smallholdings were drawn, are more amenable to successful shrimp culture, with cheap and reliable power sources and sound infrastructure.

Diversification can be turned to technical advantage by creating potential to avoid efficiency losses associated with specialisation. This potential derives from flexibility in farming operations that tempers efficiency losses caused by the pervasive production risks in smallholder agriculture. A specialised farming system may be more vulnerable to major efficiency losses because of its inflexibility in the face of unexpected adverse events over which the farmer has little control.

The model estimated in this study enables us to investigate how inefficient firms vary their technical efficiency according to the degree of specialisation. To this end, we apply the inefficiency effects stochastic frontier model specified by Battese and Coelli (1995).

We adopt the same practice as Coelli and Fleming (2003) in specifying the specialisation variable as an ogive index of concentration of output shares of shrimp and rice. This index measures deviations from an equal distribution of output shares between production activities. It is defined as:

$$(5) \qquad Ogive = \sum_{n=1}^{N} \frac{(X_n - 1/N)^2}{1/N}$$

where N is the total number of production activities under consideration; $1/N$ is perfect diversification of output among activities (equal to 0.5 for all observations); and X_n is the share of output of the n-th production activity (Ali, Alwang and Siegel 1991).

3.3 Other factors affecting technical efficiency

Seven efficiency variables in addition to the specialisation variable were tested for inclusion in the estimated efficiency effects model. They are the years of experience in shrimp and rice production, proportion of female labour employed in production, age of the household head, education level of the household head, main source of technical knowledge on production and land tenure system.

Puangsumalee, Mekhora and Fleming (2004) provide evidence on how these variables are estimated to influence the technical efficiency of the separate operations of shrimp and rice production. They also present the rationale for inclusion, measurement and expected signs of these variables.

4. Estimated model

A multi-input multi-output stochastic input distance function was estimated, and results were used to calculate a technical efficiency index for each sampled smallholder and mean technical efficiency across all smallholders during the study period. The model was based on a translog functional form that was not fully flexible in that separability was assumed between inputs and outputs owing to limitations on degrees of freedom, given the numbers of observations and parameters to be estimated. The means of the logged variables were adjusted to zero prior to estimation so that the coefficients of the first-order terms of inputs could be interpreted as partial output elasticities, evaluated at the sample means.

After combining inputs common to both shrimp and rice production, 11 input variables were tested for inclusion in the model for estimation. While it would have been desirable to include all variables, the limited number of degrees of freedom dictated that only those inputs found to be significant explanators were included, based on likelihood ratio tests. As a result of these tests, six input variables were included in the estimated model, detailed below, while seed, fry, lime, fuel and saline water were excluded.

Following Coelli and Perelman (1996), the translog input distance function is defined as:

$$
\begin{aligned}
(6)\qquad \ln d_i = {} & \beta_0 + \alpha_1 \ln YS_i + \alpha_2 \ln YR_i + 0.5\alpha_3 \ln(YS_i)^2 + 0.5\alpha_4 \ln(YR_i)^2 \\
& + \alpha_5 (\ln YS_i)(\ln YR_i) + \beta_1 \ln A_i + \beta_2 \ln L_i + \beta_3 \ln FR_i + \beta_4 \ln CR_i + \beta_5 \ln FD_i \\
& + \beta_6 \ln CS_i + 0.5\beta_7 (\ln A_i)^2 + 0.5\beta_8 (\ln L_i)^2 + 0.5\beta_9 (\ln FR_i)^2 + 0.5\beta_{10} (\ln FD_i)^2 \\
& + 0.5\beta_{11} (\ln CS_i)^2 + 0.5\beta_{12} (\ln CR_i)^2 + \beta_{13} (\ln A_i)(\ln L_i) + \beta_{14} (\ln A_i)(\ln FR_i) \\
& + \beta_{15} (\ln A_i)(\ln FD_i) + \beta_{16} (\ln A_i)(\ln CS_i) + \beta_{17} (\ln A_i)(\ln CR_i) + \beta_{18} (\ln L_i)(\ln FR_i) \\
& + \beta_{19} (\ln L_i)(\ln FD_i) + \beta_{20} (\ln L_i)(\ln CS_i) + \beta_{21} (\ln L_i)(\ln CR_i) + \beta_{22} (\ln FR_i)(\ln FD_i) \\
& + \beta_{23} (\ln FR_i)(\ln CS_i) + \beta_{24} (\ln FR_i)(\ln CR_i) + \beta_{25} (\ln FD_i)(\ln CS_i) \\
& + \beta_{26} (\ln FD_i)(\ln CR_i) + \beta_{27} (\ln CS_i)(\ln CR_i)
\end{aligned}
$$

