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Why do rice farmers in Taiwan not expand scale? Economies of scale and the estimation of short- and long-run cost efficiencies using stochastic frontier analysis with time-varying panel data model

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Abstract

In this study, stochastic frontier analysis with a time-varying panel data model was applied to analyse short- and long-run cost functions; the short- and long-run cost efficiencies of rice farms in Taiwan from 1980 to 2008 were measured by treating five size classifications in 15 counties in the form of 75 cohorts. The results reveal the presence of economies of scale and artificial inefficiency in these farms. Further, an analysis of the short- and long-run efficiencies of all the cohorts by area, size and year dummy variables indicates that even the areas where agriculture is well developed and topographic conditions are suitable have better long-run cost efficiencies, and large-scale farmland have lower long-run but higher short-run efficiencies. Due to the inefficient use of farmland in the long run, farmers do not have the incentive to expand production scale; they are unable to enjoy the economies of scale, which shows minimum cost. Finally, a random-effect estimation of panel analysis confirms that improvement in the infrastructure development of farmland and the functioning of the rental market of farmland contributes towards increasing both short- and long-run cost efficiencies.

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1. Introduction

The objective of this study is to understand the characteristics of an efficient Taiwanese rice farm that enjoys economies of scale by analysing the efficiency of different areas and scales of production. Improvement in rice-growing productivity through farmland accumulation is important for maintaining the rice-growing industry in Taiwan. However, according to Taiwan's 'Agricultural Census' and 'Agricultural Statistics Annual Report', 2000, the average area managed per rice farmer is approximately 1 ha; this figure has remained unchanged for several decades. Lo's (1983) questionnaire survey indicated that poor natural conditions of farmland and strong motivation among farmers to keep ownership of their farmland were the main reasons for the lack of progress in the accumulation of farmland among farmers. Since farmland in Taiwan is geographically dispersed, even if farmers cultivate on a larger scale, their machines have to be operated in dispersed farmland; therefore, the efficiency of their machines cannot be increased by increasing the size of their farmland. Moreover, the accumulation of farmland may further be obstructed by protective farmland policies of previous tenants; this reduces the motive of farmland owners to lend out their farmland and has even led to a recent increase in the nonagricultural use of such land. On the other hand, because the economies of scale in Taiwan are measured using the cost function from the country's rice-cost statistics, no economies of scale are detected. Kuroda (1997) had similar findings. Although some reasons that are similar to those mentioned in Lo (1983) have been mentioned, Fujiki (1999) mentioned another possible reason for the prevalence of partial or whole contract farming in Taiwan: no large difference in cost among farms of different sizes. However, Lo indicated that although an increase in contract farming may lead to an increase in the income of farmers who own machines and large farms, such farms are still less efficient than those under whole contract (purchase or rental).

As mentioned above, the reasons for the lack of expansion in management scale and the role of economies of scale in Taiwan's rice-growing industry require greater clarification. This study considers the potential of the economies of scale which may appear on stochastic frontier with efficient management. Fu, Jan and Liu (1992) and Dai (2006) analysed technical efficiency in Taiwan's rice-growing industry by using the stochastic frontier model. Their result implies that Taiwan's rice-growing industry has little technical inefficiency compared to the maximum production frontier. However, some inefficiency may have occurred due to the inefficient distribution of inputs as compared to the minimum cost using the exogenous market price of inputs. On the basis of the abovementioned studies, efficient farms are analysed in this study by measuring the efficiency of rice farms in different years and counties and of different sizes; at the same time, the economy of scale of these farms is measured using a time-varying stochastic cost frontier function.

The rest of this paper is organized in the following manner. Section 2 gives an overview of the rice production situation in Taiwan as well as the data pertaining to the government rice production cost survey. Section 3 reviews the efficiency analysis and empirical model of this study. Section 4 presents the results of the empirical analysis for the short- and long-run efficiencies and analyses the characteristics of the result by counties, scale and time. Section 5 analyses the determinants of the short- and long-run efficiencies. Section 6 summarizes the main findings of this study.

2. Cost Data of the Rice-growing Industry in Taiwan

The data set used in this study is the first cropping data from the Survey of Rice Production Costs, an annual survey conducted by the Agriculture and Food Agency (AFA) for the period 1980–2008.

Table 1 presents the summary of the data. The average labour cost is 62%; seeding/fertilizer/pesticide cost is 19%; and farmland rent is 18%. However, the expense on capital goods such as machines and buildings is merely 1%. Very few farmers in Taiwan own machinery; thus, they pay high labour costs to employ machine operators through contract farming. For example, according to the general agriculture census in Taiwan, the proportion of farmhouses that possess a combine harvester is merely 1.92%; however, the usage rate was 99.48% in 1995. It is evident that the current rice-growing industry in Taiwan is heavily dependent on contract farming. In addition, to reflect the actual situation of contract farming activities undertaken by large-scale farms that own machines, the depreciation of machinery is not included in the machine cost in this production cost data; alternatively, the data converts the depreciation of machinery into self-supplied machine labour cost following the general employment price of the machine labour in the employment market. Therefore, the standard does not need to change with the scale in the calculation of the total cost. Moreover, a rise in the cost and production per unit is observed with a sequential change. It is evident from the data of different production scales in Table 1 that the seeding/fertilizer/pesticide cost and labour cost are slightly lower for large-scale farms that manage farmland over 1.5 ha.

