Predicting Farmers' Responses to Flexible Bonus-based Agri-Environmental Payments: Empirical Findings from Rice Farming in Japan

Katsuya Tanaka

Research Center for Sustainability and Environment
Shiga University
1-1-1 Bamba, Hikone, Shiga 522-8522 Japan
Phone: +81 749-27-1154
Email: tanakak@biwako.shiga-u.ac.jp

Abstract

Agri-environmental payments (AEP) have been implemented for over 10 years, being considered a primary agri-environmental policy in Japan. However, program enrollment is close to its peak partly due to budget limitations and a rigid payment scheme. However, it might be possible to increase program participation by introducing flexible payment schemes. This study investigates the effects of different bonuses (extra payments) on farmers' AEP acceptance decisions in Japan. To this end, we conducted a survey on 576 medium- and large-scale rice farmers in four prefectures (Akita, Fukui, Shiga, and Shimane) by introducing three hypothetical bonus payments (scale, acquisition, and adjacency) and asking farmers about possible acceptance. Farmers' responses were subsequently used to derive their minimum acceptable bonus levels. The results show farmers are responsive to scale and adjacency bonus payments, but not to the acquisition bonus. The findings also indicate significant variations for the minimum acceptable bonus, thus reflecting considerable heterogeneity among farmers in the study region. From these results, Japan's AEP could attract more farmers and achieve significant efficiency gain without substantial budget increases.

Keywords: agri-environmental payments, bonus payments, flexible payments, payment for ecosystem service, Japan

JEL codes: Q15, Q18, Q57

1 Introduction

Agriculture provides a wide range of ecosystem services to the society (Boyd and Banzhaf 2006; Millennium Ecosystem Assessment 2005; Swinton et al. 2007; Zhang *et al*. 2007). Besides its material production function, such as food supply, agriculture also contributes to water conservation, flood control, water purification, local environment stabilization, recreation and green tourism, cultural formation, and environmental education. Because most of these functions are either indirect-use or have non-use value, they are not explicitly considered on the market. Due to this externality of market failure, the resulting supply of these services tends to not be sufficient for the society (Jack, Kousky, and Sims 2008).

To enhance agricultural ecosystem services, agri-environmental payments (AEP) have been implemented in various countries. AEP take various forms but are mostly voluntary payments for farmers who join the program and adopt conserving practices for promoting the ecosystem services from agricultural parcels. As such, AEP can be considered as payments for ecosystem services (PES) in agriculture. Hitherto, these payments have been major policy measures to address environmental problems in agriculture, particularly in the United States and for EU member states.

In Japan, the first national AEP ("conservation payments for farmland, water, and environment") was implemented during 2007–2011. The current second generation of AEP ("payments for conservation agriculture") has been in use since 2012, and the program was enhanced as permanent law since 2015. Under these payments, farmers who voluntarily participate in the program are required to reduce their use of chemical fertilizers and insecticides by 50 percent and adopt one of the conservation practices specified by the program[1](Ministry of Agriculture, Forestry and Fisheries 2017). The per-hectare payment ranges from JPY 3,000 to JPY 8,000, depending on the practice chosen by the farmer.[2]

However, one major problem of the current AEP is its lack of flexibility, as for any conservation practice, the per-hectare payment is uniform nationwide, not accounting for farmers' heterogeneity among different locations or farmland size. Such inflexibility may reduce the efficiency of the program and farmers' incentives to increase their levels of participation.

To provide this payment mechanism more flexibility, Smith and Shogren (2002) and Parkhurst et al. (2002) proposed an agglomeration bonus as an incentive mechanism, designed to create a contiguous habitat in forest areas. This mechanism offers a bonus payment if enrolled parcels are spatially connected with other enrolled parcels. The mechanism thus provides an incentive for non-cooperative landowners to voluntarily create a contiguous reserve across common borders (Parkhurst *et al.* 2002; Parkhurst and Shogren 2007).

Such agglomeration bonus payment programs have been implemented for promoting the reunification of fragmented forest patches in the U.S. and Canada for over a decade. However, to the best of our knowledge such bonus payments have not been introduced to the field of agriculture.

