Does renewable energy investment incentive differ by feed-in-premium types? Evidence from a laboratory experiment

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Abstract

With the aim of renewable energy penetration into electricity markets, some European countries has been introducing Feed-in Premium (FIP) institution recently as a successor of Feed-in Tariff (FIT) policy. The FIP institution includes different types of the way to add a premium on market price. Using laboratory experiment, this paper attempts to reveal the difference in renewable energy investment between two different premium types: *fixed premium* which subsidize a constant premium for any market price; and *sliding premium* which assures a certain minimum price by supplying premium when the market price is less than the minimum price.

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1. Introduction

Renewable energy will play an important role to achieve a carbon-neutral economy to which several major countries have already committed to meet by 2050. To accelerate renewable energy penetration, several policies such as installation subsidy, Renewable Portfolio Standards (RPS), and a Feed-in-Tariff (FIT) have been introduced so far. Facing a FIT's heavy burden to consumers, some European countries have been shifting from FIT to Feed-in-Premium (FIP) institution, which is integrated into an electricity market not only to give a price signal to renewable energy producers and electricity consumers but also to mitigate the tariff burden.

The FIP has several types such as a Fixed premium and a Sliding premium (lowest bound) which have respective pros and cons. The Fixed premium promises to provide renewable energy producers with a constant additional price but doesn't assure the lowest price. The Sliding premium assures the lowest price, but the premium fluctuates according to the market price.

On one hand, the Fixed premium type has a strong price signal for renewable energy producers to generate electricity in demand peak periods while the producers' profits are heavily dependent on the total price (market spot price+ fixed premium) fluctuation. In Spain, Fixed premium type had been implemented as an alternative option of FIT institution until 2007 (Ito, 2015).

On the other hand, Sliding premium mitigates the profit fluctuation because it assures that the price will be at least as high as a certain level (FIP price) by subsidizing with premium whenever the market price is below this level. In Germany, where Sliding premium was introduced in 2014 (Ito, 2015). In Japan, the government is under consideration of FIP design and on the direction to choose the Sliding premium following the experiences in Germany (METI, 2021).

Which type of FIP will lead to higher invest in renewable energy? The objective of the study is to test the difference in renewable investment incentive between the two types of FIP using a laboratory experiment.

2. Models

We model individual's decisions on investments to a renewable energy as a linear public goods game with additional return from the electricity market. We utilize linear public goods game because it is one of the simplest and well-studied models of individual's decision making with positive externality on others. Here, we outline the model with parameters used in the experiment. For more general form, see our full paper.

Let us denote individual i's investment decision as $X_i \in \{0, 1, \dots, 10\}$ $(i = 1, \dots, 4)$, and the price for each investment as $p^T(p_m)$ where $p^T(p_m)$ is the sum of the market price p_m and the premium which differs depending on the FIP type $T \in \{Fixed, Sliding\}$. Given p_m, which is a random variable taking a value between 0.1 and 1 with equal probability, $p^T(p_m)$ for each type can be written as follows:

$$p^{Fixed}(p_m) = p_m + 0.1$$

$$p^{Sliding}(p_m) = \begin{cases} 0.5 \; if \; p_m \leq 0.5 \\ p_m \; otherwise. \end{cases}$$

Thus, the premium is constant at 0.1 in Fixed premium type; while in Sliding premium, it compensates for low market price when p_m is low, and it becomes zero when p_m is high.

Now that we have defined the gain from the electricity market for each investment, we can write the payoff for player i at strategy profile $X = (X_1, \dots, X_4)$ as follows:

$$\pi_i{}^T(X) = 10 - X_i + 0.3 \sum_{j=1}^{4} X_j + p^T(p_m) X_i.$$

The first three terms are the payoffs from the public goods game, and the last term is the extra gain from selling the electricity to the market.

Finally, if the players are risk neutral, the expected return from the electricity market is 0.65 under both FIP institutions. Thus, it is still a dominant strategy to contribute zero. On the contrary, if players are risk averse and have warm glow preference, we can expect the contribution to be higher in Sliding premium than in Fixed premium institution.