where *YS* is the output of shrimp, in kilograms; *YR* is the output of rice, in kilograms; *A* is the total area devoted to shrimp and rice production, in hectares; *L* is labour inputs in shrimp and rice production, in hours; *FR* is fertiliser inputs, in kilograms; *CR* is chemicals used in rice production, in litres; *FD* is shrimp feed inputs, in kilograms; *CS* is chemicals used in shrimp production, in litres; and the subscript, *i*, denotes the *i*-th producer.

A major agricultural policy concern has been the negative impact of increased salinity on rice yields over time brought about by shrimp production. An alternative model was estimated in which the number of years of experience in shrimp production replaced the rice chemicals variable. This variable is a good proxy for the length of time that shrimp culture has been practised on a farm. Hence, it should reflect the accumulated negative effects of salinity on rice yields caused by shrimp production.

The estimating form of the stochastic input distance function was obtained by setting $-ln\ d_i = v_i - u_i$ and imposing the restriction required for homogeneity of degree +1 in inputs. The negative of $ln\ A_i$ was set as the dependent variable. As is normal practice, the v_is are assumed to be independently and identically distributed with mean zero and variance, σ_v^2; and the u_is are technical efficiency effects that are assumed to be independently distributed such that u_i is defined by the truncation at zero of the normal distribution with unknown variance, σ_u^2, and unknown mean, μ_i, defined by Coelli and Perelman (1996) as:

$$(7) \qquad \mu_i = \delta_0 + \sum_{m=1}^{8} \delta_m z_{mi} ,$$

where z_1 is enterprise specialisation, measured by the ogive index; z_2 is the number of years experience in shrimp production; z_3 is the number of years experience in rice production; z_4 is the proportion of female labour, measured as the number of female labourers divided by the total number of labourers who worked in shrimp and rice production; z_5 is the age of the head of household in years; z_6 is a dummy variable, which equals one if the main source of knowledge of production is received from the extension agency and zero otherwise; z_7 is a dummy variable for the education level of the household head, which equals one if the farmer has proceeded beyond primary school and zero otherwise; and z_8 is a dummy variable for land ownership, which equals one if at least part of the land farmed is on a tenancy arrangement and zero otherwise.

The input distances are predicted as:

$$D_i = E[\exp(u_i)|\ e_i]$$

where $e_i = v_i - u_i$ (Coelli and Perelman (1996, p. 14).

The computer software package, FRONTIER 4.1 (Coelli 1996), was applied to estimate the parameters of the model using maximum-likelihood procedures.

5. Results

A summary of results is presented in Table 1. Shrimp feed and fertiliser were found to be the main inputs influencing shrimp and rice output, with partial output elasticities (and standard errors in parenthesis) of 0.396 (0.063) and 0.095 (0.024), respectively. The elasticities for labour and shrimp chemicals are 0.058 (0.088) and 0.063 (0.015). The sum of the coefficients, α_1 and α_2, of the two output variables, shrimp and rice, is 0.953. The inverse of this figure, 1.049, provides a measure of ray scale economies (at the sample means), suggesting very slightly increasing returns to scale.

