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## Conference Paper

# Economic Evaluation of Small Hydroelectric Generation Project which aims to both Global Warming Adaptation and Regional Economic Revitalization

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# **Economic Evaluation of Small Hydroelectric Generation Project which aims to both Global Warming Adaptation and Regional Economic Revitalization**

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**Abstract:** In this paper, we propose a small hydroelectric generation project with citizen participation which includes not only donation to the project but also cooperation in some activities such as cleaning and patrols. And we evaluate the project economically based on the WTW by using the conjoint analysis and the computable general equilibrium analysis. As a result, the WTW for the project has been estimated as a function of its various attributes; revenue from electricity sales of the project, profit to the local community, and reward to contributors. And, if reward for volunteer activity is set higher, amount of labor is increased more and goods price is decreased more. At that time, the GRP is decreased and the EV is increased. That is to say, when such type small hydroelectric generation project with citizen participation is introduced, the value added of the region is decreased, but the utility level of household is increased.

**JEL classification:** Q42, Q51, R13

**Keywords:** *small hydroelectric generation, global warming adaptation, regional economic revitalization, conjoint analysis, computable general equilibrium analysis*

## **1. Introduction**

After the Kyoto Protocol, the renewable energy project is well-known as a project to reduce the greenhouse gas emission; that is a project for mitigation to global warming. After the Great East Japan Disaster, it is also a noteworthy project for adaptation to global warming, because the project is to provide various energy sources and to produce energy locally for local consumption. Then such kind projects are discussed in many local governments in Japan. At that time, people will be asked for big burden for the project in the future. In many local cities, problems such as falling birth rate, aging, and stagnation of regional economy are important subjects, so it is hard to give the priority to the project for adaptation. In addition, in spite of abundance of natural resources such as forest, wind, water, and sunlight, the local city

has a problem that funds for the project which utilizes these resources cannot be procured by financial difficulties.

On the other hand, through development of the renewable energy project by utilizing such natural resources, the local economy is expected to be revitalized. For example, in Iida City which is a local city in Japan, a renewable energy project with citizen participation has been promoted under cooperation of the public and the private sectors. They raise funds from residents firstly, and invest funds to a solar power project, and get revenue from electricity sales of the project, and pay dividends to residents finally.

Such type renewable energy project will give the local community some effects. On the environment aspect, firstly, the carbon dioxide emission will be reduced by introducing the renewable energy system. On the social aspect, secondly, redundancy of energy supply at disaster will increase by providing various energy sources and producing energy locally for local consumption. On the economic aspect, thirdly, the local employment will be stimulated if local contractors will construct the renewable energy system. For the solar power system to be installed on the roof of house, particularly, it may be a condition for quality of construction site to withstand long-term use, and there is an idea that it should be performed by contractors with local site knowledge. For installation by local contractors, as a result, various effects are expected; it is easy to request repair and maintenance after installation and relationship of trust with local residents will be constructed. Therefore, there should be the renewable energy project which would achieve both global warming adaptation and regional economic revitalization.

Furthermore, through such type project with citizen participation, environmental activity of local residents will be activated, and we can expect that semi-public service will be improved and satisfaction of local residents will rise. In this paper, we propose a small hydroelectric generation project with citizen participation which includes not only donation to the project but also cooperation in some activities such as cleaning and patrols. And we evaluate the project economically based on the willingness to work (WTW) by using the conjoint analysis and the computable general equilibrium analysis.

## **2. Proposal of small hydroelectric generation project**

The small hydroelectric generation refers to the small-scale power generation to take advantage of small rivers and canals for agriculture. Further, since it generates power by using the small drop, it is possible to utilize unused resources of river water effectively. Therefore, there are following advantages in the small hydroelectric generation.

- Since it uses small rivers and canals as they are, there is no need to build a big dam anew.

- Since it utilizes unused resources of river water, it leads to improvement of river environment.
- Since technology and know-how related to the hydroelectric generation are established in Japan, it can be introduced easily.

Such a small hydroelectric generation needs to install small-scale power generation facilities at small rivers and canals in the region, and needs to develop and maintain canals and rivers in order to ensure proper water flow. In particular, in order to run efficiently the small hydroelectric generation, daily maintenance such as cleaning of trash in rivers and patrolling of power generation facilities is important. Then, we propose a following small hydroelectric generation project which aims to both global warming adaptation and regional economic revitalization.

- As for development of small rivers and canals and installation of small-scale power generation facilities, the small hydroelectric generation company is responsible for this, which is launched by voluntary residents in the region as a project to help revitalize local.
- As for daily maintenance such as cleaning of trash in rivers and patrolling of power generation facilities, local residents, who install the small hydroelectric facility, participate and cooperate in this.
- As for task which requires technical expertise such as maintenance of power generation facilities, the professional contractor is entrusted.
- A part of revenue from electricity sales of the project is reduced to the region where the small hydroelectric facility is installed.

Figure 1 illustrates contents mentioned above. Here, the following points are significantly different from the solar power generation project described above.

- It can be expected not only to have investment and donation in the financial terms but also to have participation and cooperation in some activities such as cleaning and patrolling.
- Profits derived from the project which utilizes local resources can be returned to the region.
- These improve satisfaction of local residents and contribute to regional activation.

