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Conference Paper

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55th Congress of the European Regional Science Association: "World Renaissance: Changing roles for people and places", 25-28 August 2015, Lisbon, Portugal

Provided in Cooperation with:

European Regional Science Association (ERSA)

Suggested Citation: Ohno, Eiji; Mori, Ryuta; Matsumoto, Akira (2015) : Economic Evaluation of Small-scale Renewable Electricity Generation Project with Community Participation by Regional I-O Analysis in which WTW is incorporated, 55th Congress of the European Regional Science Association: "World Renaissance: Changing roles for people and places", 25-28 August 2015, Lisbon, Portugal, European Regional Science Association (ERSA), Louvain-la-Neuve

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Economic Evaluation of Small-scale Renewable Electricity Generation Project with Community Participation by Regional I-O Analysis in which WTW is incorporated

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Abstract: Small-scale renewable electricity generation projects have the potential to address not just the need to reduce greenhouse gas emissions to combat climate change, but also to provide local, sustainable economic and community revitalization. In this paper, we have proposed a small hydroelectric generation project with citizen participation which includes cooperation in some activities such as cleaning and patrols, and have evaluated the project economically by using the regional I-O analysis in which the WTW is incorporated. The WTW for the project have been estimated by using the conjoint analysis as a function of its various attributes, namely revenue from the project's electricity sales, profits earned for the local community, and rewards given to contributors. The results show that the amount of WTW provided by resident volunteers will increase with increasing unit value of reward, but the amount of reward paid to volunteers will also increase. On the other hand, the operating income of the establishment that has contracted maintenance of the small hydroelectric supply sector will decrease, and its influence will spread through the inter-industry relations. Then, we have analyzed such economic ripple effect by using the regional I-O table for analysis of small hydroelectric generation project. By considering the range of the "unit value of reward" and the "substitution rate of resident volunteers", even if the project is deficit, we have found a good countermeasure which can be expected positive effects.

JEL classification: Q42, Q51, R13

Keywords: *small-scale renewable electricity generation, community participation, community revitalization, regional input output analysis, willingness to work*

1. Introduction

Following the Kyoto Protocol, renewable energy projects are well-known as possible ways to reduce the greenhouse gas emissions, that is, project for mitigation of global warming.

After the Great East Japan Disaster, such projects are also noteworthy possibilities for adaptation to global warming, because they can provide various energy sources and locally produce energy for local consumption. Such projects are currently being discussed by many Japanese local governments. If such projects are enacted, people will be asked to contribute a sizeable proportion of the project's implementation and upkeep. In many Japanese areas, problems such as a falling birth rate, aging, and stagnation of the regional economy are important subjects, so adaptation projects are not automatically high priority. In addition, despite an abundance of natural resources such as forests, wind, water, and sunlight, local cities can face financial problems in funding projects that utilize these resources.

On the other hand, development of renewable energy projects utilizing such natural resources can provide a big boost to revitalizing local economies. For example, in Iida City, a small city in Japan, a renewable energy project with citizen participation has been promoted through cooperation between the public and the private sectors. Funds were first raised from residents, then invested in a solar power project, with the revenues from the project's electricity sales being used to pay dividends back to residents.

Such renewable energy projects will offer a range of benefits to local communities. In terms of environmental impacts, carbon dioxide emissions will be reduced by introducing a renewable energy system. For the social aspect, energy supply redundancy during a disaster will increase by the provision of various energy sources and the local production of energy for local consumption. In terms of aspects, local employment will be stimulated if local contractors are used to construct the renewable energy system. For a solar power system to be installed on house roofs, it may be a particular requirement that the quality of construction site be able to withstand long-term use, and furthermore, it does not seem unreasonable to stipulate that construction works should be performed by contractors with local site knowledge. Installation by local contractors, in turn, has various knock-on effects; proximity makes it is easy for residents to request for repair and maintenance after installation, and a relationship of trust with local residents will evolve. Therefore, using local contracts means the renewable energy project could achieve both global warming adaptation and regional economic revitalization.