Table 1
Estimates of Stochastic Frontier Production Function

Variable	Estimated coefficient	Standard error	*t*-value
Constant	-1.293	0.018	-72.832
$ln\ Y_s$	-0.507	0.062	-8.175
$ln\ Y_r$	-0.445	0.061	-7.314
$ln\ Y_s^2$	-0.246	0.057	-4.332
$ln\ Y_r^2$	-0.171	0.072	-2.367
$ln\ Y_s * lnY_r$	0.109	0.040	2.699
ln L/A	0.058	0.088	0.659
ln FR/A	0.095	0.024	3.991
ln CR/A	-0.055	0.025	-2.205
ln FD/A	0.396	0.063	6.288
ln CS/A	0.063	0.015	4.087
$ln\ (L/A)^2$	1.646	1.088	1.512
$ln\ (FR/A)^2$	0.005	0.034	0.132
$ln\ (CR/A)^2$	-0.076	0.123	-0.615
$ln\ (FD/A)^2$	0.624	0.239	2.608
$ln\ (CS/A)^2$	0.097	0.030	3.250
*ln (L/A) * ln (FR/A)*	-0.360	0.155	-2.328
*ln (L/A) * ln (CR/A)*	0.259	0.249	1.043
ln (L/A) ln (FD/A)*	-1.008	0.501	-2.012
ln (L/A) ln (CS/A)*	-0.230	0.124	-1.858
*ln (FR/A) * ln (CR/A)*	0.036	0.052	0.686
*ln (FR/A) * ln (FD/A)*	0.192	0.073	2.626
*ln (FR/A) * ln(CS/A)*	-0.027	0.024	-1.150
*ln (CR/A) * ln(FD/A)*	-0.176	0.131	-1.346
*ln (CR/A) * ln (CS/A)*	0.041	0.043	0.952
*ln (FD/A) * ln (CS/A)*	0.125	0.061	2.051
γ	0.618	0.167	3.693
Likelihood-ratio test of the one-sided error			17.24

This finding is consistent with results reported by Mekhora (2001, p. 149) for average rice and shrimp producers. It is also consistent with the results reported by Mekhora et al. (2004) who found little evidence of scale inefficiency for 'best-practice' producers, with estimated scale efficiency measures of 0.970 and 0.985, respectively, for shrimp and rice production (where one is perfect scale efficiency). Most scale-inefficient shrimp producers experienced increasing returns to scale while there were more scale-inefficient rice producers who experienced decreasing returns to scale than producers who experienced increasing returns to scale.

Three sets of hypothesis tests were undertaken using likelihood-ratio tests, with all hypothesis tests conducted using a 5 per cent level of significance. First, the value of the test statistic for the null hypothesis of no technical inefficiencies of production (17.24) was found to be substantially greater than the critical value of obtained from Table 1 of Kodde and Palm (1986) for five restrictions (10.37). We thus conclude that the technical inefficiency term (u_i) is a significant addition to the model. Second, three z-variables were found to contribute significantly (jointly and individually) to the explanation of technical inefficiencies in smallholder shrimp and rice production. Third, it was found that the other five z-variables did not contribute significantly to the explanation of technical inefficiencies in smallholder production.

The value of gamma in the estimated model is 0.62, with a standard error of 0.17. This estimated value suggests that 62 per cent of the disturbances are due to inefficiency and 38 per cent are due to stochastic events.

For direct comparison with the technical efficiency indices reported by Mekhora et al. (2004), the inverse of the distance function measure ($1/D$) is reported in this section so that the indices lie between 0 and 1. Technical efficiency indices (which have a feasible range from zero to one, with one being fully efficient) vary from 0.872 to 0.997, with a mean technical efficiency index of 0.977. This fairly narrow range closely mirrors that for rice production alone (0.915 to 0.997, and a mean of 0.971) but is quite a deal less than the range of indices for shrimp production alone (0.687 to 0.994, with a mean of 0.921) (Mekhora et al. 2004). The high mean technical efficiency indicates that a significant but nevertheless limited opportunity exists to expand total output without using more inputs or introducing improved production technologies in either enterprise.