Therefore, the objective of this study is to investigate the effects of different bonuses on farmers' AEP adoption decisions in Japan. To this end, we conducted a survey on 576 medium- and large-scale rice farmers in four prefectures in Japan, namely Akita, Fukui, Shiga, and Shimane. We proposed three hypothetical bonus payments (scale, acquisition, and adjacency) and asked about possible acceptance. Farmers' responses were then used to derive minimum acceptable bonus levels. The analytical procedure is described in the next section.

2 Analytical framework

2.1 Estimating minimum acceptable bonuses

We propose a model to predict farmers' decisions to whether accept bonuses under the current AEP program.[3] Let π_i^c and π_i^a be farmer *i*'s profit per hectare with and without bonus payments, respectively. If practice with bonus payment is more profitable (i.e., $\pi_i^c > \pi_i^a$), then farmer i will accept the bonus payment (R). Therefore, the probability that farmer i accepts the bonus is $\Pr(D_i) \geq R$.

Assuming farmers' decisions are binary and modeled using a logit model, the cumulative density function of the opportunity cost is defined by (Maddala 1983):

$$F_i(R) = \Pr(D_i \leq R)$$
$$= \frac{\exp(X'\beta + R\gamma)}{1 + \exp(X'\beta + R\gamma)}, \qquad (1)$$

where X is the vector of economic and physical variables affecting farmer i's adoption decision and β and γ are the parameters to be estimated. Differentiating Equation (1) with respect to the bonus payment (R), we obtain the probability density function of bonus acceptance:

$$f_i(\mathrm{R}) = \frac{\exp(X'\beta + R\gamma)}{[1 + \exp(X'\beta + R\gamma)]^2}. \qquad (2)$$

By integrating Equation (2) over R, we obtain the expected value of the farmer i's minimum acceptable bonus level for adopting AEP:

$$E(\mathrm{OC}) = \int_0^\infty R \frac{\exp(X'\beta + R\gamma)}{[1 + \exp(X'\beta + R\gamma)]^2} \cdot \gamma dR$$
$$= \frac{\exp(X'\beta + R\gamma)}{1 + \exp(X'\beta + R\gamma)}\Bigg|_0^\infty + \int_0^\infty R \frac{\exp(X'\beta + R\gamma)}{[1 + \exp(X'\beta + R\gamma)]^2} \cdot \gamma dR$$
$$= \frac{1}{\gamma}\log\left(1 + \frac{1}{X'\beta}\right). \qquad (3)$$

Equation (3) is a simple formula and can yet be used to calculate farmer-specific acceptable bonuses, which is easily done using farmers' characteristics and their coefficients from the logit model. To do so, we require information on farmers' decisions, such as farmers' responses to participation in the AEP program at given bonus levels. We also need to identify the factors that affect those decisions. Because there is no existing AEP program providing bonus payments, we conducted a farm survey to obtain farmers' responses to hypothetical bonus payment as part of the current AEP in Japan.

2.2 Farm survey

To examine how farmers respond to bonus payment schemes, we conducted a farm survey on 576 medium- and large-scale rice farmers in four prefectures: Akita, Fukui, Shiga, and Shimane. Agriculture is intensive in all these prefectures. The survey was conducted from September to November, 2016.

In the questionnaire, we asked various questions, such as basic characteristics of the farmer and his/her farmland and current practices. Then, we asked several questions on the AEP program, including current enrollment status, possible future participation, and perception of agriculture environmental problems.

Subsequently, we presented the farmers with a scenario of a hypothetical bonus payment and asked them whether they would accept a bonus payment. Our policy scenario included three different bonus payments: (1) scale, (2) acquisition, and (3) adjacency bonuses. The scale bonus is an extra payment for farmers enrolling more than 10 hectares of land in the AEP program,[4] the acquisition bonus provides an extra payment for newly acquired farmland, and the adjacency bonus is for farmland adjacent to other AEP farmlands (adjacent land can be owned by anyone). Sample questions are displayed in Figure 1.

(Figure 1 around here)

To collect various responses under different bonus levels while maintaining simplicity, we set up a one-time binary question (accept or not) with four bonus levels: 10, 20, 30, and 40 percent increases from the baseline (i.e., current uniform payment level).

Among the 576 farmers, 346 responded to our survey (60 percent response rate). Excluding responses lacking information, a total of 303 responses was used for analysis (52 percent final response rate).