[Table 1]

Table 2 presents the per hectare average production cost of the first paddy-rice product according to counties[1] for 1980–2008. It is evident from the table that the southern zone (c9–c12) has the highest average production, followed by the central zone (c6–c8), the eastern zone (c13–c15) and the northern zone (c1–c5). Further, the total average cost is the highest for the central zone, followed by the southern, northern and eastern zones. However, although farmland rent is higher in the northern and central zones, the seeding/fertilizer/pesticide cost is higher in the southern and eastern zones. It is evident from the above account that counties are heterogeneous in terms of rice production in Taiwan.

[Table 2]

3. Review of the Efficiency Analysis and Empirical Model

This study uses stochastic frontier analysis for measuring short- and long-run efficiencies of rice production in Taiwan. Stochastic frontier analysis has been used in numerous research fields; moreover, many studies elucidate the effect factor of the detected inefficiency on measurement. In addition, the application of stochastic frontier analysis, which uses panel data, increased with the popularity of panel data. Cornwell, Schimidt and Sickles (1990), Kumbhakar (1990) and Battese and Coelli (1992) developed the time-varying stochastic frontier analysis that uses panel data for measuring efficiency. Battese and Coelli apply this analysis to the rice production function of the panel data on Indian rice farmhouses. However, because acquiring panel data is difficult, Kumbhakar and Heshmati (1995) and Heshmati and Kumbhakar (1997) treated government statistics on dairy and rice farms as cohort data and analysed the efficiency of these farms using the panel data method of stochastic frontier analysis. The present study follows Heshmati and Kumbhakar and treats different time-series production cost data adapted from government statistics for different areas and production scales as panel data. Moreover, the present study employs Battese and Coelli's time-varying efficiency model.

Following Fu, Jan and Liu (1992), this study uses the Cobb–Douglas form for estimating the cost

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[1] In the Survey of Rice Production Costs, if a city adjoins a county, the data on the production cost of the county is included in the production of the adjoining city. For example, the data of 'Taipei County and Taipei City' are included in the data for 'Taipei'. Since there is very little rice grown in 'cities', this study showed the values for the cities along with those for the 'county'.

frotier in Taiwan's rice-growing industry. Equations 1 and 2 present the short-run variable cost frontier and long-run total cost frontier to be estimated, respectively.

$$\ln \mathrm{VE}_{it} = \alpha_{0t} + \alpha_y \ln \mathrm{Q}_{it} + \sum_n \alpha_n \ln \mathrm{w}_{nit} + \alpha_a \ln \mathrm{a}_{it} + \varepsilon_{it}^{\mathrm{VE}} \ ; \quad \varepsilon_{it}^{\mathrm{VE}} = \mathrm{v}_{it}^{\mathrm{VE}} + \mathrm{u}_{it}^{\mathrm{VE}} \tag{1}$$

$$\ln \mathrm{E}_{it} = \beta_{0t} + \beta_y \ln \mathrm{Q}_{it} + \sum_n \beta_n \ln \mathrm{w}_{nit} + \varepsilon_{it}^{\mathrm{E}} \ ; \quad \varepsilon_{it}^{\mathrm{E}} = \mathrm{v}_{it}^{\mathrm{E}} + \mathrm{u}_{it}^{\mathrm{E}} \tag{2}$$

where i = farm cohorts and t = 1980, 1981... 2008. In Equation 1, n = current expenditure, labour and machinery, and in Equation 2, n = current expenditure, labour, machinery and farmland.

The explained variable of Equation 1, VE_{it}, represents the variable expenditure that includes cost other than farmland rent of farm i (cohort i) at time t. The explanatory variable of Equation 2, E_{it}, represents the total expenditure of farm i (cohort i) at time t. Q_{it} is the rice production; w_{nit} is the price of the nth element that farm i uses at time t; and a_{it} represents the farmland area that farm i uses during time t. $\varepsilon_{it}^{\mathrm{VE}}$ and $\varepsilon_{it}^{\mathrm{E}}$ are the error terms of the short- and long-run cost functions, respectively. Further, these functions include random noise, v_{it}, which follows a normal distribution, and an inefficiency error term, u_{it}, which follows a nonnegative truncated normal distribution. α and β are the parameters to be estimated. It must be noted that all these assumptions of distribution are in keeping with Battese and Coelli (1992). Finally, the empirical regression result of Equations 1 and 2 is obtained using maximum likelihood estimation. In addition, the short- and long-run cost efficiencies of farm are calculated.