Furthermore, through such a type of project with citizen participation, local residents will become both more environmentally aware and active, and we can expect that the quality of the semi-public service will improve and local residents will have higher levels of satisfaction. Accordingly, in this paper, we propose a small hydroelectric generation project with citizen participation that includes not only citizen donations to the project but also cooperation in some activities such as cleaning and patrols. And, we evaluate the project economically by using the regional I-O (input-output) analysis in which the WTW (willingness to work) is incorporated.

2. A small-scale renewable electricity generation project

Small hydroelectric generation refers to the small-scale power generation able to take advantage of small rivers and canals used for agriculture. Furthermore, since it generates power by using a small drop, it is possible to effectively utilize unused river water resources. Therefore, small hydroelectric generation offers the following advantages:

- Since it can use small rivers and canals in their natural state, there is no need to build new big dams.
- Since it utilizes unused river water resources, it leads to improvements in river environments.
- Since technology and know-how related to hydroelectric generation are well-established in Japan, such small-scale projects can be implemented easily.

The proposed small hydroelectric generation requires installation of small-scale power generation facilities along small rivers and canals in the target region, and thus the canals and rivers need to be developed and maintained to ensure proper water flow. In particular, for the small hydroelectric generation to run efficiently, daily maintenance, such as dredging trash from rivers and patrolling of power generation facilities, is important. Accordingly, we propose a following small hydroelectric generation project that aims to address both global warming adaptation and regional economic revitalization.

- A small hydroelectric generation company can be made responsible for the development of small rivers and canals and installation of small-scale power generation facilities; such a company can be launched by resident volunteers in the region as a project to help revitalize the local economy.
- Daily maintenance, such as dredging trash from rivers and patrolling power generation facilities, can be conducted coordinated by the local residents who installed the small hydroelectric facility.
- Tasks requiring technical expertise such as maintenance of power generation facilities will be tendered out to a professional contractor.
- A proportion of the project's revenue from electricity sales is allocated to the region where the small hydroelectric facility is installed.

Now, the following points are significantly different from the solar power generation project described above:

- A project can be expected not only to offer investment and donation opportunities in financial terms but also to elicit participation and cooperation by the community in activities such as dredging and patrolling.
- Profits derived from the project that utilizes local resources can be returned to the region.
- These improve the satisfaction of local residents and contribute to regional activation.

3. Interview survey

To estimate the utility function of households to use for the benefit evaluation, a web-based interview survey was conducted in early October 2013. The survey was targeted at people living in Nagano Prefecture, including Iida City, who were over 20 years old. A total of 1,096 responses were obtained, but only 1,077 were valid. Basic statistics of the survey respondents are shown in Table 1.

The survey was titled “Attitude survey on global warming adaptation and regional economic revitalization.” The questionnaire contained the following contents:

- Question 1: Personal attributes: gender, age, occupation, annual income, activities related to environmental protection, and so on.
- Question 2: Awareness of the impact and measures of global warming.
- Question 3: Awareness of the renewable energy project and the small hydroelectric generation project.
- Question 4: Pair comparison of hypothetical small hydroelectric generation projects; willingness to pay.
- Question 5: Pair comparison of hypothetical small hydroelectric generation projects; willingness to work without reward.
- Question 6: Pair comparison of hypothetical small hydroelectric generation projects; willingness to work with reward, 1st time.
- Question 7: Pair comparison of hypothetical small hydroelectric generation projects; willingness to work with reward, 2nd time.
- Question 8: Understanding of the survey contents.

For the survey to effectively analyze individual differences in evaluation results, some questions regarding personal attributes were sought in Question 1. As an introduction to the survey’s topic, Questions 2 and 3 offered some figures and pictures to make it easy for respondents to recognize the impact and measurement of global warming.