2.3 Data

To estimate the farmers' responses to different bonus schemes, we used various explanatory variables. First, BONUS_SCALE, BONUS_ACQ, and BONUS_ADJ are the levels of three different types of offered bonuses (scale, new acquisition, and adjacency). RES_SCALE, RES_ACQ, and RES_ADJ are dependent variables reflecting farmers' responses to the above bonus levels, respectively.

ADOPTION is a dummy variable for farmers currently enrolling in the AEP program. RATE_EFF and RATE_CONT are farmers' perceptions about the importance of operational efficiency and continuity of their businesses, respectively, ranging from 1 to 4 (unimportant to important).

AGE is the farmer's age and RISKATT the farmer's attitude towards risk, measured using the question on risky business operations, taking the value 1 if a farmer is risk-taker, and 0 otherwise.

To address heterogeneity among prefectures, three dummy variables are included for Akita, Fukui, and Shimane prefectures, with Shiga as the baseline.

Descriptive statistics of the independent and dependent variables are presented in Table 1.

(Table 1 around here)

3 Results and discussion

Table 2 shows the estimated results for three bonus payment schemes. Overall, the three models explain the data reasonably well, particularly for the scale and adjacency bonus schemes. The results indicate the scale and adjacency bonuses are statistically significant, which implies farmers are highly responsive to bonus schemes and willing to increase their potential AEP participation.

By contrast, the new acquisition bonus is not significant, probably because it is not sufficient for new acquisitions, which are usually more costly and risky.

(Table 2 around here)

Table 3 summarizes the estimated minimum acceptable bonus for scale and adjacency. These are calculated using the estimated results and equation (3). As the table shows, the mean bonus level is estimated at around 24 percent for both bonus schemes. This implies that, on average, farmers would increase their degree of enrollment for payments above 24 percent.

For the scale bonus, the estimated minimum value is below 3 percent, but the maximum is over 70 percent. Similar trend can be found for the adjacency bonus. These results imply significant variation among farmers.

(Table 3 around here)

Table 3 also summarizes the estimated values for different prefectures. As per the table, the mean of the minimum acceptable bonus is lowest in Shiga, at only around 13 percent on average for both bonus schemes. The estimated values are nearly double for the other three prefectures.

Figures 2 and 3 present histograms of the estimated minimum acceptable bonuses for scale and adjacency, respectively. While the histogram of the scale bonus is nearly symmetrical, that of the adjacency is right-skewed. Such differences in the shape of histograms indicate heterogeneity among farmers in accepting bonus payments.

(Figure 2 around here)

As Figure 2 indicates, only 10 percent of bonus payments would attract nearly 15 percent of farmers. Attractiveness would rise as bonus levels increase—nearly half of total farmers respond to a 20 percent bonus payment. Similar trends are estimated for the adjacency bonus. Figure 3 illustrates that a 10 and 20 percent of adjacency bonus would attract between 15 and 40 of the surveyed farmers, respectively.

(Figure 3 around here)

For both bonus payments, our models predict farmers are responsive. The proportions of farmers accepting bonuses exceeds that of bonus levels, implying bonus schemes improve AEP efficiency.

Efficiency can be further improved if different bonus levels are offered to individual farmers, depending on the minimum acceptable bonuses estimated in this study.

4 Conclusions

To empirically analyze the effect of introducing flexible payment schemes on Japan's AEP, this study investigated how different bonus payments affect farmers' acceptance decisions. To achieve this objective, we conducted a survey in medium- and large-scale 576 rice farmers in four prefectures (Akita, Fukui, Shiga, and Shimane), introducing three hypothetical bonus payments (scale, acquisition, and adjacency) and asking farmers about possible acceptance. Their responses were then used to derive minimum acceptable bonus levels.

The results show farmers are quite responsive to scale and adjacency bonus payments, but not to the acquisition bonus. Our results also show significant variation in minimum acceptable bonus levels, reflecting considerable heterogeneity among farmers in the study region.

Overall, we find bonus payments can possibly enhance farmers' participation in the current AEP program in Japan. However, effectiveness and bonus levels significantly differ among farmers and prefectures. As such, policymakers should consider introducing such bonus payment schemes, while taking heterogeneity into account. If such considerations are successful, AEP would attract more farmers while maintaining budget levels.