The data used in the present study for constructing the cost function have been taken from the Survey of Rice Production Costs of the AFA. The change in the sampling of the Survey of Rice Production Costs is lower than 5% per year. The survey includes the cost data of 15 counties (areas), and each county has five different farmland sizes from 1980 to 2008. This study treated the data as panel data. There are 75 cohorts and 29 years in this study. The five classifications of farmland sizes are less than 0.5 ha, 0.5–0.75 ha, 0.75–1.0 ha, 1.0 ha–1.5 ha and over 1.5 ha. This classification is appropriate because the sampling is similar to the distribution of farmers who mainly grow rice, as shown in the agricultural census in Taiwan.

Labour and machinery are necessary for rice production. The data of the price indexes for each of these (2001 as the base year) have been taken from Indices of Prices Paid by Farmers in 'Agricultural Statistics Annual Report', which is compiled by the Statistics Office of the Council of Agriculture in Taiwan. Since current inputs include seeds, fertilizers and pesticides, the current input price is determined as a multilateral price index, which uses the ratio of the production cost of the four above mentioned elements as the weight for multiplication. The agricultural machine price and labour cost in this study also use the agricultural machine price index and labour wage price index of Indices of Prices Paid by Farmers. The labour wage price index includes the general workforce and the employment of labour for ploughing, transplanting or harvesting through contract farming. Here, labour wage and agricultural machine price are assumed to be the same for farmland of all sizes and in all counties. In addition, in the long-run fixed cost function, the rent per hectare of farmland in the Survey of Rice Production Costs for each county and farmland size was used as data. In the short-run variable cost function, the data on farmland area from the Survey of Rice Production Costs for each county and farmland size was used. Finally, a time trend is also used for the efficiency estimation.

4. Empirical Analysis

The empirical result of the stochastic frontier analysis with a time-varying panel data model using

Equations 1 and 2 is presented in Tables 3 and 4, respectively. In the stochastic frontier analysis, the residual of the empirical form, which cannot be interpreted by random noise, was significantly interpreted by the inefficient error term—39% in the short-run variable cost function and 93% in the long-run fixed cost function. These results indicate that there is artificial inefficiency in the management of Taiwan's rice-growing industry. Moreover, since the inefficiency term could be significantly interpreted, the stochastic frontier analysis could explain the management of the rice-growing industry. Since the estimation uses the Cobb–Douglas form, the cost function must satisfy the homogeneity of the input prices. Since the null hypothesis of homogeneity is not rejected in both regressions of this study, the result of this study is consistent with the assumption of Cobb–Douglas production function. For the sake of comparison, this study also presents the results of the fixed-effect estimation and OLS regression. In addition, the economy of scale is estimated using the formula given by Friedlaender and Spady (1981).

[Table 3]

[Table 4]

The stochastic frontier estimation of the variable cost function yielded a short-run economy of scale of 1.68 and that of the cost function yielded a long-run economy of scale of 1.75. In other words, there is a significant economy of scale in Taiwan's rice-growing industry. In addition, both values of the economy of scale obtained by the estimation of the fixed-effect and OLS regression are smaller than the values of the economy of scale obtained for the short- and long-run cost functions using the stochastic frontier analysis. This is probably because the stochastic frontier analysis measured the smallest efficient cost structure. Moreover, as compared with the econometric models of existing studies, most of which are estimated using a cross-sectional analysis, this study captured the characteristics of county and farmland size using panel data; thus, this study was able to capture the economy of scale in Taiwan's rice-growing industries that other studies were unable to capture.

Next, the efficiency estimated by the short-run variable and long-run total cost functions is examined; for the sake of simplicity, the terms short-run cost efficiency and long-run cost efficiency are used in the following account. Short-run efficiency expresses how current, labour and capital inputs are effectively used when farmland size is fixed. Long-run efficiency takes into consideration the utilization of farmland and expresses how current, labour and capital inputs, as well as farmland, are effectively used. It is believed that the greater the efficiency in production activity, the closer the production cost to the cost frontier. In this study, the closer the measured efficiency is to 1, the higher the efficiency of the farm, and the closer the measured efficiency is to 0, the lower the efficiency of the farm.

Initially, the average long-run and sort-run cost efficiency is 0.65 and 0.86 respectively for all samples. Fig. 1 presents the efficiency for both distributions of all samples from 1980 to 2008. The short-run cost efficiency is over 70%; however, the long-run cost efficiency varies between 25% and 100%, thereby making the variation a wide one. Thus, it is evident that there is no clear difference in the efficiency of the current, labour and capital inputs among all the cohorts; however, there is a large difference in the efficiency of farmland utilization among all the cohorts.

[Figure 1]

In order to elucidate the characteristics of the efficiency of each cohort, the county, size and year dummies are regressed on the short- and long-run cost efficiencies. The base county (Taipei), the smallest size and the year 1980 do not use dummy variables; however, it is evident from the other parameters of the county or size dummies how a county and different sizes influence efficiency. Table 5 presents the effect of counties, size and years on short- and long-run cost efficiencies.