3. Experimental Design and Operation

We compared the Fixed premium and Sliding premium type FIP institutions using the game outlined in Section 2 in between subject design. The game was repeated 10 times in same group. The experiment was programmed using oTree (Chen et al., 2016), and conducted on zoom.

The procedure was as follows. Subjects first arrive on zoom and entered the main room one by one where they had their name changed to subject ID before being moved to a breakout room where the experiment starts. Thus, anonymity was kept in this experiment. The experiment starts with oral explanation of the consent form after which the subjects filled out the form on web. Then, subjects read the instruction and solved the understanding quiz online on oTree. The questions were asked and answered via private chat with the experimenter. After all subjects answered the understanding quiz correctly, the main experiment started, followed by a questionnaire. The subjects were paid for 500 Yen participation fee and the points they had earned in one randomly chosen round at the rate of 1 point = 100 Yen.

Experiment was conducted in 2021 using undergraduate student sample of Ritsumeikan University. The experiment was conducted on zoom. We recruited subjects from three main campuses using the university's webpage. In total, 76 subjects (36 in Fixed premium and 40 subjects in Sliding premium treatment) participated. There were no statistically significant different in subjects characteristics, such as Gender, willingness to take risk (Dohmen et al. 2011), and Social Value Orientation (Murphy et al., 2011). The experiment lasted for about 1.25 hours, and the average payment was 2,259 Yen.

4. Result and Discussion

4.1 Descriptive Analysis

This subsection provides the results of descriptive analysis conducted to test the hypotheses drawn from the theoretical analysis in Section 2. The theoretical analysis shows that (1) if subjects are risk neutral and are maximizing their own monetary payoffs, the contribution in Fixed and Sliding premium treatments would both be zero; and (2) if the subjects are risk averse and have warm glow preference, the contribution in Sliding premium treatment would be higher than that in Fixed premium treatment. We show that the results of the experiment did not support both (1) and (2).

Figure 2 shows the transition of average contribution (in left) and profit (in right) per treatment. First, as the figure depicts, the average contribution is higher than zero in both treatments, and it is higher in Fixed premium than in Sliding premium treatment. Average contribution over all periods is 5.328 for the Fixed premium and is 4.630 for the Sliding premium treatment. Although the comparison of the distribution of per-individual average contribution across the two treatments using Wilcoxon rank-sum test were statistically significant at 10% level (*p*-value = 0.087), we were not able to reject the null hypothesis at the group average level. To control for both heterogeneities, we conducted a panel-data analysis.

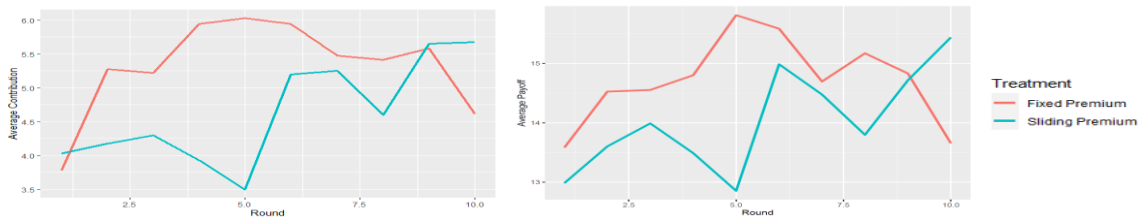

Figure 2 Transition of Average Contribution (Left) and Profit (Right) conditional on treatment

4.2 Regression Result

Using the panel-dataset, we estimate generalized-least-squares (GLS) regressions by a random effect model to explain individual contributions. The dataset contains the observations from 76 subjects who have their attribute variables such as gender, prosocial attitude, and risk attitude.

Table 1 presents regression estimates of three models. The model 1 includes neither an interaction term of FIP type and round number nor an interaction term of Fixed premium dummy and prosocial angle. The model 2 include an interaction term of FIP type and round number but doesn't include an interaction term of Fixed premium dummy and prosocial angle. The model 3 includes all the interaction terms.

The table shows that the coefficient of Fixed premium dummy variable gets significantly

positive (+2.032～+3.766) when controlling the round proceeding effects which is significantly positive (+0.195 per round) in the Sliding premium case. This result suggests that the Fixed premium type stimulates the contribution than the Sliding premium type while the Sliding premium instrument gradually stimulates the contribution as illustrated in section 4.1.