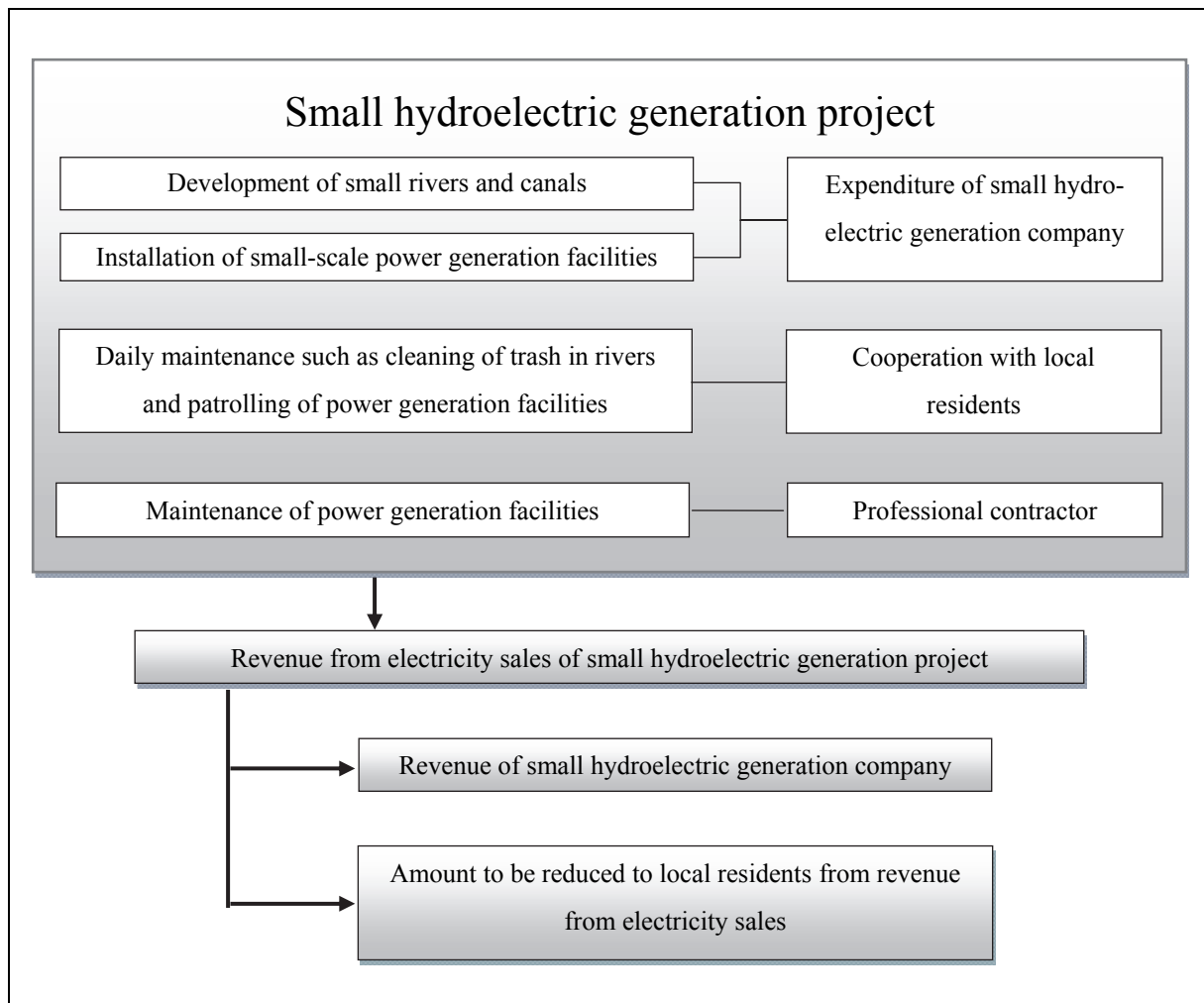


Figure 1: Scenario of small hydroelectric generation project

### 3. Economic evaluation based on WTW

#### (1) Previous studies on WTW

Ohno (1998) measured environmental damage cost in the Hokuriku coastal areas due to the heavy oil spilled from the Nakhodka, by using the contingent valuation method (CVM). At that time, since many volunteers gathered from all over the country and recovered the coast which was contaminated by the heavy oil washed ashore, Ohno proposed the willingness to work (WTW) as a new index which is alternative to the willingness to pay (WTP) in the CVM, based on definition of the compensating surplus (CS) or the equivalent surplus (ES). That is, the WTW in the CVM can be described as follows.

- In case of environmental improvement:

Based on definition of the CS, ask household the maximum amount of labor that he thinks worth to serve in order to obtain the environmental improvement while maintaining his utility level of case without the environmental improvement.

- In case of environmental degradation:

Based on definition of the ES, ask household the maximum amount of labor that he/she thinks worth to serve in order to avoid the environmental degradation while maintaining his utility level of case with the environmental degradation.

Since the above labor is occasionally observed in people's daily life, people may be answered easily to this question in the questionnaire survey.