[Table 5]

The scale dummy in Table 5 indicates that the larger the farm size, the higher the short-run cost efficiency and the lower the long-run cost efficiency. Further, the year dummy in Table 5 indicates that short-run cost efficiency slowly increases with time while long-run cost efficiency decreases over time.

Furthermore, the county dummy indicates the following counties presented in the descending order of their short-run cost efficiencies: Yilan, Taitung, Miaoli, Taoyuan, Yunlin, Hsinchu, Tainan, Kaohsiung, Hualien, Pingtung, Nantou, Changhua, Chiayi, Taipei and Taichung. When farmland is assumed to be a fixed input, counties influence the short-run cost efficiency. In this regard, although the topography of the eastern zone, which includes Taitung, is not as flat as that of other zones, farmland usage does not affect the estimation of the short-run cost efficiency, which is high in Taitung. In addition, counties that have a high degree of urbanization have lower short-run cost efficiency. The county dummy indicates the following counties in the descending order of their long-run cost efficiencies: Yunlin, Tainan, Kaohsiung, Changhua, Pingtung, Taitung, Yilan, Chiayi, Miaoli, Taoyuan, Hualian, Hsinchu, Taichung, Nantou and Taipei. Since the long-run cost efficiency reflects the efficiency of farmland utilization, counties with well-developed agriculture and better topographical conditions have better long-run cost efficiencies, for example, Yunlin and other counties located to the south of Yunlin. These results will remain unchanged even if a simple comparison of average efficiency is conducted on the basis of farmland size, county and year instead of a regression analysis using dummy variables. However, this paper conducted a regression analysis in order to measure the effect of the target dummies by controlling other dummies.

The stochastic frontier analysis with a time-varying panel data model presented in this section revealed the existence of economy of scale in Taiwan's rice-growing industry and the increasing tendency of short-run variable cost efficiency with an increase in farmland size. The long-run cost efficiency of a larger farm is lower than that of a smaller farm. Since short-run variable cost efficiency is higher in larger farms, it is evident that farmers in Taiwan do not increase the size of their rice farms despite the existence of economy of scale mainly because farmland utilization is inefficient and farmland cost is part of the total cost. In other words, in the long run, there are numerous large farms located in areas with bad agricultural conditions, because of which they cannot enjoy the advantage of their size. As a result, there is no progress in the accumulation of farmland among large-scale rice farmers in Taiwan. This result supports the opinion presented in the first section of the study, which advocates that large rice farms do not have the incentive to save cost by increasing size because their production cost is not sufficient to achieve the smallest cost structure in Taiwan. It seems necessary to improve the efficiency of farmland utilization in order to increase the competitive power of Taiwan's rice production industry by expanding farmland scale.

V. Determinants of Short- and Long-run Cost Efficiencies

On the basis of the present contention, this section explains the determinants of short- and long-run cost efficiencies. The explanatory factor for this efficiency is selected from the data obtained in the general survey of each county for four years: 1990, 1995, 2000 and 2005. The explained variables are the short- and long-run cost efficiencies of 75 cohorts for each corresponding year, which have been estimated earlier. In addition, in order to avoid any error in the single-year estimation, this section also regresses on the moving average pattern of the efficiency for the previous and next five years from the general survey year as the explanatory variable.

The rate of infrastructure development of farmland in every county, which indicates the general maintenance of farms and greatly influences efficiency of cultivation, is selected as the first explanatory variable. In addition, the level of contract farming, which is believed to contribute greatly to raising the efficiency of Taiwan's rice-growing industry in the 1980s, is selected as the second explanatory variable. The number of contract farming centres for crops in each cultivated area in each county can be used to represent the level of prevalent contract farming. Moreover, the ratio of farmers who own all their cultivated farmland to those who own some farmland in each county is selected as the third explanatory variable for expressing the briskness of borrowing and loaning in the farmland market. When the ratio of farmers who own all their cultivated farmland is higher in a county, the rental market of farmland in that county is not considered to be active; when the rental market of farmland is obstructed, it is difficult to achieve the effective allocation of farmland and other inputs, thereby causing a decline in efficiency. In addition, although human capital—which includes education level and age—is generally used as an explanatory variable for explaining management efficiency in many studies, the data on education level and age that could be obtained for this study only pertain to each county; such limited data cannot sufficiently explain the efficiency of different farmland sizes in a county. In reality, the use of these variables as explanatory variables does not indicate a significant influence on efficiency. Fortunately, the education level among people of each county in Taiwan is not very different due to the success of educational expansion in Taiwan; thus, human capital could be not considered as an explanatory variable here.

This estimation is regressed using panel analysis with time trend. The estimation result is presented in Table 6. In addition, on the basis of the Hausman test, the random effect estimation of the panel estimation cannot be rejected; thus, the random effect rather than the fixed effect is adopted in this study. The estimation satisfies a 10% level of significance, and the estimation is very similar irrespective of whether the corresponding year or the moving average for five years is used as the explanatory variable.

