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Direct Payment Subsidies for Environmentally-Friendly Agriculture on Rice Production in Shiga, Japan

Danielle Katrina Santos[a], Koji Shimada[b,*]

[a]Graduate School of Economics, Ritsumeikan University, 1-1-1 Noji-Higashi, Kusatsu, Shiga 525-8577, Japan
[b]College of Economics, Ritsumeikan University, 1-1-1 Noji-Higashi, Kusatsu, Shiga 525-8577, Japan
shimada@ec.ritsumei.ac.jp

Environmentally-friendly agriculture has been promoted for over two decades as a response to environmental degradation and biological loss. Lake Biwa, which is a major water source in Kinki region, has suffered eutrophication resulting in occurrences of freshwater red tide and blue-green algae bloom. As a result, Shiga Prefectural government has implemented a direct payment subsidy system which would promote the environmentally-friendly agricultural (EFA) practices in order to reduce pollution load and improve the quality of Lake Biwa eco-system. This study aims to determine profit efficiency among EFA rice farmers in Shiga Prefecture using the Stochastic Frontier Approach. A cross-sectional survey was conducted among 82 farmers from top rice-producing cities in Shiga Prefecture, using a structured questionnaire. Results showed that EFA farmers increased their net farm income by 99 %, amounting to 652,414 JPY/ha compared to the 658,553 JPY/ha income of conventional farmers. However, production costs were also found to be higher among EFA farmers, especially on labor costs, which accounted for 42 % of the total production cost. The study investigated the farmer and farm-specific factors affecting deviations from the profit frontier and discussed the policy implications for the promotion and popularization of EFA in the future.

1. Introduction

Rice remains to be the most important cereal product in Japan, comprising 30 % of the total agricultural output in 2018 (e-Stat, 2018). During the past decade, studies on rice and production have increased in developing countries, however, few studies on rice production have been conducted in developed nations, including Japan, where self-sufficiency in rice is recorded at 66 % (Smart Agri, 2019). The development of new and better policies is intended to keep up with the pressure of guaranteeing food security amidst an increasingly volatile and shifting climate. Among the policies which had a successful response and implementation at the prefectural level is the Environmentally-friendly Agricultural Direct Payment System, which was first adopted by Shiga Prefecture in Kinki region. Their agro-environmental policy is one of the most advanced and known for its uniqueness since one of its policy objectives is conservation of Lake Biwa, which occupies one-sixth of the entire prefecture area (Chen et al., 2013). Environmentally-friendly Agricultural Direct Payment is a system in which farmers are given direct payment subsidies in exchange for their efforts to shift from conventional to environmentally-friendly rice farming (Shiga Prefecture, 2018). The system supported 17 environmentally-friendly rice farming initiatives; however, this study will only focus on 3 initiatives, namely: organic farming, IPM, biotope, as well as the planting of cover crops, and the reduction of chemical fertilizers and synthetic pesticides by 50 %.
The subsidy payment amount varies for each initiative, ranging from 40,000 JPY/ha for practices which only requires 50 % reduction in chemical fertilizers and synthetic pesticides, to 120,000 JPY/ha for practices which requires 100 % reduction in chemical fertilizers and synthetic pesticides.
The cultivation of high-yielding varieties and intensive use of chemicals have been thriving in Japan. Japan is considered to be one of the world's top fertilizer and pesticide consumers, with a consumption of about 37 Mt of fertilizer in early 2000s, and 1.8 Mt of pesticides in 2017 (FAOSTAT, 2020). In addition, Japan has also been included in the world's top GHG emitters, with over 1,300 Mt CO_2-eq. (Lee et al., 2018). As a result, various problems caused by intensive farming, such as water, soil and air pollution, and destruction of

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biodiversity have emerged. The Japanese government has recognized its responsibility to address agro-environmental issues in its domestic agricultural policy, and widely promoted environmentally-friendly direct payment subsidies across prefectures as a result.