This study has several limitations. First, our hypothetical questions are quite simple, asking farmers whether to increase enrollment while the actual degree of enrollment is unknown. For example, Layton and Siikamäki (2009) develop a beta-binomial regression model to address both program participation and the amount of land enrollment. Our model can be expanded similarly to analyze the degree of participation, as well as binary participation decisions.

Second, this study analyzed only four prefectures. Although the prefectures were selected based on the importance of the issue and intensity of rice production, a larger-scale analysis would be needed to derive effective and generalizable policy implications, as the AEP is a nationwide payment program. Finally, the empirical analysis for a large-scale survey with more detailed payment scenarios would be an important expansion of this study.

References

Banerjee, S., Kwasnica, A. M., and Shortle, J. S. (2012). Agglomeration bonus in small and large local networks: a laboratory examination of spatial coordination. *Ecological Economics*, 84, 142-152.

Boyd, J., & Banzhaf, S. (2006) "What are ecosystem services? The need for standardized environmental accounting units." *Discussion Paper 06-02*. Resources for the Future, Washington, DC.

Engel, S., Pagiola, S., & Wunder, S. (2008). Designing payments for environmental services in theory and practice: An overview of the issues. Ecological economics, 65(4), 663-674.

Jack, B. K., Kousky, C., & Sims, K. R. (2008) "Designing payments for ecosystem services: Lessons from previous experience with incentive-based mechanisms." *Proceedings of the National Academy of Sciences* 105(28), 9465-9470.

Layton, D. F., & Siikamäki, J. (2009) "Payments for ecosystem services programs: predicting landowner enrollment and opportunity cost using a beta-binomial model." *Environmental and Resource Economics* 44(3), 415-439.

Maddala, G. S. (1983) *Limited-Dependent and Qualitative Variables in Econometrics*. Cambridge University Press.

Millennium Ecosystem Assessment (2005) *Ecosystems and Human Well-Being: Synthesis*. Island Press, Washington, DC.

Ministry of Agriculture, Forestry and Fisheries (2017) *Guideline of payments for conservation agriculture 2017*. URL: http://www.maff.go.jp/j/seisan/kankyo/kakyou_chokubarai/attach/pdf/mainp-29.pdf (accessed on January 1, 2018).

Parkhurst, G. M., Shogren, J. F., Bastian, C., Kivi, P., Donner, J., & Smith, R. B. (2002) "Agglomeration bonus: An incentive mechanism to reunite fragmented habitat for biodiversity conservation." *Ecological Economics*, 41(2), 305-328.

Parkhurst, G. M., & Shogren, J. F. (2007) "Spatial incentives to coordinate contiguous habitat." *Ecological Economics* 64(2), 344-355.

Parkhurst, G. M., Shogren, J. F., Bastian, C., Kivi, P., Donner, J., & Smith, R. B. (2002). Agglomeration bonus: an incentive mechanism to reunite fragmented habitat for biodiversity conservation. Ecological economics, 41(2), 305-328.

Smith, R. B., & Shogren, J. F. (2002). "Voluntary incentive design for endangered species protection" Journal of Environmental Economics and Management, 43(2), 169-187.

Swinton, S. M., Lupi, F., Robertson, G. P., & Hamilton, S. K. (2007). Ecosystem services and agriculture:

cultivating agricultural ecosystems for diverse benefits.

Tanaka, K., & Wu, J. (2006) “The empirics of environmental and distributional impacts of conservation targeting strategies.” *American Agricultural Economics Association Annual Meeting* (July 23-26, Long Beach, CA).

Zhang, W., Ricketts, T. H., Kremen, C., Carney, K., & Swinton, S. M. (2007) “Ecosystem services and dis-services to agriculture.” *Ecological Economics* 64(2), 253-260.

Notes

[1] The program accepts various conservation practices effective in reducing global warming, enhancing biodiversity, or both, namely three nationwide practices (cover cropping, use of organic compost, organic agriculture) and various prefecture-specific practices. In our study region, for example, Shimane Prefecture has seven practices, including integrated pest management, living mulch, winter flooding.

[2] USD 1 is approximately JPY 110 (as of May 2018).