[Table 6]

It is evident from Table 6 that when the infrastructure development rate of farmland increases, both short- and long-run cost efficiencies rise significantly. When the infrastructure development rate increased by 1%, short-run efficiency rose by 0.018% and long-term efficiency rose by 0.044%, a greater increase. In this study, it was found that promoting infrastructure development of farmland not only improves the quality of farmland for cultivation but can also solve the farmland's dispersion problem, thereby enabling effective cultivation using agricultural machinery in large-scale farming. Infrastructure development of farmland is considered to be an effective method for promoting farmland accumulation. Although its contribution to efficiency is smaller in the short run because it is mainly effective on farmland input in the long run, the increase in the quality of farmland maintenance still leads to an increase in the effective utilization of other inputs by adjusting the distribution of inputs.

Further, the prevalence of contract farming, calculated by using the number of contract farming centres for crops in the cultivated area in each county as the proxy variable, has a positive effect on the long-run cost efficiency and a negative effect on the short-run cost efficiency. The positive effect of contract farming on the long-run cost efficiency is brought about by an increase in the efficiency of machines through the expansion of farmland cultivation scale using the machinery of trustee farms, which are mainly large-scale farms. However, when the commission for contract farming is awarded, the utilization of machinery for contract farming in the short run usually cannot adjust smoothly with the utilization of other inputs. Thus, the commission cost of partial machine contract farming is approximately 60%, which is constantly included in the production cost of small-scale farmers who have no plans to expand their farms in the short run. Therefore, the inflexible distribution of inputs has a negative influence on short-run efficiency.

Finally, it is evident from Table 6 that when there is an increase in the ratio of farmers who own all their cultivated farmland to those who own some farmland, both short- and long-run cost efficiencies decrease. When this ratio increases by 1%, short-run efficiency decreases by 0.017% and long-run efficiency decreases more by 0.063%. This indicates that management efficiency may be worse in an area in which the rental market for farmland is weak. This ratio is remarkably higher in the urbanized areas in Taiwan. This implies that the rental market function of farmland is weak in the urbanized areas in Taiwan, because land-use zoning regulations, aimed at preventing new development and preserving agricultural utilization, allow the use of farmland by the nonagricultural sector that has insufficient land. In addition, the result obtained in this study indicates that when the rental market of farmland is weak, the long-run total cost utilization is ineffective because the farmland is not expanded to become a large-scale one. Moreover, the short-run variable cost utilization, which indicates the effectiveness of the usage of variable inputs, also tends to become ineffective when the rental market of farmland is weak.

5. Summary and Conclusions

In this study, the stochastic frontier analysis with a time-varying panel data model was applied to analyse short- and long-run cost functions and measure short- and long-run cost efficiencies of rice farms in Taiwan for 1980 to 2008 by treating five size classifications in 15 counties in the form of 75 cohorts. Moreover, area disparity and differences in scale classification between the efficient and inefficient management of rice farms was also analysed. Through the analysis of the short- and long-run cost frontiers in this study, the existence of economy of scale and artificial inefficiency was confirmed. In other words, because there is merit of scale on the cost frontier, an efficient management can enjoy average cost saving from expansion of scale. However, because of inefficient management on a large scale, the economy of scale, that is, minimum cost, cannot be enjoyed. As a result, even if economy of scale exists in rice farms with a rather small scale of cultivation, most rice farmers with inefficient management have no incentive to expand the scale of cultivation. Moreover, a comparison of the estimated efficiency of all cohorts in the short and long run reveals that the average of the estimated long-run fixed cost efficiencies are less than the average of the estimated short-run variable cost efficiencies by 21%. Further, the variation of estimated long-run efficiencies is greater than the variation of the estimated short-run efficiencies; long-run efficiencies decrease with time whereas short-run efficiencies increase. Therefore, the inefficient use of farmland in the long run is the most important factor responsible for the fact that Taiwanese rice farmers cannot enjoy the advantage of economy of scale. Furthermore, after analysing the short- and long-run efficiencies of all cohorts by area, size and year dummy variables, it is revealed that even areas where agriculture is well-developed and topographic conditions are suitable have better long-run cost efficiency; large-scale farmland have lower long-run efficiency but higher short-run efficiency. Finally, a random-effect estimation of panel analysis confirms that improvement in the infrastructure development rate of farmland and the functioning of the rental market of farmland will contribute to an increase in both the short- and long-run cost efficiencies. However, an acceleration of contract farming may only increase the long-run cost efficiency.