In relation to above, Ohno (1999) measured benefits of countermeasure against sea level rise in Tuvalu which faces to crisis of national survival due to sea level rise, by using the CVM. At that time, Ohno proposed the WTW, by considering that people of Tuvalu cannot pay money because they are not rich materially even if they recognize values to countermeasure against sea level rise. Afterward, Ohno (2001) compared estimated values of the WTP and the WTW, and showed that a bias problem of the WTW is smaller than that of the WTP. In addition, there are some studies on benefit measurement by applying the WTW; Ogawa et.al. (1999), Ohora and Ohno (2002 and 2005), and Oba and Aoyama (2008).

## **(2) Use of WTW**

The WTP, which is measured by the CVM or the conjoint analysis conventionally, is obtained by converting change of utility level due to change of environmental goods (non-market goods) in money term, and it is a hypothetical economic value which does not appear in the actual market. In the cost-benefit analysis of environmental policy, the benefit is derived by summing the market value which appears in the actual market and the non-market value which does not appear. On the other hand, the input-output analysis of environmental policy treats values such as produce and income which appear in the actual market, but does not treat the non-market value which does not appear. However, the WTW may be considered as labor which appears in the actual market. Therefore, the input-output analysis from a new point of view will be possible, by replacing the market value (evaluated by the WTW) to the non-market value (evaluated by the WTP) which is not addressed in the conventional input-output analysis.

## **4. Interview survey**

In order to estimate the utility function of household to be used for the benefit evaluation, the web-based interview survey was carried out early October 2013. Subject of the survey was people who lives in Nagano Prefecture including Iida City and are over 20 years old. As a result of the survey, 1,096 responses were obtained, but valid responses were 1,077. Basic statistics of respondents in this survey are shown in Table 1.

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%		

The survey was entitled as “the attitude survey on global warming adaptation and regional economic revitalization”. The questionnaire was designed with the following contents.

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

In the survey, in order to analyze individual difference of evaluation results, some questions regarding personal attributes were provided in Question 1. As introduction of survey, Questions 2 and 3 were set with some figures and pictures, in order to make it easy to recognize impact and measure of global warming.

Major questions of this study are Questions 4, 5, 6 and 7, and parts which are dealt with in this paper are answers of Questions 6 and 7. Under such a scenario shown in Figure 1, two questions of binomial choice format were provided 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, and the subjects were selected desirable one. Variables of A1 (B1) to A4 (B4) in Table 2 are 1) revenue from electricity sales of small hydroelectric generation project, 2) percentage of amount to be reduced to local residents from revenue of electricity sales, 3) amount of work required for local residents, and 4) reward to work. By using values as shown in Table 3, we created 26 kinds of binomial choice format questions in total, and prepared 13 ways of questionnaire sheets which have two questions of binomial choice format in each sheet.

Table 2: Sample of question of binomial choice format

<p>Question: Which do you prefer to cooperate with the following small hydroelectric generation projects "A" or "B"? Please choose one which applies to you.</p> <p>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".</p> <p>&lt; Small hydroelectric generation project "A" &gt;</p> <ul style="list-style-type: none"> <li>- Revenue from electricity sales of small hydroelectric generation project:  <u>"A1" thousand USD per year</u></li> <li>- Percentage of amount to be reduced to local residents from revenue from electricity sales: <u>"A2" %</u></li> <li>- Amount of work (*) required for local residents: <u>"A3" hours per year</u></li> <li>- Reward to work (*): <u>"A4" USD per hour</u></li> </ul> <p>&lt; Small hydroelectric generation project "B" &gt;</p> <ul style="list-style-type: none"> <li>- Revenue from electricity sales of small hydroelectric generation project:  <u>"B1" thousand USD per year</u></li> <li>- Percentage of amount to be reduced to local residents from revenue from electricity sales: <u>"B2" %</u></li> <li>- Amount of work (*) required for local residents: <u>"B3" hours per year</u></li> <li>- Reward to work (*): <u>"B4" USD per hour</u></li> </ul> <p>(*) work concerning to daily maintenance such as cleaning of trash in rivers and patrolling of power generation facilities.</p>
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Table 3: Variables of A1 (B1) to A4 (B4) in Table 2

Variables	Properties	Levels
Revenue from electricity sales	Order category	100 and 200 [thousand USD / 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	4 and 8 [USD / hour]
Gender	Dummy	Male = 1, Female = 0
Age	Continuous	- [years old]
Annual income	Continuous	- [thousand USD / year]
Status of activities	Environmental conservation activities	Dummy
	Neighborhood association activities	Dummy
		Donation and/or participation without pay = 1, No involvement = 0
Degree of interest	Global warming	Order category
	Renewable energy	Order category
	Small hydroelectric generation	Order category
		Great interest = 100, Considerable interest = 75, Normal interest = 50, Little interest = 25, No interest = 0

## 5. Conjoint analysis

### (1) Specification of utility function

When we construct an evaluation model for small hydroelectric generation project shown in Figure 1, individual utility function is specified as Equation (1).

$$V = a_1X_1 + a_2X_1X_2 + a_3X_3X_4 + \left\{ a_4 + \sum_{i=5}^n a_iX_i \right\} X_3 \quad (1)$$

where  $V$ : utility level of small hydroelectric generation project,

$X_1$ : revenue from electricity sales of small hydroelectric generation project,

$X_2$ : percentage of amount to be reduced to local residents from revenue from electricity sales,

$X_3$ : amount of work required for local residents,

$X_4$ : reward to 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, the second, the third and the fourth terms on the right-hand side of Equation

(1) mean elements relating to benefits on the local employment, the local public service, the cooperator's income and the cooperator's burden, respectively.