The major questions of this study are Questions 4, 5, 6, and 7, and the parts dealt with in this paper are the answers to Questions 6 and 7. Two questions of binomial choice format were posed to each subject. In each question, two hypothetical small hydroelectric generation projects, which have different profiles as shown in Table 2, were presented to the subjects, who were asked to select the more desirable one. Variables ranging from A1 (B1) to A4 (B4) in Table 2 are (1) revenue from electricity sales from the small hydroelectric generation project; (2) percentage of amount to be reduced for local residents from electricity sales revenue; (3) amount of work required by local residents; and (4) rewards for engaging in this work. By using the values shown in Table 3, we created 26 binomial choice format questions in total, and prepared 13 different questionnaire sheets, each of which has two binomial choice format questions.

Table 1: Basic statistics of respondents

Gender	Proportion	Age	Proportion	Occupation	Proportion
Male	51.8%	20-24	7.0%	Company employee	32.8%
Female	48.2%	25-29	13.3%	Self-employed person	11.1%
Total	100.0%	30-34	8.4%	National public official	0.4%
		35-39	11.9%	Local public official	3.9%
		40-44	10.2%	Organization staff	1.4%
		45-49	9.5%	Part-time worker	15.0%
		50-54	12.3%	Househusband/wife	18.4%
		55-59	7.7%	Student	2.5%
		60-64	11.4%	No occupation	12.8%
		65-69	5.5%	Others	1.7%
		over 70	3.0%	Total	100.0%
		Total	100.0%		

Table 2: Sample binomial choice format questions

Question: Which do you prefer to cooperate with the following small hydroelectric generation projects “A” or “B”? Please choose one which applies to you.

- 1) I prefer to cooperate with project “A”.
- 2) I prefer to cooperate with project “B”.
- 3) I may cooperate with either projects “A” or “B”.
- 4) I do not want to cooperate with neither projects “A” nor “B”.

< Small hydroelectric generation project “A” >

- Revenue from electricity sales of small hydroelectric generation project:

“A1” million JPY per year

- Percentage of amount to be reduced to local residents from revenue from electricity sales: “A2” %

- Amount of work (*) required for local residents: “A3” hours per year

- Reward to work (*): “A4” JPY per hour

< Small hydroelectric generation project “B” >

- Revenue from electricity sales of small hydroelectric generation project:

“B1” million JPY per year

- Percentage of amount to be reduced to local residents from revenue from electricity sales: “B2” %

- Amount of work (*) required for local residents: “B3” hours per year

- Reward to work (*): “B4” JPY per hour

(*) work concerning to daily maintenance such as dredging trash from rivers and patrolling of power generation facilities.

Table 3: Variables of A1 (B1) to A4 (B4) in Table 2

Variables	Properties	Levels
Revenue from electricity sales	Order category	10 and 20 [million JPY / year]
Percentage of amount to be reduced	Order category	5 and 10 [%]
Amount of work	Order category	1, 4, 12, and 50 [hours / year]
Reward to work	Order category	400 and 800 [JPY / hour]

Note) 1 USD = 120 JPY (July 2015)

4. Measurement of WTW

(1) Specification of utility function

When constructing an evaluation model for the small hydroelectric generation project, the individual utility function is specified as Equation (1):

$$V = a_1 X_1 + a_2 X_1 X_2 + a_3 X_3 X_4 + \left\{ a_4 + \sum_{i=5}^n a_i X_i \right\} X_3 \quad (1)$$

where V : utility level of the small hydroelectric generation project;

X_1 : revenue from electricity sales of the small hydroelectric generation project;

X_2 : percentage of amount to be reduced for local residents from electricity sales revenue;

X_3 : amount of work required by local residents;

X_4 : reward for engaging in this work;

X_i : personal attributes; for example, gender, age, annual income; and

a_1, a_2, a_3, a_4, a_i : unknown parameters.