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Table 1. Per hectare production cost of the first paddy-rice crop in Taiwan for 1988, 1998 and 2008 (New Taiwan dollars)

	1988		1998		2008		Average for 1980–2008					
							Average		0–0.5 ha	0.5–0.75 ha	0.75–1.0 ha	1.0–1.5 ha
Seeding/fertilizer/pesticide cost	13,712	(19%)	18,161	(18%)	25,078	(22%)	16,804	(19%)	17,151	17,026	16,640	16,607
Labour cost	42,093	(60%)	64,898	(64%)	67,614	(59%)	54,066	(62%)	56,146	54,896	53,907	53,037
Machine and buildings cost	571	(1%)	605	(1%)	748	(1%)	666	(1%)	814	747	654	614
Farmland rent	14,136	(20%)	17,457	(17%)	20,588	(18%)	15,602	(18%)	15,481	15,440	15,657	15,490
Production per unit (kg)	5,421		5,839		6,679		5,828		5,836	5,800	5,842	5,829

Table 2. Per hectare average production cost of the first paddy-rice crop in Taiwan according to counties (New Taiwan dollars)

County		Seeding/fertilizer/pesticide cost	Labour cost	Machine and buildings cost	Farmland rent	Production per unit (kg)
Code	Name					
c1	Taipei	12,920	61,858	1,360	17,793	4,794
c2	Yilan	13,432	49,590	546	16,737	5,463
c3	Taoyuan	12,466	53,960	800	15,461	4,862
c4	Hsinchu	13,262	56,690	783	17,001	5,159
c5	Miaoli	14,239	53,038	937	18,109	5,342
c6	Taichung	17,437	60,836	530	19,124	6,055
c7	Changhua	20,280	53,635	485	18,599	6,700
c8	Nantou	17,717	56,363	505	19,718	5,682
c9	Tainan	20,460	51,118	379	11,860	6,654
c10	Yunlin	20,371	49,412	400	15,968	6,522
c11	Chiayi	20,502	56,113	501	12,824	6,525
c12	Kaohsiung	16,890	53,043	621	14,956	6,469
c13	Pingtung	18,776	54,788	645	12,559	6,687
c14	Taitung	16,073	48,325	912	9,817	5,322
c15	Hualien	17,239	52,219	592	13,503	5,181

Table 3. Empirical result of the short-run variable cost function

	Stochastic frontier model			Comparison					
Econometric model	Battese and Coelli (1992)			Fixed-effects regression			Pooled OLS		
	coefficient	Z	P > |z|	coefficient	T	P > |t|	coefficient	T	*P* > |*t*|
Rice production	0.040	2.80	0.01	0.025	1.74	0.08	0.129	10.10	0.00
Price of current inputs	0.383	13.48	0.00	0.383	13.40	0.00	0.382	10.08	0.00
Labour wage	0.465	25.65	0.00	0.465	25.55	0.00	0.439	18.33	0.00
Price of capital goods	0.102	1.46	0.15	0.102	1.45	0.15	0.147	1.58	0.11
Farmland area	0.933	56.82	0.00	0.969	50.87	0.00	0.829	63.40	0.00
Time series	0.004	4.46	0.00	0.002	2.52	0.01	0.001	1.23	0.22
Constant	2.078	8.25	0.00	2.220	8.71	0.00	1.888	5.79	0.00

Notes: $\frac{\sigma_u^2}{\sigma_u^2 + \sigma_v^2}$ = 0.39 (SD is 0.05); the residual that was significantly interpreted by the inefficient error term is 39%.

H_0: coefficients of the current inputs + coefficients of labour wage + coefficient of the price of capital goods = 1. Since the *p*-value is 0.36, H_0 cannot be rejected.

The values of economy of scale for the stochastic frontier model, fixed-effect regression and pooled OLS are 1.68, 1.22 and 1.33, respectively.

Table 4. Empirical result of the long-run total cost function

	Stochastic frontier model			Comparison					
Econometric model	Battese and Coelli (1992)			Fixed-effect regression			Pooled OLS		
	coefficient	Z	P > |z|	Coefficient	T	P > |t|	coefficient	T	P > |t|
Rice production	0.570	41.75	0.00	0.612	48.23	0.00	0.914	174.09	0.00
Price of current inputs	0.380	9.72	0.00	0.373	9.24	0.00	0.428	6.94	0.00
Labour wage	0.252	9.69	0.00	0.243	9.03	0.00	0.161	4.09	0.00
Price of capital goods	0.252	2.61	0.01	0.294	2.96	0.00	0.244	1.61	0.11
Farmland rent	0.178	9.67	0.00	0.158	8.12	0.00	0.290	19.87	0.00
Time trend	–0.006	–5.29	0.00	–0.001	–0.76	0.45	–0.004	–2.44	0.02
Constant	1.263	3.63	0.00	1.249	3.50	0.00	–1.499	–2.87	0.00

Notes: $\frac{\sigma_u^2}{\sigma_u^2 + \sigma_v^2}$ = 0.93 (SD is 0.02); the residual that was significantly interpreted by the inefficient error term is 93%.

H_0: coefficients of the current inputs + coefficients of labour wage + coefficient of the price of capital goods + coefficients of farmland rent = 1. Since the *p*-value is 0.41, H_0 cannot be rejected.

The values for the economy of scale for the stochastic frontier model, fixed-effect regression and pooled OLS are 1.75, 1.63 and 1.09, respectively.