Despite the widespread promotion, the share of organic farming in Japan has not significantly increased. To understand how the status quo can be improved, studies that determine factors constraining adoption of environmentally-friendly agricultural practices should be conducted. Since few studies have been conducted on the rice sector and profit efficiency of rice farmers in Japan, this study intends to compare costs and returns between conventional and environmentally-friendly rice farming, determine profit efficiency, and identify the factors affecting profit efficiency of rice farmers.

2. Literature review

Starting from Farrell's (1957) pioneering work, efficiency was defined as the ability to produce a given level of output at the lowest cost. He proposed a measure of efficiency by dividing this concept into technical efficiency (TE) and allocative efficiency (AE). The assumption is that the production function of the efficient firm is known, but in reality this function is hardly known. To measure efficiency, parametric approaches such as Stochastic Frontier Analysis was proposed. Economic efficiency (EE), which is also called cost efficiency, is the product of both TE and AE. Due to the scarce resources faced by farmers, estimation of TE and AE should be done simultaneously. This study estimated profit efficiency using the following profit function model of Lau-Yotopoulos (1971) in Eq(1):

$$\pi_j = f(P_{ij}) + e_j \quad (1)$$

where π_j is the normalized profit computed for j_{th} farm; P_{ij} is the price of the variable input i_{th} faced by j_{th} farm; and e_j is an error term. To normalize this profit function, each input price was divided by the average market price of rice.

The error term was assumed to behave in a manner consistent with the frontier concept (Ali and Flinn, 1989) in Eq(2), that is,

$$e_j = V_i - U_i \quad (2)$$

where V_i is the symmetric error term and U_i is a one-sided error term. From Equation (2), the V_is are assumed to be independently and identically distributed (i.i.d) as $N(O, \sigma_v^2)$. The U_is are assumed to have a half-normal non-negative distribution $N(O, \sigma_u^2)$. The V_is and U_is are also assumed to be independent of each other. V_i reflects random noise and can take both positive and negative values while U_i represents inefficiency. That is, it represents the shortfalls of the actual profit, due to technical and managerial constraints, from its maximum possible value. It assumes only nonnegative values (Abdulai and Huffman, 1998).

Following Rahman (2003), the profit efficiency of farmers in the context of the two-stage stochastic profit frontier model was defined in Eq(3) as:

$$E\pi_i = E[exp(-U_i)] \quad (3)$$

where $E\pi_i$ is the profit efficiency computed for i_{th} farm and $exp(-U_i)$ is the ratio of the actual output to the maximum possible output.

Frontier production models have been widely used in the field of agricultural economics, of which earlier studies have focused on Indian agriculture. Huang et al. (1986) were first to apply stochastic frontier method to estimate a profit frontier using the Indian data on 64 small and 51 large farms. They found individual farm economic efficiency to be greater in large farms.

Studies had also included institutional factors such as family ties with village leaders (Wang et al, 1996), extension services (Rahman, 2003), and infrastructure (Adeleke et al., 2008) in the estimation of the efficiency model. In Japan, very few studies in the field of agriculture had used stochastic profit frontier. One of the earliest studies on profit efficiency estimation is the study conducted by Honma and Higuchi (1993), where they found the mean profit efficiency of large-scale rice farmers to be 20 % but failed to account for the factors affecting efficiency due to lack of quantitative data. In addition, the study conducted by Sakamoto and Kusakari (2009) investigated the effects of the set-aside programs on profit efficiency in Japanese rice production of 174 sample farms in Tohoku region. Results showed that the set-aside program has a negative effect on the allocative efficiency of farmers due to excessive use of inputs in small farms and price drop in the sales price of rice. In view of the available literature, no study has been found to have assessed the relationship between profit efficiency and institutional factors such as subsidy, and interaction between technology adoption (EFA) and the socio-economic factor such as farm size. This study sought to find whether institutional factors such as direct payment subsidies provide an incentive to improve profit efficiency in rice production.