[3] This formula was first proposed by Tanaka and Wu (2006).

[4] In this scale bonus question, farmers with less than 10 hectares of farmland can be eligible for this bonus if either they devote all farmland to the AEP or increase total farmland to 10 hectares (then being able to receive acquisition as well as scale bonuses).

1. Scale bonus

Assume per-hectare payment to be **increased by 20%** if the area of enrollment is **more than 10 ha**. Would you be willing to increase your enrollment for this bonus payment?

☐ **Yes** ☐ **No**

2. Acquisition bonus

Assume per-hectare payment to be **increased by 20%** for parcels recently acquired from other farmers. Would you be willing to increase enrollment for this bonus payment?

☐ **Yes** ☐ **No**

3. Adjacency bonus

Assume per-hectare payment to be **increased by 20%** for parcels adjacent with other enrolled parcels (including other farmer's parcels). Would you be willing to increase enrollment for this bonus payment?

☐ **Yes** ☐ **No**

Figure 1 Sample questions for scale, acquisition, and adjacency bonus

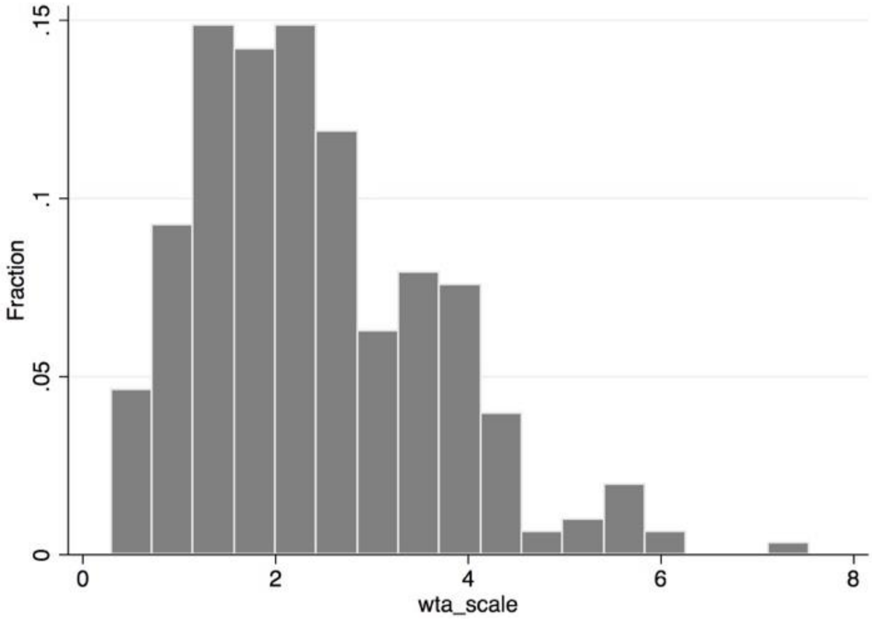

Figure 2　Histogram of estimated minimum acceptable bonus level (scale bonus)