Table 5. The analysis of the characteristics of efficiency for all cohorts: The regressions on short- and long-run cost efficiency by using dummy variables of counties, size and year

Explanatory variable	Explained variable	Short-run cost efficiency	(*t*-value)	Long-run cost efficiency	(*t*-value)
Cons	Constant	0.755**	(210.42)	0.805**	(203.77)
c2	Yilan	0.159**	(55.82)	0.130**	(41.66)
c3	Taoyuan	0.102**	(34.84)	0.095**	(29.68)
c4	Hsinchu	0.084**	(29.34)	0.079**	(25.25)
c5	Miaoli	0.109**	(37.83)	0.120**	(38.35)
c6	Taichung	–0.018**	(-6.45)	0.079**	(25.39)
c7	Changhua	0.023**	(8.10)	0.155**	(49.58)
c8	Nantou	0.025**	(8.63)	0.079**	(25.10)
c9	Tainan	0.080**	(27.67)	0.178**	(56.56)
c10	Yunlin	0.086**	(30.10)	0.187**	(60.35)
c11	Chiayi	0.003	(1.06)	0.128**	(41.35)
c12	Kaohsiung	0.070**	(24.63)	0.170**	(54.93)
c13	Pingtung	0.030**	(10.34)	0.145**	(46.67)
c14	Taitung	0.158**	(54.59)	0.136**	(43.24)
c15	Hualien	0.064**	(22.61)	0.082**	(26.61)
s2	0.5–0.75 ha	0.005**	(3.17)	–0.152**	(–83.87)
s3	0.75–1.0 ha	0.014**	(8.23)	–0.245**	(–134.76)
s4	1.0–1.5 ha	0.017**	(10.29)	–0.309**	(–170.25)
s5	Over 1.5 ha	0.024**	(14.06)	–0.449**	(–244.02)
t2	1981	0.011**	(2.64)	0.000	(0.08)
t3	1982	0.013**	(3.21)	–0.003	(–0.63)
t4	1983	0.015**	(3.64)	–0.006	(–1.36)
t5	1984	0.016**	(4.03)	–0.010**	(–2.15)
t6	1985	0.018**	(4.34)	–0.013**	(–2.84)
t7	1986	0.021**	(5.07)	–0.015**	(–3.41)
t8	1987	0.021**	(5.21)	–0.019**	(–4.29)
t9	1988	0.024**	(6.02)	–0.020**	(–4.50)
t10	1989	0.026**	(6.32)	–0.023**	(–5.28)
t11	1990	0.027**	(6.67)	–0.027**	(–6.05)
t12	1991	0.029**	(7.12)	–0.029**	(–6.60)
t13	1992	0.031**	(7.56)	–0.032**	(–7.16)
t14	1993	0.032**	(7.91)	–0.035**	(–7.89)
t15	1994	0.034**	(8.33)	–0.039**	(–8.68)
t16	1995	0.036**	(8.78)	–0.041**	(–9.18)
t17	1996	0.036**	(8.99)	–0.044**	(–9.98)
t18	1997	0.038**	(9.51)	–0.048**	(–10.86)
t19	1998	0.040**	(9.89)	–0.051**	(–11.58)
t20	1999	0.041**	(10.26)	–0.054**	(–12.30)
t21	2000	0.043**	(10.63)	–0.057**	(–13.02)
t22	2001	0.044**	(10.90)	–0.061**	(–13.91)
t23	2002	0.046**	(11.35)	–0.064**	(–14.49)
t24	2003	0.047**	(11.68)	–0.067**	(–15.15)
t25	2004	0.049**	(12.05)	–0.070**	(–15.76)
t26	2005	0.050**	(12.37)	–0.073**	(–16.63)
t27	2006	0.051**	(12.75)	–0.077**	(–17.45)
t28	2007	0.053**	(13.10)	–0.080**	(–18.20)
t29	2008	0.054**	(13.43)	–0.083**	(–18.96)

Notes: The base county is Taipei; the base classification is lower than 0.5 ha; and the base year is 1980.

** signifies that the estimation satisfies the 5% significance level.

Table 6. Determinants of the short- and long-run cost efficiencies for the years 1990, 1995, 2000 and 2005

Explained variable / Explanatory variable for each county	Short-run efficiency Random-effect panel analysis		Long-run efficiency Random-effect panel analysis		Short-run efficiency OLS pooled analysis	Long-run efficiency OLS pooled analysis
	Corresponding year	5-year moving average	Corresponding year	5-year moving average	Corresponding year	Corresponding year
Infrastructure development rate of farmland	0.018**	0.018**	0.043**	0.044**	0.054	0.042
	(3.93)	(3.84)	(1.91)	(1.97)	(15.28)	(2.08)
Number of contract farming centres for crops in each cultivated area	–0.002*	–0.002*	0.009**	0.009**	–0.046	0.032
	(–1.70)	(–1.47)	(1.91)	(1.92)	(–12.56)	(1.53)
Ratio of farmers who own all their cultivated farmland/who own some farmland	–0.017*	–0.017*	–0.063*	–0.060*	–0.213	–0.239
	(–1.69)	(–1.74)	(–1.70)	(–1.65)	(–5.18)	(–1.01)
Time series	0.007**	0.007**	–0.024**	–0.024**	–0.022	–0.006
	(7.07)	(7.48)	(–6.64)	(–6.85)	(–6.34)	(–0.27)
Constant	–0.131**	–0.130**	–0.339**	–0.353**	0.959	0.253
	(–2.85)	(–2.86)	(–1.93)	(–2.05)	(5.3)	(0.24)