## (2) Derivation of WTW

When we describe people's choice behavior concerning questions of binomial choice format in Table 2 within the framework of the random utility theory, we can express one'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 one's decision to choose project "A" or "B",

$V_A, V_B$ : utility levels of one's decision to choose project "A" or "B", and

$\omega$ : parameter of variance (generally  $\omega = 1$  for convenience).

By using theoretical choice probabilities of Equations (2) and (3), we can also explain people's choice behavior concerning "agree" and "disagree" with a small hydroelectric generation project. At the time, the utility levels in cases of "agree" and "disagree" are measured by applying values ( $X_1, X_2, X_3, X_4$ ) of the project and values (0, 0, 0, 0) of no project into Equation (1), respectively. Then amount of work can be defined when half numbers of 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).

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

## (3) Estimation of utility function

The simultaneous probability density function, which means the likelihood function, for people's choice behavior concerning questions of binomial choice format in Table 2 is constructed by using theoretical probabilities of Equations (2) and (3). Then unknown parameters of Equation (1) are estimated by the maximum likelihood procedure, by applying answers of the questionnaire. The number of samples which were applied to estimation of utility function was 4,308, because two questions of binomial choice format were provided to each subject and two ways of answer were interpreted in each question.

1) I prefer to cooperate with project "A":

$$V_A > V_B \quad \text{and} \quad V_A > V_0$$

2) I prefer to cooperate with project "B":

$$V_A < V_B \quad \text{and} \quad V_B > V_0$$

3) I may cooperate with either projects "A" or "B":

$$V_A > V_0 \quad \text{and} \quad V_B > V_0$$

4) I do not want to cooperate with neither projects "A" nor "B":

$$V_A < V_0 \quad \text{and} \quad V_B < V_0$$

where  $V_0$ : utility levels of one's decision to choose "no project".

Table 4 indicates the result of parameter estimation of utility function by the Conjoint Analysis. It is found that most of estimated parameters have enough statistical significance level because their t-values exceed 1.960 at the significance level 2.5%.

Table 4: Estimated parameters of utility function

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

#### (4) Measurement of WTW

By applying estimated parameters in Table 4 to Equation (4), the WTW for small hydroelectric generation project which is proposed in this study is evaluated. Since the WTW is evaluated by the function of various attributes of small hydroelectric generation project, we show three figures which indicate relation between WTW and each attribute; Figures 2, 3 and

4. Figure 2 indicates relation between WTW and “ $X_1$ : revenue from electricity sales”; where values of “ $X_2$ : percentage of amount to be reduced” and “ $X_4$ : reward to work” are set to 5 % and 4 USD per hour, respectively. Figure 3 indicates relation between WTW and “ $X_2$ : percentage of amount to be reduced”; where values of “ $X_1$ : revenue from electricity sales” and “ $X_4$ : reward to work” are set to 100 thousand USD per year and 4 USD per hour, respectively. Figure 4 indicates relation between WTW and “ $X_4$ : reward to work”; where values of “ $X_1$ : revenue from electricity sales” and “ $X_2$ : percentage of amount to be reduced” are set to 100 thousand USD per year and 5 %, respectively. In addition, value of "age" is set to 40 years old which is around the mean value in Nagano Prefecture, and value of "annual income" is set to 40 thousand USD per year by reference to the "Basic Survey on Wage Structure 2012" by the Ministry of Health, Labor and Welfare. As for other individual attributes, they are set to the mode values of this survey.

From Figures 2 and 3, the WTW is found to increase linearly with increase of "revenue from electricity sales" and also with increase of "percentage of amount to be reduced". From Figure 4, on the other hand, it is found that the WTW increases rapidly with increase of "reward to work" from around 8 USD per hour and becomes infinite at 10.76 USD per hour. Now, the minimum wage rate in Nagano Prefecture, where the subjects live, is 7.13 USD per hour, which is effective from 19 October 2013. Therefore, it is expected that subjects become to recognize the work as the wage labor when the value of "reward to work" is beyond around 8 USD per hour.

Furthermore, Figures 5, 6, 7, 8 and 9 indicate relations between WTW and " $X_4$ : reward to work" in different " $X_6$ : age", " $X_7$ : annual income", " $X_9$ : status of neighborhood association activities", " $X_{10}$ : status of global warming" and " $X_{12}$ : degree of interest in small hydroelectric generation", respectively. The values of attributes that do not appear in those figures, fixed values are set in the same manner as above. As a result, from Figure 5, you can see that "younger people" have higher rate of increase of WTW for the work due to increase of reward to the work. Similarly, from Figures 6, 7, 8 and 9, you can see that "people who have lower annual income", "people who have not participated in neighborhood association activities yet", "people who have lower interests in global warming" and "people who have lower interests in small hydroelectric generation" have higher rate of increase of WTW due to increase of reward. However, you may imagine that "younger people", "people who have lower annual income", "people who have not participated in neighborhood association activities yet", "people who have lower interests in global warming" and "people who have lower interests in small hydroelectric generation" have lower WTW for the work when they have no reward to the work. These figures show the reverse trend. As for this issue, we will inspect the utility function form of Equation (1) and the WTW function form of Equation (4) in the next stage of our research.