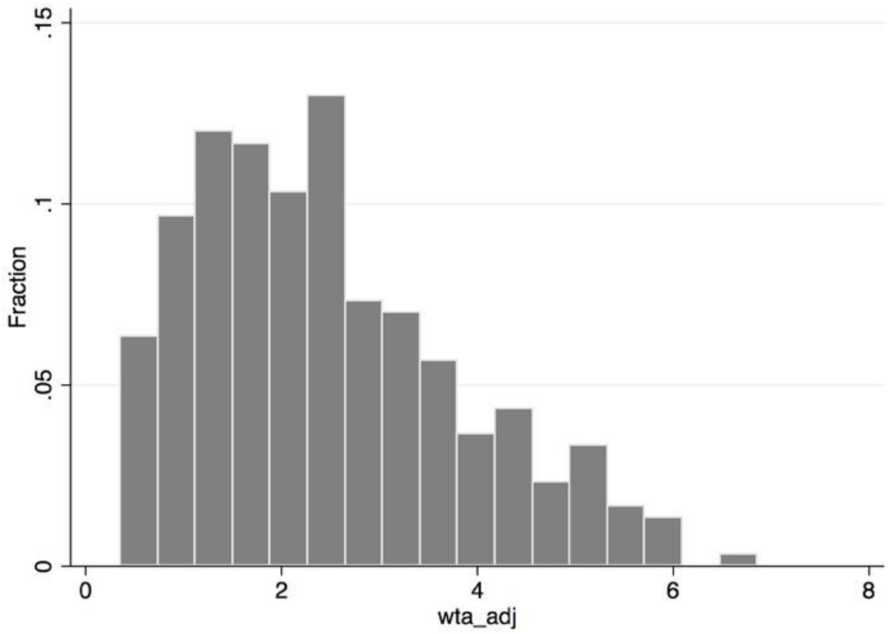

Figure 3　Histogram of estimated minimum acceptable bonus level (adjacency bonus)

Table 1 Descriptive statistics

Variables	Definition	Unit	Mean	S.D.	Min.	Max.
RES_SCALE	Farmer's response to scale bonus	Binary	0.42	0.49	0.00	1.00
RES_ACQ	Farmer's response to acquisition bonus	Binary	0.42	0.49	0.00	1.00
RES_ADJ	Farmer's response to adjacency bonus	Binary	0.44	0.50	0.00	1.00
BONUS_SCALE	Level of scale bonus	1–4	2.52	1.12	1.00	4.00
BONUS_ACQ	Level of acquisition bonus	1–4	2.51	1.14	1.00	4.00
BONUS_ADJ	Level of adjacency bonus	1–4	2.48	1.13	1.00	4.00
ADOPTION	Current enrollment of AEP	Binary	0.50	0.50	0.00	1.00
SIZE	Size of total farmland	Ha.	37.31	35.55	0.40	302.00
RATE_EFF	Farmer's perception: efficiency of operation	0–4	2.44	0.93	0.00	4.00
RATE_CONT	Farmer's perception: continuity of business	0–4	2.35	1.05	0.00	4.00
AGE	Farmer's age	Yeas	56.80	11.10	25.00	76.00
RSIKATT	Farmer's attitudes toward risks	Binary	0.17	0.37	0.00	1.00
AKITA	Dummy for Akita Prefecture	Binary	0.36	0.48	0.00	1.00
FUKUI	Dummy for Fukui Prefecture	Binary	0.15	0.36	0.00	1.00
SHIMANE	Dummy for Shimane Prefecture	Binary	0.36	0.48	0.00	1.00

Table 2 Estimated results of logit models for three bonus payments

Variables	Scale		Acquisition		Adjacency	
	Type of bonus					
Intercept	-0.445		0.113		-0.352	
BONUS	0.409	***	0.157		0.354	***
ADOPTION	0.869	***	1.324	***	1.019	***
SIZE	-0.008	**	-0.005		-0.007	*
RATE_EFF	-0.280	*	-0.164		-0.160	
RATE_CONT	0.325	**	0.301	**	0.255	*
AGE	-0.018		-0.032	**	-0.018	
ATT_RISK	0.575	*	0.409		0.700	**
D_AKITA	-0.140	**	0.437		-0.189	*
D_FUKUI	0.011		0.035		-0.259	
D_SHIMANE	-0.612	*			-0.430	
n	303		301		300	
Log likelihood	-184.106		-182.764		-184.271	
Psudo R^2	0.107		0.114		0.110	

Note 1: The dependent variables are farmers acceptance of the bonus payment.
Note 2: *, **, *** indicate statistical significance at 10%, 5%, 1%, respectively.

Table 3 Predicted minimum acceptable bonus levels for rice farmers in the four prefectures (%)

Bonus type	Prefecture	*n*	Mean	S.D.	Min.	Max.
Scale	Akita	101	28.58	13.74	6.44	75.40
	Fukui	48	22.22	10.48	6.21	45.42
	Shiga	42	13.84	7.78	2.95	30.32
	Shimane	112	24.51	11.05	6.61	58.59
	Total	303	24.02	12.44	2.95	75.40
Adjacency	Akita	101	26.84	14.60	5.94	59.88
	Fukui	48	26.12	13.82	8.22	68.58
	Shiga	42	12.28	7.32	3.58	38.93
	Shimane	109	27.12	11.37	5.59	59.65
	Total	300	24.78	13.45	3.58	68.58

Note: The bonus represents the percentage increase from the baseline uniform paymen