Note: As a result of the Hausman test for the four panel analyses, the chi-square values are 0.720, 1.380, 0.930 and 0.850, all of which are less than the 5% critical value of the chi-square distribution; thus, the null hypothesis was not rejected and a random-effect model was adopted.

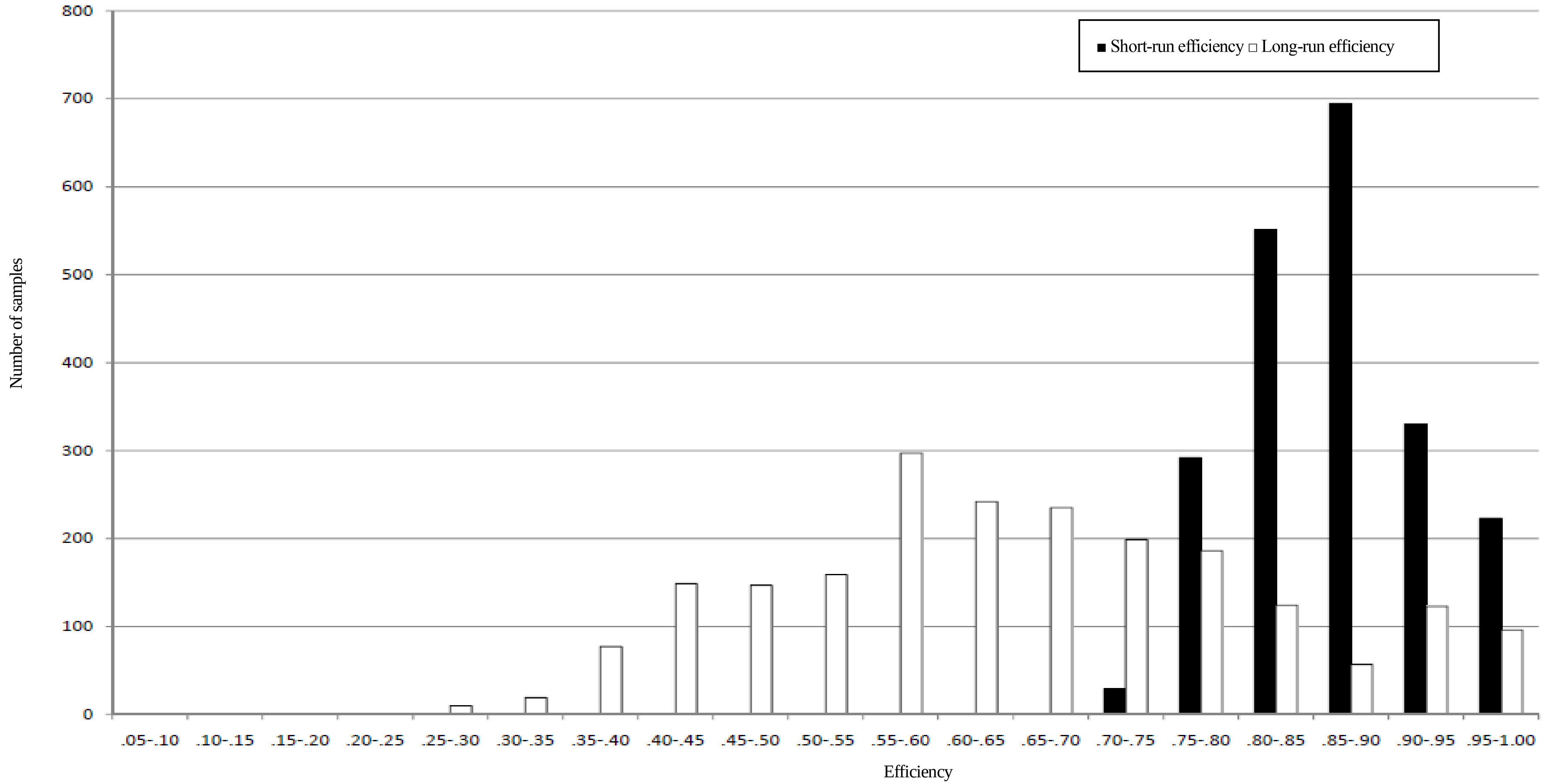

Fig. 1. Distribution of efficiency for short- and long-run cost utilization for all samples from 1980 to 2008