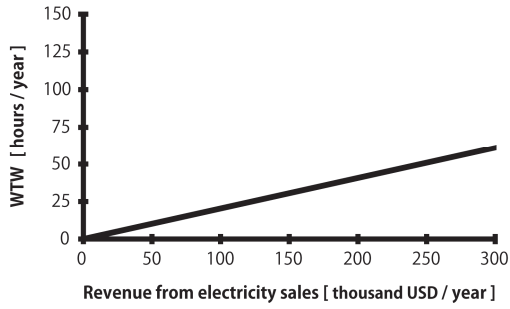


Figure 2: Relation between WTW and  $X_1$

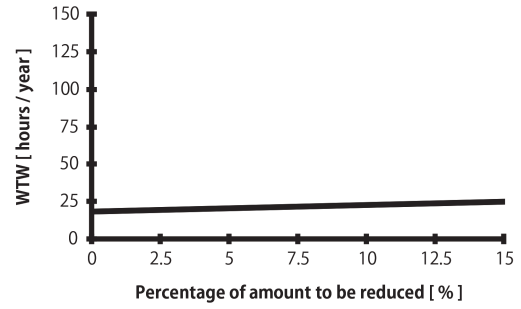


Figure 3: Relation between WTW and  $X_2$

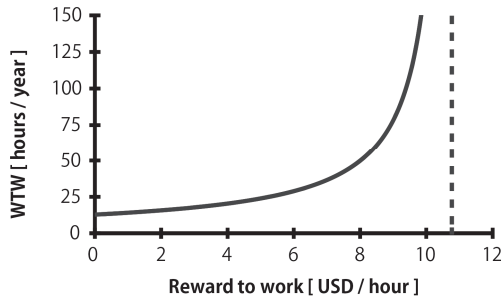


Figure 4: Relation between WTW and  $X_4$

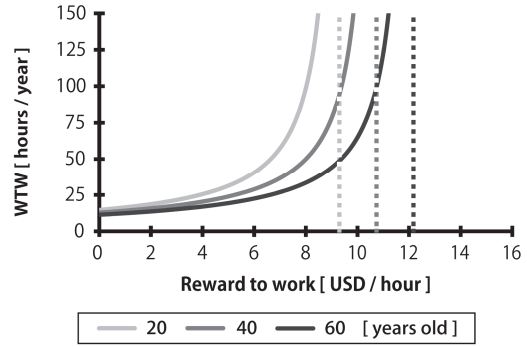


Figure 5: Relation between WTW and  $X_4$ , in different  $X_6$

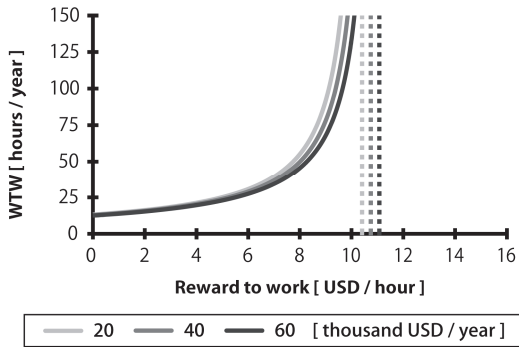


Figure 6: Relation between WTW and  $X_4$ , in different  $X_7$

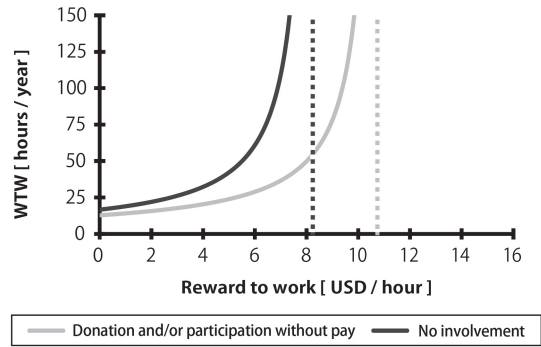


Figure 7: Relation between WTW and  $X_4$ , in different  $X_9$

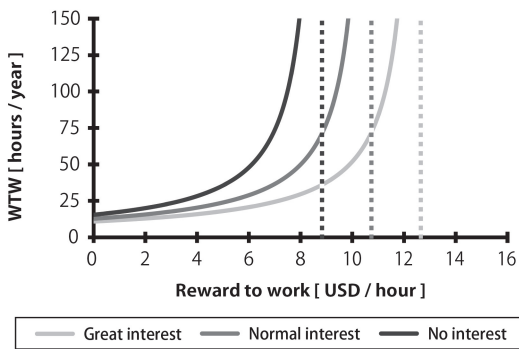


Figure 8: Relation between WTW and  $X_4$ , in different  $X_{10}$

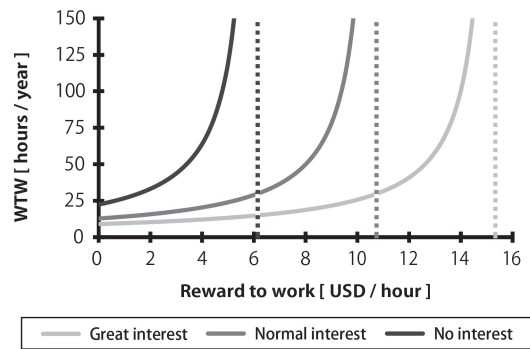


Figure 9: Relation between WTW and  $X_4$ , in different  $X_{12}$

## 6. Computable general equilibrium analysis

### (1) Scenarios of simulation

Based on the WTW evaluated above, the computable general equilibrium analysis is implemented. We set wage labor and volunteer labor in the hydroelectric generation sector, and assume that quantity and/or quality of volunteer labor change by reward to work. Then, some scenarios are set as follows.

Scenario 0) the hydroelectric generation sector has wage labors and ‘pure’ volunteer labors who receive no reward and have enough quality; that is the equilibrium solution as a reference.

Scenario 1) the hydroelectric generation sector has wage labors and volunteer labors who receive some reward and have not enough quality; that is the equilibrium solution under some scenario.

Comparing with economic condition at the equilibrium solution as a reference, we measure increase in the value added of factor input and value of equivalent variation at the equilibrium solution under some scenario.

### (2) The social account matrix

We have classified industrial sectors into 13 (AGR, MIN, HYD, ELE, GAS, COM, FIN, REA, TRA, TEL, PUB, SER and UNK as shown in Table 5), and made the social account matrix of Nagano Prefecture in Japan. Then, assuming that all markets are perfectly competitive and using intermediate inputs and primary factors (LAB and CAP as shown in Table 5), industrial sectors create and sell goods and pay factor income to households.

### (3) The model

The model is based on a computable general equilibrium model used in Hosoe et al. (2004), where a sub-model for the production sector is modified. The production function of each industrial sector is defined as Equation (5).

$$Y_j = b_j \prod_h F_{h,j}^{\beta_{h,j}}, \quad \forall j \quad (5)$$

where  $Y_j$ : composite factor,  $F_{h,j}$ : factor input,  $b_j$ : scale parameter,  $\beta_{h,j}$ : share parameter, subscripts  $i, j$ : industrial sector, and subscript  $h$ : input factor.