The first to the fourth term on the right-hand side of Equation (1) mean elements relating to the benefits for local employment, local public services, cooperator's income, and a cooperator's burden, respectively.

(2) Derivation of WTW

When we describe people's choice of behavior in response to the binomial choice format questions in Table 2 within the framework of the random utility theory, we can express an individual's choice behavior as the following logit model:

$$P_A = \frac{\exp[\omega \cdot V_A]}{\exp[\omega \cdot V_A] + \exp[\omega \cdot V_B]} \quad (2)$$

$$P_B = 1 - P_A \quad (3)$$

where P_A, P_B : theoretical probabilities of an individual choosing project "A" or "B";

V_A, V_B : utility levels of an individual's decision to choose project "A" or "B"; and
 ω : parameter of variance (generally $\omega = 1$ for convenience).

Using the theoretical choice probabilities derived in Equations (2) and (3), we can also explain people's choice behavior concerning "agree" and "disagree" with the implementation of a small hydroelectric generation project. Utility levels for "agree" and "disagree" are measured by applying values (X_1, X_2, X_3, X_4) for having the project and the values (0, 0, 0, 0) for no project into Equation (1), respectively. Then amount of work can be defined when half the local residents agree with the project; that is the median value of willingness to work (WTW). The value is derived as X_3 in Equation (4) when $V=0$ in Equation (1):

$$X_3 = \frac{a_1 X_1 + a_2 X_1 X_2}{a_3 X_4 + \left\{ a_4 + \sum_{i=5}^n a_i X_i \right\}} \equiv WTW \quad (4)$$

(3) Estimation of the utility function

Table 4 indicates the result of the parameter estimation of the utility function using conjoint analysis. It was found that most estimated parameters were statistically significant because their t-values exceed 1.960 at the 2.5% significance level.

Table 4: Estimated parameters of the utility function

Variables	Estimated value	t-value	Appendices
X_1	6.621×10^{-3}	9.061	X_1 : Revenue from electricity sales
$X_1 * X_2$	1.599×10^{-2}	1.898	X_2 : Percentage of amount to be reduced
$X_3 * X_4$	5.386×10^{-3}	6.487	X_3 : Amount of work
X_3	-7.544×10^{-2}	-9.128	X_4 : Reward to work
$X_5 * X_3$	—	—	X_5 : Gender
$X_6 * X_3$	-3.670×10^{-4}	-2.903	X_6 : Age
$X_7 * X_3$	-7.106×10^{-5}	-1.473	X_7 : Annual income
$X_8 * X_3$	—	—	X_8 : Environmental conservation activities
$X_9 * X_3$	1.347×10^{-2}	3.652	X_9 : Neighborhood association activities
$X_{10} * X_3$	2.036×10^{-4}	2.404	X_{10} : Interest in global warming
$X_{11} * X_3$	—	—	X_{11} : Interest in renewable energy
$X_{12} * X_3$	4.964×10^{-6}	5.757	X_{12} : Interest in small hydroelectric generation
Hit ratio	0.722		
Likelihood ratio	0.133		
Number of samples	4,308		

(4) Measurement of WTW

By multiplying WTW per person by potential number of volunteers, we can derive amount of WTW. WTW per person is calculated by applying parameters in Table 4 to Equation (4). The potential number of volunteer is measured by assuming as follows;

- The subject of the volunteer is 20-74 years old residents.
- Participation rate of volunteers is one person per household near the power generation facility.
- Participation rate of volunteers varies linearly in the region of less than 1 km from the power generation facility.
- Participation rate of volunteers is zero in the region of more than 1 km from the power generation facility.

And the population density is assumed to be evenly distributed in the urban space. Then, the scope of application of the WTW function in this study is defined as 1/9 of 20-74 years old residents. Basic statistics of Nagano Prefecture in 2010 are as follows; population is 2,152,449 persons, area is 13,562 km², population density is 161.9 persons per km², and household member is 2.71 persons (Nagano Prefecture, 2013).