6. Evidence of economies of scope

The coefficients from the estimated model were used to calculate the measure of scope economies in the shrimp and rice production system, defined in equation (4), for the pair of outputs at the means of the sample data. The resulting estimate is +0.34, indicating scope economies exist. A Taylor series expansion was used to estimate the standard error in order to test the hypothesis that scope economies do not exist. The estimated standard error is 0.04 indicates that we would strongly reject the null hypothesis of no scope economies at one per cent level of significance.

The estimated coefficient of scope economies is quite substantial, indicating that there is a potential productivity gain to smallholders from enterprise diversification when adopting 'best-practice' production methods. Increased productivity occurs particularly with diversification from traditional rice production into a combination of rice production and shrimp culture while still retaining a significant subsistence base in the latter, given that the farming system under observation continues to rely heavily on the farm inputs of household labour, management and land resources. The ability of 'best-practice' smallholders to make productive use of surplus family labour in slack periods and avoid bottlenecks in labour usage is crucial. Rice and shrimp activities would appear to complement each other in this respect, given variations in their demands for family labour and management resources throughout the year.

The implications for reciprocal on-farm negative externalities between rice and shrimp production, if indeed they do exist, appear to be strongly outweighed by these production complementarities within the farming system. It is likely that smallholders are able to 'internalise' the negative externalities in both directions to a substantial degree, even if inter-farm externalities persist as a result of farmers discharging waste into the shared waterways and harming the production activities of other farmers. Farmers achieve this 'internalisation' by regular use of fresh water in a semi-closed pond system of shrimp production that minimises pond contamination and also protects them from the activities of surrounding growers who discharge effluent into the waterways or whose shrimp experience diseases (Mekhora 2001, p. 19).

7. Effects of salinity on rice yields

Results of the estimated model including years of shrimp production indicated no significant negative salinity effects. Indeed, the partial output elasticity of the years of shrimp production is positive although insignificant. This result is consistent with the results of research conducted by the Department of Soil Development, which had failed to find evidence of salinity leaching from the shrimp pond and affecting rice fields. Salt water from the shrimp pond rarely seeps into adjacent soils due to the clay soil type.

In any event, it is difficult to discern whether salinity occurs naturally or is an outcome of shrimp production. The lower part of Central Thailand used to be coastline and the ground water in this area is naturally salty. Soil samples 30 cm in depth from the pond bottom collected during the study period revealed no differences in water salinity among sample farms.

8. Factors influencing technical inefficiency in production

The estimated coefficient on the efficiency variable, enterprise specialisation, is significantly greater than zero. As reported above, a likelihood-ratio test that this coefficient is zero is rejected, with a calculated likelihood ratio value of 18.00 considerably higher than the critical value of 3.84. This result indicates that the benefits smallholders derive from specialising mainly in one of the enterprises significantly outweigh the benefits of flexibility in undertaking the two enterprises.

Greater technical inefficiencies from diversification were expected to stem chiefly from the move by smallholders from predominantly rice production into mixed rice and shrimp production. First, this form of diversification introduces a more complex farming system and, second, shrimp culture is in general more prone to technical inefficiency than rice production. It was pointed out in section 5 that the mean technical efficiency index in rice production is very high, at 0.97, and no smallholder has a technical inefficiency index below 0.90. The mean technical efficiency index in shrimp production is quite a bit lower, at 0.92, with the lowest index only 0.69. The results confirm this expectation of higher technical inefficiency with a more diversified farming system. While Mekhora (2001, pp. 19-20) reported recent improvements in the management of shrimp ponds, these gains do not appear to have been sufficient to counter the stresses of organisational complexity created by greater enterprise diversity.

Only two other efficiency variables were found to influence technical efficiency significantly on the basis of likelihood-ratio tests. One of these variables, the education level of the head of the farm household, has a coefficient with a significant and negative sign. This estimate suggests that more years of schooling reduces technical inefficiency in the farming system as more educated household heads are better able to cope with their many tasks and adapt to multiple production activities. Second, the coefficient of the dummy variable for land ownership has a significant and positive sign. This result indicates that farmers who work their own land are less technically efficient than those who rent at least part of the land they farm.