As for scale parameter of the hydroelectric generation sector, there is assumed to be a relationship of Equation (6) between conditions at the equilibrium solution as a reference and at the equilibrium solution under some scenario.

$$\frac{b_{HYD}(1)}{b_{HYD}(0)} = \left\{ \frac{L_{HYD}(0) + \mu \cdot \{WTW_{HYD}(1) - WTW_{HYD}(0)\}}{L_{HYD}(0)} \right\}^{\beta_{LAB, HYD}} \quad (6)$$

$$L_{HYD}(0) = \frac{F_{LAB, HYD}(0)}{w(0)} \quad (7)$$

where  $b_{HYD}(0)$  and  $b_{HYD}(1)$ : scale parameters of the hydroelectric generation sector at the equilibrium solution as a reference (0) and at the equilibrium solution under some scenario (1).

$WTW_{HYD}(0)$  and  $WTW_{HYD}(1)$ : values of the willingness to work, that is amount of volunteer labors, of the hydroelectric generation sector at the equilibrium solution as a reference (0) and at the equilibrium solution under some scenario (1).

$L_{HYD}$ : amount of labors of the hydroelectric generation sector,

$F_{LAB, HYD}$ : labor input of the hydroelectric generation sector,

$w$ : wage rate; which is set to 15.91 USD per hour, and

$\mu$ : quality level of volunteer labor compared with wage labor; which is set to 0.1, 0.2, ..., 0.9 and 1.0.

Table 5: Sectors and factors in the social account matrix

Sectors		Factors	
AGR	Agriculture, forestry and fisheries	LAB	Labor
MIN	Mining, manufacturing and construction	CAP	Capital
HYD	Hydroelectric generation		
ELE	Electricity		
GAS	Gas and water		
COM	Commerce		
FIN	Finance and insurance		
REA	Real estate		
TRA	Transportation		
TEL	Telecommunications		
PUB	Public service		
SER	Service		
UNK	Classification unknown		

#### (4) Input data to simulation

Parameters of the model are defined by the input-output table of Nagano Prefecture in 2005. In that year, the gross regional product of Nagano Prefecture is 82 billion USD per year, and the gross domestic product of Japan is 5,039 billion USD per year. Other basic statistics of Nagano Prefecture in 2005 are as follows; population is 2,196,114 persons, area is 13,561 km<sup>2</sup>, and population density is 161.9 persons per km<sup>2</sup>.

When we evaluate economically a small hydroelectric generation project which aims to both global warming adaptation and regional economic revitalization, we set amount of WTW as input data to the model. The median value of WTW, that is the value of each volunteer, can be measured by using Equation (4) and estimated parameters in Table 4. On the other hand, potential number of volunteers is set to 254 persons based on population density of Nagano Prefecture, by assuming that half of residents who live within 1 km distance from the power generation facility would participate in the project.