This study aims to analyze the economic effects of introduction of the free volunteers or the paid volunteers who receive a small reward or drink, so we have calculated amount of WTW in each unit value of reward. The unit value of reward which uses in this simulation is set in increment of 100 within the scope from 0 to 800 [JPY / hour]. Because minimum wage rate in Nagano Prefecture was defined as 728 [JPY / hour] from 1 October 2014 (Nagano Labour Bureau of the MHLW, 2014), if the unit value of reward exceeds this value significantly, the subject must recognize it as wage labor rather than volunteer.

When we calculate amount of WTW, the values of appendices in Table 4 are set as constant as follows;

- $X_1 = 3,182$ [thousand JPY / year]: revenue from electricity sales of small hydroelectric generation project; see Table 6;
- $X_2 = 5$ [%]: percentage of amount to be reduced to local residents from revenue from electricity sales;
- $X_4 = 0, 100, 200, 300, 400, 500, 600, 700$ and 800 [JPY / hour]: reward to work;
- $X_5 = \text{N/A}$: gender;
- $X_6 = 40$ [years old]: near the average value of age in Nagano Prefecture (Ministry of Health, Labour and Welfare, 2012);
- $X_7 = 4,000$ [thousand JPY / year]: near the average value of annual income in Nagano Prefecture (Ministry of Health, Labour and Welfare, 2012);
- $X_8 = \text{N/A}$: environmental conservation activities;
- $X_9 = 0.0$: neighborhood association activities;
- $X_{10} = 0.5$: interest in global warming;

- X_{11} = N/A: interest in renewable energy; and
- X_{12} = 0.5: interest in small hydroelectric generation.

Then, we have derived amount of WTW and reward as shown in Table 5.

Table 5: Amount of WTW and reward

Unit value of reward [JPY / hour]	0	100	200	300	400	500	600	700	800
Amount of WTW [hours / year]	146	160	178	199	228	266	319	402	549
Amount of reward [thousand JPY / year]	0	16	36	60	91	133	191	281	440

5. Regional I-O analysis in which WTW is incorporated

(1) Scenarios of analysis

As mentioned above, this study aims to analyze the economic effects of introduction of the free volunteers or the paid volunteers, by using the regional I-O analysis in which the WTW is incorporated. And, a small hydroelectric generation project is assumed and analyzed in this study. The profile of project is shown in Table 6, which has been set in reference to the "Hydro Valley Planning Guide Book" (New Energy Foundation, 2005) and the "Research Report on Introduction Potential of Renewable Energy" (EX Research Institute Ltd. et.al., 2011).

Table 6: A small hydroelectric generation project assumed in this study

Item	Scale
Power generation scale [kW]	16
Amount of annual electricity sales [kWh / year]	127,283
Unit price of electricity sales [JPY / kWh]	25
Revenue from annual electricity sales [thousand JPY / year]	3,182
Construction cost of power generation facilities [thousand JPY]	67,904