3. Methodology

The data for this study were collected from three cities in Shiga Prefecture namely Otsu City, Kusatsu City, and Koka City. The study followed a three-stage sampling technique. The first stage involved purposive selection of the three cities. Second, within each city, environmentally-friendly rice producing farms were purposively selected. Lastly, at the farm group level, the farm group leaders and managers were identified and consulted to distribute the questionnaire to their members. Due to the sensitivity of the questions, difficulty in generating a sampling frame from which to randomly select respondents was experienced. As a result, only farmers who are likely to participate in the survey were selected by the farm leaders. Overall, 82 farmers participated in this study.

Descriptive analysis was performed for the socio-economic characteristics of the rice farmers in the study area, while stochastic frontier analysis using the profit function specified in equation (i) was done to determine profit efficiency.

The lack of consistency in the assumptions about the distribution of efficiency has become a problem using the two-stage stochastic frontier approach. It assumes that the efficiency terms are identically distributed in the estimation of the stochastic frontier model in the first stage. This assumption is contradicted by the fact that the regression of efficiency terms on the explanatory variables suggest that terms are not identically distributed (Kumbhakar and Lovell, 2000). In order to overcome this inconsistency, profit efficiency of farms was estimated using a one-step approach. In this approach, the inefficiency effects were defined as a function of the farm-specific factors (as in the two-stage approach) but were incorporated directly into the maximum likelihood estimates (MLE) (Kumbhakar et al., 1991).

The econometric specification for the profit frontier followed a Cobb-Douglas function in implicit form based from the restrictions drawn by Chand and Kaul (1986). The specification is shown in Eq(4) as follows:

$$ln\pi_j = \beta_0 + \beta_1 lnX_1 + \beta_2 lnX_2 + \beta_3 lnX_3 + \beta_4 lnX_4 + (V_i - U_i) \quad (4)$$

Where π_j is profit computed for j_{th} farm: $X_1$is number of days worked/ha: X_2 is seed cost/ha; X_3 is pesticide cost/ha; X_4 is fertilizer cost/ha; β_0 is constant; and β_i is the coefficient of the parameters to be estimated. In this functional form, profit is a function of input and output prices and not the quantity of output and input. The assumption is that the optimal output and input have already been predetermined.

The study further investigated the sources of profit efficiencies for the surveyed farmers. Empirically, inefficiency (U_i) was transformed into efficiency ($E\pi_i$) in this study, where efficiency model is specified in Eq(5) as:

$$E\pi_i = \delta_0 + \delta_1 Z_1 + \delta_2 Z_2 + \delta_3 Z_3 + \delta_4 Z_4 + \delta_5 Z_5 + \delta_6 Z_6 + e_j \quad (5)$$

Where $E\pi_i$ is efficiency term; Z_1 is EFA adoption dummy (0=No, 1=Yes); Z_2 is EFA subsidy amount (JPY/ha); Z_3 is income stability subsidy amount (JPY/ha); Z_4 is Koshihikari dummy (0=No, 1=Yes); Z_5 is farm size (ha); Z_6 is EFA Adoption $(0 = \text{No}, 1 = \text{Yes}) \times$ Farm Size (ha); δ_{0-6} is efficiency model coefficients; and e_j is error term of the j_{th} farm. The rationale for including these explanatory variables was due to observed deviations from the profit frontier were assumed to result from the above farm-specific factors based from previous studies. These variables were also tested for multicollinearity where results showed there is a small positive correlation between the variables $(|r| < 3)$. MLE of the parameters of the stochastic profit frontier function and the efficiency model defined by equations (iv) and (v) are obtained using Frontier 4.1c.