Figure 4 indicates that the median value of WTW increases with increase of reward. So, we simulate economic ripple of small hydroelectric generation project by controlling the reward to work. Table 6 is a list of input datum to the simulation.

Table 6: List of input datum to simulation

Reward [USD / hour]	0	1	2	3	4	5	6	7	8
Number of volunteers [persons]	254	254	254	254	254	254	254	254	254
Amount of WTW [hours / year]	2,151	2,364	2,626	2,953	3,375	3,942	4,748	5,997	8,261
Amount of reward [USD / year]	0	2,364	5,251	8,858	13,499	19,709	28,487	41,982	66,089

#### (5) Results of simulation

Results of economic evaluation of a small hydroelectric generation project are shown in Figures 10, 11, 12, 13, 14 and 15. Figures 10 and 11 indicate increase of the gross regional product (GRP) in Nagano Prefecture under some scenario. Difference between them is whether considering payment of reward. The payment is cost for companies, but it is revenue for households and there is a possibility to increase consumption of households. So, we show both figures; the latter considers the payment, and the former does not. Both figures indicate that the GRP in Nagano Prefecture is more reduced when reward is set higher and/or quality level of volunteer labor is higher.



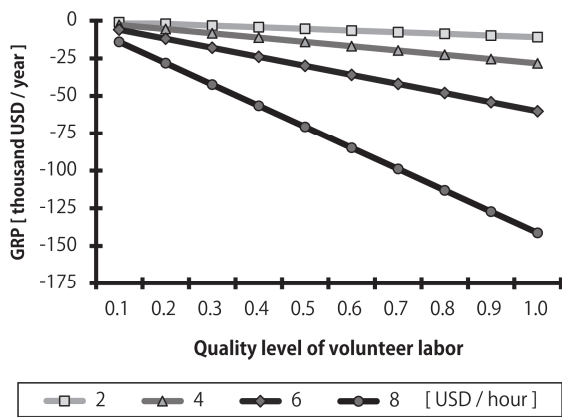


Figure 10: Increase of gross regional product

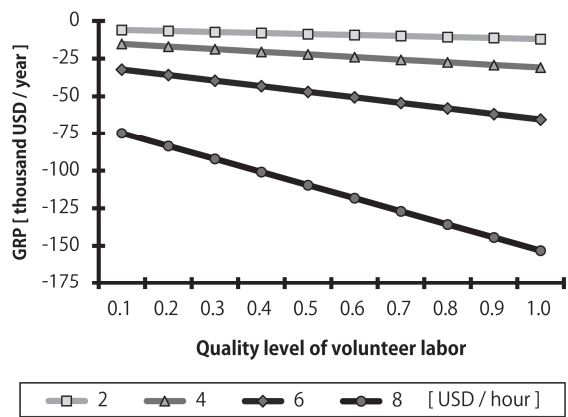


Figure 11: Increase of gross regional product - considering payment of reward

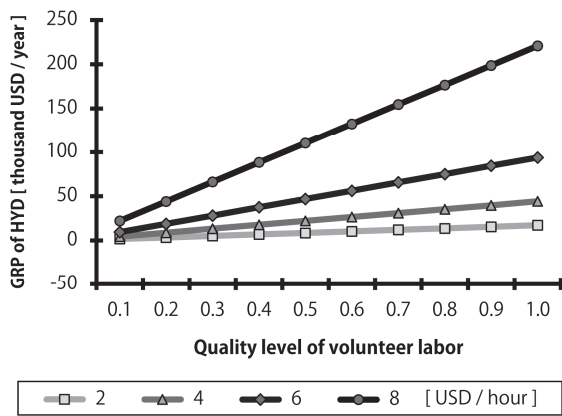


Figure 12: Increase of GRP of HYD

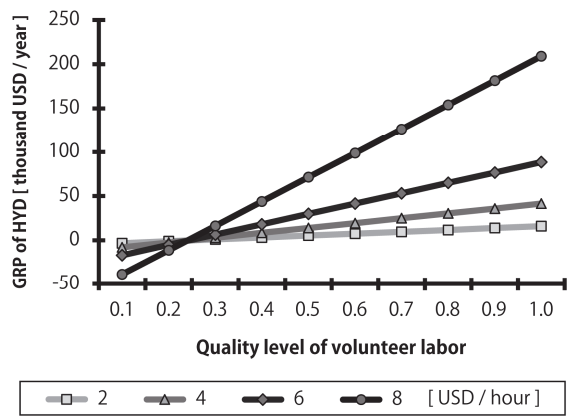


Figure 13: Increase of GRP of HYD - considering payment of reward

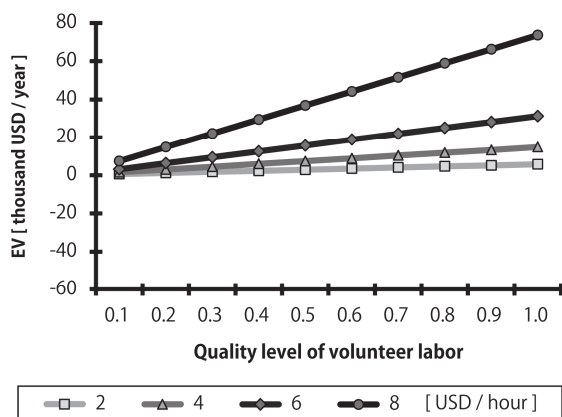


Figure 14: Value of equivalent variation

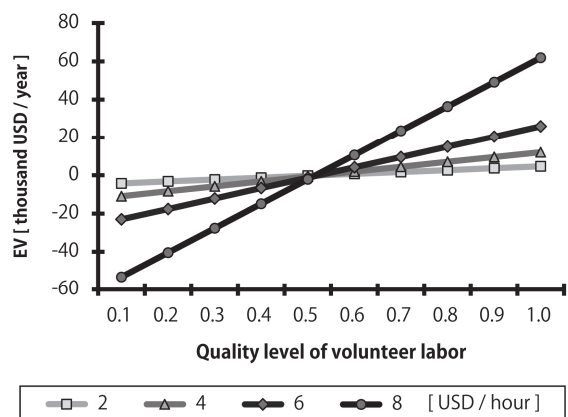


Figure 15: Value of equivalent variation - considering payment of reward

Figures 12 and 13 indicate increase of the GRP of the hydroelectric generation sector (HYD) in Nagano Prefecture under some scenario. Difference between them is as same as difference between Figures 10 and 11. Contrary to the above results, both figures indicate that the GRP of HYD in Nagano Prefecture is more increased when reward is set higher and/or quality level of volunteer labor is higher. On the other hand, you can see that the GRP is more decreased when quality level of volunteer labor is lower than 0.2 and reward is set higher.

Figures 14 and 15 indicate value of the equivalent variation (EV) in Nagano Prefecture under some scenario. Difference between them is same above. Similar to the above results, both figures indicate that the EV in Nagano Prefecture is more increased when reward is set higher and/or quality level of volunteer labor is higher. And you can see that the EV is more decreased when quality level of volunteer labor is lower than 0.5 and reward is set higher.