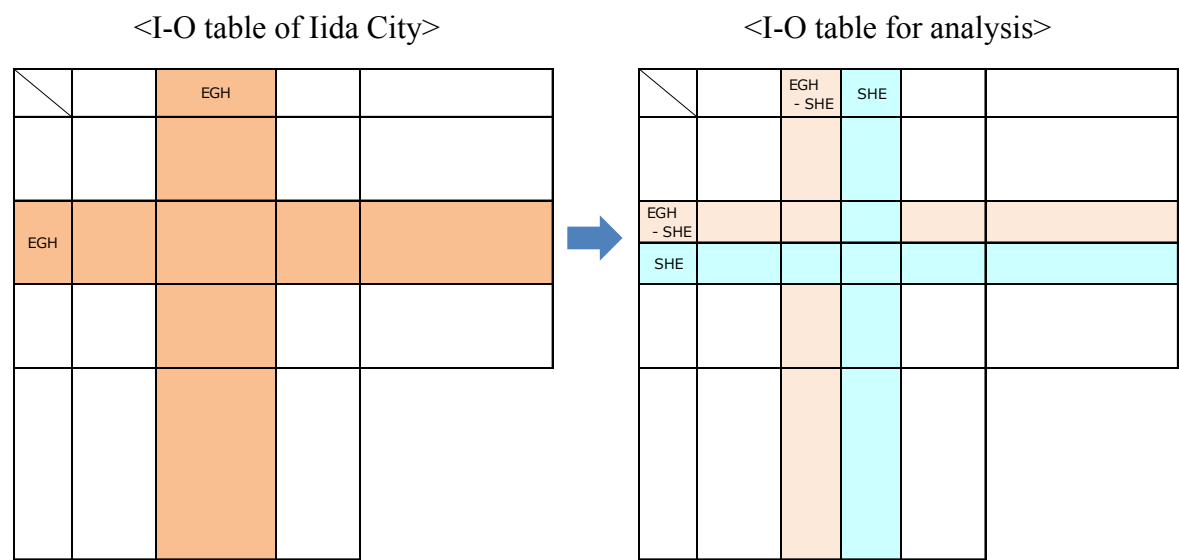
A direct economic effect by introducing resident volunteers is reduction in costs associated with routine maintenance. This effect is expected to vary greatly depending on the work ability of resident volunteers; for example, volunteers who can patrol along rivers and waterways, who can dredge trash from rivers and waterways, and who can perform a light work on power plant operation. In other words, we have to consider the work ability of resident volunteers who are substituted for professionals. In this study, the work ability of

resident volunteers is defined as the rate of substitution for professionals. By changing the rate of substitution for each unit value of reward, we analyze the economic effect by introducing resident volunteers.

(2) Regional I-O table for analysis

We have analyzed the economic effect by introducing resident volunteers, by using the regional I-O table for analysis of small hydroelectric generation project. The regional I-O table is the Iida City I-O table (2010) which is transformed from the Nagano Prefecture I-O table (2005); where Iida City is a city in Nagano Prefecture (Ohno et.al., 2015).

The industrial sectors of the I-O table are classified into 34; in which the EGH (electricity, gas, and heat supply) sector exists, but the SHE (small hydro-electricity supply) sector does not exist independently. For analysis of small hydroelectric generation project, the SHE sector has been separated from the EGH sector as shown in Figure 1.



Note) EGH: electricity, gas, and heat supply
 SHE: small hydro-electricity supply

Figure 1: Regional I-O table for analysis of small hydroelectric generation project

(3) Results of analysis

By introducing resident volunteers, the costs associated with routine maintenance of the small hydro-electricity supply sector may be reduced, and the operating surplus of the sector may increase. As shown in Table 5, the amount of WTW provided by resident volunteers will increase with increasing unit value of reward, but the amount of reward paid to volunteers will also increase. On the other hand, the operating income of the establishment that has contracted maintenance of the small hydroelectric supply sector will decrease, and its

influence will spread through the inter-industry relations. Then, we have analyzed such economic ripple effect by using the regional I-O table for analysis of small hydroelectric generation project. Therefore, the economic effect of introducing resident volunteers refers to change of amount of operating surplus of the small hydro-electricity supply sector.

The results are shown in Figure 2. In this figure, the vertical axis represents the operating surplus of the small hydro-electricity supply sector, and the horizontal axis represents the substitution rate of resident volunteers. Some different lines are drawn in this figure, and these indicate some different cases of the unit value of reward. The most important point in observing Figure 2, the operating surplus represented by the vertical axis is whether or not a positive value. If the operating surplus becomes positive, it means that there is an economic effect by introducing resident volunteers. If it becomes negative, it means that there is no economic effect.