4. Results and discussion

The socio-economic characteristics of the respondents are presented in Table 1. Results showed that the average age of EFA farmers is 61 y, while that of conventional farmers is 56 y. One could then infer from this result that rice farmers from both groups in the study area are ageing. In addition, the average educational attainment for EFA farmers is 13 y while that of conventional farmers is 14 y. Conventional farmers were relatively more educated having acquired education from either vocational school or university. The average number of years spent on EFA farming was 10 y and the EFA program has been implemented in Shiga Prefecture over the past 16 y. This may imply that as a farmer’s experience increases, so does his skills in optimally allocating the resources at his own disposal. Lastly, it was revealed that farm income is significantly different between the two groups, with EFA farmers receiving a higher income at 1,317,720 JPY/ha. EFA farmers also enjoyed a bountiful harvest of 3,333 kg against the 2,450 kg for conventional rice farmers. This resulted in a difference of 883 kg. Grain yield under organic farming is often lower than conventional farming, as a result of pest infestation due to elimination of pesticides and fertilizers. Likewise, the average farm size is larger among EFA rice farmers, recorded at 3 ha.

Table 1: Socio-economic and production characteristics of rice farmers, 2018-2019

Variable	All Samples (n=82)	EFA Rice Farmers (n=45)	Conventional Rice Farmers (n=37)	Difference	*t* stat
Age (y)	59	61	56	-4.89*	-1.68
Education (y)	14	13	14	1.06**	2.38
EFA Farming Experience (y)	5	10	0	-9.87***	-11.6
Net Farm Income (JPY/ha)	1,020,291	1,317,720	658,553	-652,414*	-1.72
Output (kg)	2,935	3,333	2,450	-883**	-2.30
Farm size (ha)	1.9	3	0.5	-2.5***	-2.90

Significant at ***p<0.01, **p<0.05,*p<0.1
Source: Author's own survey, 2018-2019.

Table 2 shows the stochastic profit frontier and the factors affecting profit efficiency. Based from the results, profitability increases with an increase in market price. The profit elasticity with respect to market price is 1.258 indicating that an increase in the price of rice by 1,000 JPY/60 kg, profit will increase by 1,258 JPY/60 kg on a per hectare basis. Among the variable inputs, only labor was significant. This means that an increase of one day/ha in the number of days worked will reduce profitability by 0.49 %. This implies that labor significantly leads to a decreased profit due to the cost incurred from additional labor requirement in rice production among EFA farmers. Table 2 also shows the results of the efficiency model, which are the factors considered to influence efficiency of rice farmers in the study area. The coefficients on EFA adoption, EFA subsidy, farm size, and interaction between EFA adoption and farm size were found to be significant. Among these variables, EFA adoption and farm size had the expected positive sign. This implies that encouraging the adoption of EFA practices and increasing the cultivation area for rice production would improve the technical efficiency of rice farmers and result in increased profit efficiency.

Table 2: Maximum-likelihood estimates of the Cobb-Douglas stochastic profit frontier function and profit efficiency of rice farmers for 82 samples in Japan, 2018-2019.

Variable	Parameter	Coefficient (se)
Stochastic Profit Frontier Model		
Constant	β_0	1.258*** (0.3925)
Labor (man-days/ha)	β_1	-0.4891*** (0.0837)
Seed cost (JPY/ha)	β_2	-0.1629 (0.1309)
Pesticide cost (JPY/ha)	β_3	0.0027 (0.1367)
Fertilizer cost (JPY/ha)	β_4	-0.2356 (0.1808)
Efficiency Model		
Constant	δ_0	0.2177*** (0.0314)
EFA Adoption	δ_1	0.5372*** (0.0496)
EFA Subsidy	δ_2	-1.28e-06*** (1.54e-07)
Koshihikari dummy	δ_3	-0.0014 (0.0362)
Farm size	δ_4	0.0818*** (0.0277)
$EFA \times Farm\ size$	δ_5	-0.0768*** (0.0281)
Diagnostic Statistics		
Sigma-square		2.665
Gamma ($\gamma = \delta^2 u/\delta^2$)		0.79***
Log likelihood function		-116.7