Table 1　Panel regression results

dependent: contribution	model 1	model 2	model 3
fixed premium FIP	0.393	2.032***	3.766***
	(0.881)	(3.071)	(3.553)
sliding FIP#round number		0.195***	0.195***
		(3.401)	(3.406)
fixed premium FIP#round number		-0.072	-0.071
		(-1.202)	(-1.200)
prosocial angle	0.019	0.020	0.052**
	(1.286)	(1.307)	(2.426)
fixed premium FIP#prosocial angle			-0.063**
			(-2.086)
group total contribution (t-1)	0.047**	0.035*	0.035*
	(2.547)	(1.837)	(1.827)
market price (t-1)	-0.437	-0.452	-0.442
	(-1.151)	(-1.202)	(-1.177)
gender(female=1)	-0.909**	-0.916**	-0.852*
	(-2.018)	(-2.032)	(-1.921)
trust in others	-0.570**	-0.569**	-0.513**
	(-2.505)	(-2.499)	(-2.278)
environmental knowledge	-0.103	-0.099	-0.202
	(-0.387)	(-0.370)	(-0.759)
environmental behavior	-0.087	-0.093	-0.051
	(-0.478)	(-0.510)	(-0.282)
risk take attitude	0.230**	0.230**	0.261***
	(2.299)	(2.304)	(2.631)
concern for others (dum)	0.894	0.893	0.737
	(1.354)	(1.353)	(1.130)
altruism (dum)	0.446	0.462	0.354
	(0.927)	(0.961)	(0.746)
understanding	-0.009	-0.006	-0.010
	(-0.055)	(-0.034)	(-0.062)
Constant	4.189**	3.209*	2.416
	(2.435)	(1.842)	(1.379)
Observations	684	684	684
Number of participantid_in_session	76	76	76
r2 within	0.00675	0.0292	0.0292
r2 between	0.307	0.299	0.341
r2 overall	0.125	0.135	0.152
z-statistics in parentheses			
*** p<0.01, ** p<0.05, * p<0.1			

Regarding a prosocial angle, although it does not show any significant effects on the contribution to renewable energy in both model 1 and model 2, its coefficient turns to be significantly positive (+0.052) in model 3 in which an interaction terms of interaction term of Fixed premium type dummy and prosocial angle is added. In the same model, the coefficient of the interaction term is negatively significant (－0.063) and these findings lead to an important implication: The prosocial subjects in the Sliding premium tend to invest more in renewable energy than the individualistic subjects while, under the Fixed premium type, there is no substantial difference between individualistic and prosocial subjects.

The estimation result also shows that, in all models, risk-talers contribute more by

0.230~0.261 than others while an interaction term of risk attitude and FIP type doesn't show any significant effect on the individual contribution (that is not shown in the Table 1).

5. Conclusion

This paper investigated a possible difference in the effect of renewable energy promotion between two types of Feed-in Premium (FIP) institution (Fixed premium and Sliding premium) using a laboratory experiment. The investment in renewable energy can be regarded as both private-goods investment and public-goods contribution because it not only increases profits from FIP but also expand positive externalities such as air pollution and climate change mitigation in cooperation with other contributors. We take into account the current FIP design in several countries where a fixed premium is added to a market price or a fluctuating premium is added to the price so as to assure a lowest renewable power price.

First, we found that the Fixed premium type stimulates the contribution than the Sliding premium while the Sliding premium instrument gradually stimulates the contribution and reaches at the same contribution level as the Fixed premium. Considering the fact that some countries has been shifting to the Sliding premium type as explained in Introduction, our finding may be controversial to judge which type is more effective and sustainable. In order to get a clearer answer, it will be necessary to implement an additional experiment with more rounds to find a longer-term difference between the types.

Second, it is found that a prosocial subject in the Sliding premium tends to invest more in renewable energy than the individualistic ones in the same groups. Considering the Sliding premium has been introduced in some countries, prosocial power companies or investors may play an important role in renewable energy penetration in these countries although the finding has to be scrutinized more theoretically and empirically.

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