Of the five efficiency variables found not to influence technical inefficiency significantly, the signs on all variables were in line with those reported by Mekhora et al. (2004). The years of experience of the household head in shrimp and rice farming and the proportion of female labour were found to be associated with lower technical inefficiency. The age of the household head and extension as a source of production knowledge were associated with higher technical inefficiency. Their insignificance, however, suggests no conclusion should be reached on their influences on technical inefficiency.

9. Conclusion

This study has provided information about economies of scope and specialisation efficiencies in farming systems comprising two enterprises of shrimp and rice production on 52 sampled smallholdings in four provinces of Thailand. Information is also provided on the extent of technical inefficiency in overall production on these smallholdings. Significant scope economies were found to exist between the two enterprises but they were offset by diversification inefficiencies. Hence, specialisation in one of the two enterprises has two effects on productivity that operate in opposite directions. The first effect is a negative impact on productivity via loss of scope economies. The second effect is a reduction in productivity caused by diversification inefficiencies or, to put it another way, a loss of specialisation efficiencies.

In addition to the degree of enterprise specialisation, the level of schooling of the household head and the tenure system in shrimp and rice production were identified as variables that significantly influence technical inefficiency. As expected, higher education is associated with lower technical inefficiency. Tenancy is also associated with lower technical inefficiency. Results indicate that a small but significant level of technical inefficiency exists, which means there is limited opportunity to expand crop output without resort to greater use of factor inputs or the introduction of improved production technologies.

References

Ali, R., Alwang, J. and Siegel, P.B. 1991, *Is Export Diversification the Best Way to Achieve Export Growth and Stability?: A Look at Three African Countries*, Working Papers Series 729, Policy, Research and External Affairs, Agriculture Operations, World Bank, Washington, D.C.

Battese, G.E., and Coelli, T.J. 1995, 'A model for technical inefficiency effects in a stochastic frontier production function for panel data', *Empirical Economics* 20, 325-332.

Coelli, T.J. 1996, *A Guide to FRONTIER Version 4.1: A Computer Program for Stochastic Frontier Production and Cost Function Estimation*, CEPA Working Papers No. 7/96, Department of Econometrics, University of New England, Armidale.

Coelli, T. and Fleming, E. 2003, Diversification economies and specialisation efficiencies in a mixed food and coffee smallholder farming system in Papua New Guinea, Contributed paper presented at the 25th International Conference of Agricultural Economists, Durban, August.

Coelli, T.J. and Perelman, S. 1996, *Efficiency Measurement, Multi-Output Technologies and Distance Functions: With Application to European Railways*, CREPP WP 96/05, Centre de Recherche en Economie Publique et Economie de la Population, Université de Liège.

Coelli, T.J., Rao, D.S.P. and Battese, G.E. 1998, *An Introduction to Efficiency and Productivity Analysis*, Kluwer, Boston.

Deller, S.C., Chicoine, D.L. and Walzer, N. 1988, 'Economies of size and scope in rural low-volume roads', *Review of Economics and Statistics* 70(3), 459-465.

Farrell, M.J. 1957, 'The measurement of productive efficiency', *Journal of the Royal Statistical Society, Series A, Part 3* 120, 253-290.

Kodde, D.A. and Palm, F.C. 1986, 'Wald criteria for jointly testing equality and inequality restrictions', *Econometrica* 54, 1243-1248.

Mekhora, T. 2001, Production efficiency in Thailand's rice and shrimp industries, PhD thesis, University of Western Australia, Perth.

Mekhora, T., Puangsumalee, P. and Fleming, E. 2004, 'The economic efficiency of smallholder shrimp and rice production in Thailand: stochastic frontier and data envelopment analyses', *KMITL Journal* (forthcoming).