Standard errors in parentheses, significant at ***p<0.01, **p<0.05,*p<0.1

In addition, increasing the cultivation area for rice prodution by a hectare could increase profit efficiency by 0.08. On the other hand, EFA subsidy and the interaction between EFA adoption and farm size were significant but have a negative effect. This implies that if EFA subsidy is increased by 100,000 JPY/ha, profit efficiency of farmers will decrease by 0.13. On the other hand, the interaction term between EFA adoption and

farm size will reduce profit efficiency among EFA rice farmers who have larger areas (≥ 10 ha) cultivated to rice by as much as 0.08.
The distribution of the profit efficiency of individual farmers is presented in Figure 1. The highest efficiency level was 0.86 and the lowest was 0.05. The mean profit efficiency is 0.42 which is below the frontier level. This implies that profit could be increased by 0.58 by improving technical and allocative efficiency.

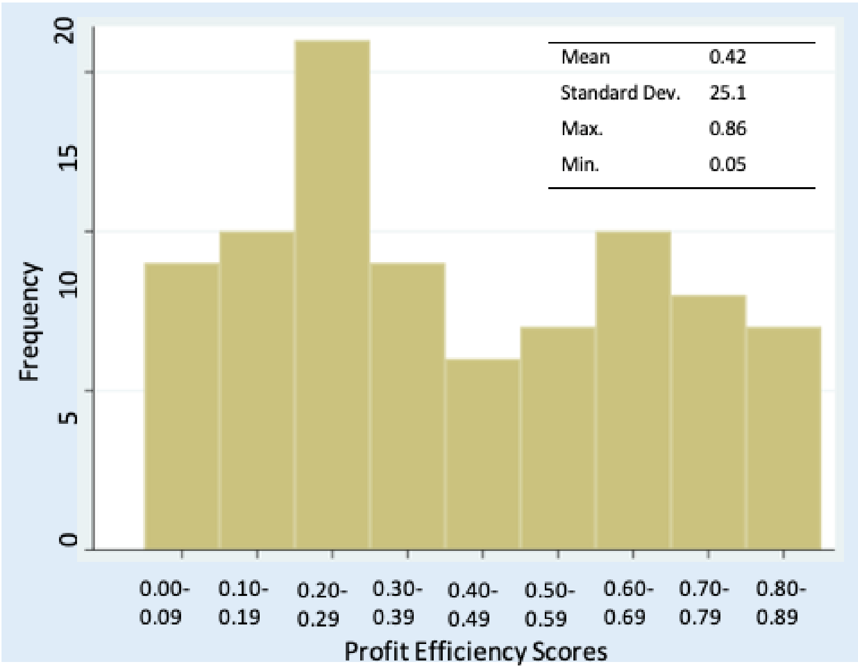

Figure 1: Frequency distribution of profit efficiency of rice farmers in Japan.

5. Conclusion

This study estimated the profit efficiency of environmentally-friendly rice farmers and determined the factors affecting their profit efficiency. The analysis of socio-economic characteristics of the 82 respondents showed that farmers were ageing and quite experienced in EFA rice production. Further, the level of educational attainment was high among respondents. Farm income and output were also statistically different between EFA and conventional rice farmers, where higher farm income and output were recorded for EFA farmers. Respondents were also majorly small-scale farmers with a mean farm size of 2 ha.
The stochastic profit frontier analysis showed that profit efficiency levels of farmers ranged from 0.05 to 0.86, where labor was the only significant variable which negatively affects profitability. The institutional and farm-specific factors positively affecting profit efficiency were EFA adoption, income stability subsidy, and farm size. Within the limitations of this study, particularly on small sample size and purposive selection of study sites, it may be concluded that increased profit efficiency among farmers is achieved not because of direct payment subsidies but due to adoption of EFA and land expansion. However, when conventional farmers switch to EFA farming, larger farm size is not sustainable for EFA rice production due to its small scale of investment and less capital requirement.
Smaller farms should be allocated to EFA production to improve allocative efficiency by reducing labor intensity to manageable levels and increase technical efficiency by improving small-scale managerial techniques for enhanced profit efficiency. Policies aimed at popularization of EFA through provision of higher price premium, reform in the direct payment subsidy system, and land consolidation should be considered.

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