In Figure 2, for example, we focus on the case that the unit value of reward is 800 [JPY / hour]. When the substitution rate of resident volunteers is 0 [%], the operating surplus of the small hydro-electric supply sector is -0.65 [million JPY / year]. This means that the economic effect by introducing resident volunteers who have no ability is -0.65 [million JPY / year]. This economic effect will increase with increasing the substitution rate of resident volunteers. However, when the substitution rate exceeds 52 [%], the amount of WTW exceeds the consignment workload, and the line has been finished at this point. In this case, there is no possibility that the economic effect becomes positive.

For example, we focus on the case that the unit value of reward is 600 [JPY / hour]. When the substitution rate is 80 [%], the operating surplus is 0 [million JPY / year]. And when the substitution rate is 90 [%], the amount of WTW exceeds the consignment workload and the operating surplus is 0.05 [million JPY / year]. In this case, when the range of substitution rate is from 80 to 90 [%], the economic effect becomes positive. Furthermore, we focus on the case that the unit value of reward is 0 [JPY / hour], that is no reward. When the substitution rate of resident volunteers is 0 [%], the operating surplus of the small hydro-electric supply sector is -0.21 [million JPY / year]. This means that the original project is deficit.

The results which are observed similarly in all cases are shown in Table 7. This figure indicates the ranges of the "unit value of reward" and the "substitution rate of resident volunteers" which can be expected positive effects when we introduce some resident volunteers into the project. Therefore, even if a small hydroelectric generation project which aims to both global warming adaptation and regional economic revitalization is deficit, we have found a good countermeasure which can be expected positive effects. However, it is usually not realistic that the substitution rate is more than 100 [%], because it means that the ability of resident volunteers is better than that of professionals. Such cases might be discussed in the strategic policies of the local government; for example, a policy to exploit the talented engineers who have already retired.

Although introduction of volunteer activities is finished when the amount of WTW exceeds the consignment work load in Figure 2, more volunteer activities may be introduced if external economic benefits of volunteers are expected. For example, if the bond of community are strengthened by that residents participate in volunteer activities, the bond strengthened can compensate for the lack of government services such as disaster prevention and welfare, and improvement of resident satisfaction may be expected. By evaluating such external economic benefits and practicing social cost benefit analysis, it is possible to discuss that more volunteer activities should be introduced or not. Such external economic benefits can be measured by the opportunity cost of volunteer activities or the time value of WTW, but this matter will be discussed at the next stage.

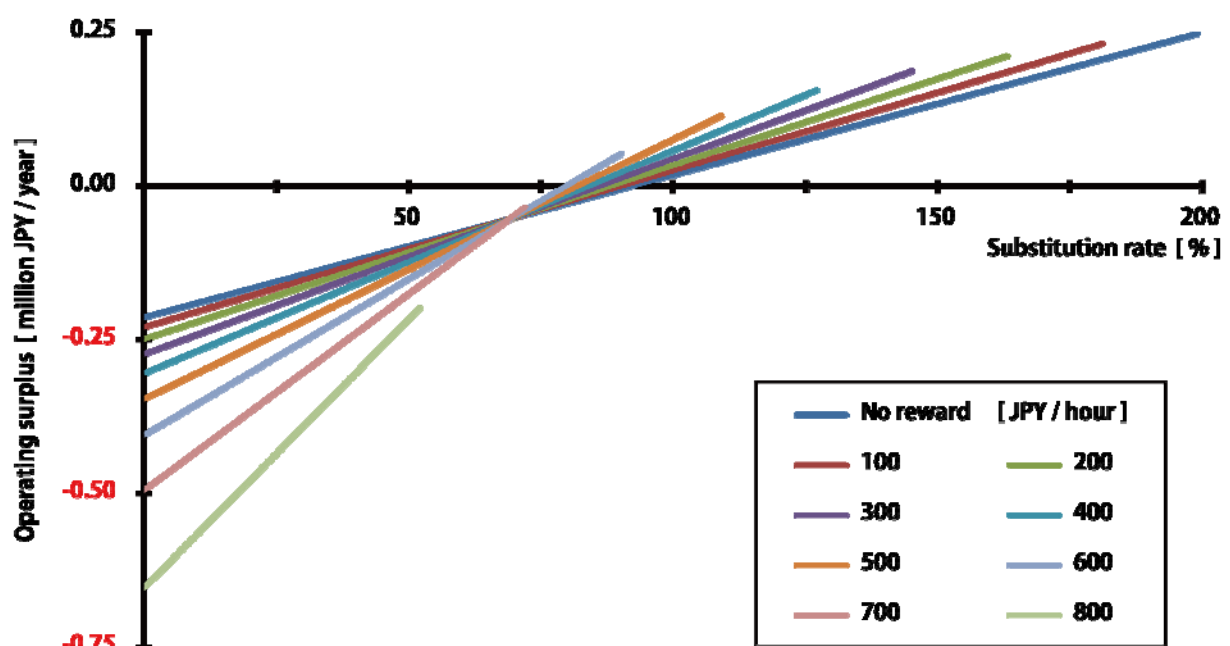


Figure 2: Relation between operating surplus of SHE sector and substitution rate of volunteers

Table 7: Range of substitution rate which makes operating surplus positive value

Unit value of reward [JPY / hour]	Range of substitution rate [%]
No reward	93 – 199
100	91 – 181
200	89 – 163
300	87 – 145
400	85 – 127
500	83 – 109
600	80 – 90
Over 700	N/A

6. Concluding remarks

Small-scale renewable electricity generation projects have the potential to address not just the need to reduce greenhouse gas emissions to combat climate change, but also to provide local, sustainable economic and community revitalization. In this paper, we have proposed a small hydroelectric generation project with citizen participation which includes cooperation in some activities such as cleaning and patrols, and have evaluated the project economically by using the regional I-O analysis in which the WTW is incorporated.

The WTW for the project have been estimated by using the conjoint analysis as a function of its various attributes, namely revenue from the project's electricity sales, profits earned for the local community, and rewards given to contributors. The results show that the amount of WTW provided by resident volunteers will increase with increasing unit value of reward, but the amount of reward paid to volunteers will also increase. On the other hand, the operating income of the establishment that has contracted maintenance of the small hydroelectric supply sector will decrease, and its influence will spread through the inter-industry relations.

Then, we have analyzed such economic ripple effect by using the regional I-O table for analysis of small hydroelectric generation project. By considering the range of the "unit value of reward" and the "substitution rate of resident volunteers", even if the project is deficit, we have found a good countermeasure which can be expected positive effects. As a result, it is possible to reduce the subsidies of regional governments with respect to the project, and it is possible to devote that amount of budget to improvement of other administrative services.

Although introduction of volunteer activities is finished when the amount of WTW exceeds the consignment work load in this case study, more volunteer activities may be introduced if external economic benefits of volunteers are expected. For example, if the bond of community are strengthened by that residents participate in volunteer activities, the bond strengthened can compensate for the lack of government services such as disaster prevention and welfare, and improvement of resident satisfaction may be expected. By evaluating such external economic benefits and practicing social cost benefit analysis, it is possible to discuss that more volunteer activities should be introduced or not. Such external economic benefits can be measured by the opportunity cost of volunteer activities or the time value of WTW, but this matter will be discussed at the next stage.

Subsequently, when this type of small hydroelectric generation project with citizen participation is introduced, household utility levels increase. Understanding the dynamism between these factors can allow regional governments to adapt the scheme to best fit the needs of individual regions.

Acknowledgment: This research is supported by two funds; 1) the Policy Studies of Environmental Economics II of the Ministry of the Environment, Japan, 2012-2014, and 2) the Academic Research Incentive Subsidy Program of Meijo University, Japan, 2015. Here we would like to show our special thanks for these funds.

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