As a result, if reward for volunteer activity is set higher, amount of labor is increased more and goods price is decreased more. At that time, the GRP is decreased and the EV is increased. That is to say, when such type small hydroelectric generation project with citizen participation is introduced, the value added of the region is decreased, but the utility level of household is increased.

## **7. Concluding remarks**

In this paper, we have proposed a small hydroelectric generation project with citizen participation which includes not only donation to the project but also cooperation in some activities such as cleaning and patrols. And we have evaluated the project economically based on the WTW by using the conjoint analysis and the computable general equilibrium analysis.

The WTW for the project has been estimated as a function of its various attributes; revenue from electricity sales of the project, profit to the local community, and reward to contributors. And, if reward for volunteer activity is set higher, amount of labor is increased more and goods price is decreased more. At that time, the GRP is decreased and the EV is increased. That is to say, when such type small hydroelectric generation project with citizen participation is introduced, the value added of the region is decreased, but the utility level of household is increased.

On the other hand, revenue from electricity sales of the project should vary with number of contributors, which is the WTW. As for profit to the local community and reward to contributors, these are positioned as policy variables. Therefore, by using our evaluation model, we will be able to evaluate various policies for the renewable energy project; for example, policies which make revenue maximize, policies which make social utility maximize and policies which make social cost minimize.

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## Appendix

We have adopted the following simultaneous equations system as the applied general equilibrium model used in Hosoe et al. (2004).

- Production sector

$$Y_j = b_j \prod_h F_{h,j}^{\beta_{h,j}}, \quad \forall j \quad (\text{A.1})$$

$$F_{h,j} = \frac{\beta_{h,j} p_j^y}{p_h^f} Y_j, \quad \forall h, j \quad (\text{A.2})$$

$$X_{i,j} = ax_{i,j} Z_j, \quad \forall i, j \quad (\text{A.3})$$

$$Y_j = ay_j Z_j, \quad \forall j \quad (\text{A.4})$$

$$p_j^z = ay_j p_j^y + \sum_i ax_{i,j} p_i^q, \quad \forall j \quad (\text{A.5})$$

- Government sector

$$T^d = \tau^d \sum_h p_h^f FF_h \quad (\text{A.6})$$

$$T_j^z = \tau_j^z p_j^z Z_j, \quad \forall j \quad (\text{A.7})$$

$$T_i^m = \tau_j^m p_j^m M_i, \quad \forall i \quad (\text{A.8})$$

$$X_i^g = \frac{\mu_i}{p_i^q} (T^d + \sum_j T_j^z + \sum_j T_j^m - S^g), \quad \forall i \quad (\text{A.9})$$

- Investment and savings

$$X_i^v = \frac{\lambda_i}{p_i^q} (S^p + S^g + \varepsilon S^f), \quad \forall i \quad (\text{A.10})$$

$$S^p = ss^p \sum_h p_h^f FF_h \quad (\text{A.11})$$

$$S^g = ss^g (T^d + \sum_j T_j^z + \sum_j T_j^m) \quad (\text{A.12})$$

- Household sector

$$X_i^p = \frac{\alpha_i}{p_i^q} (\sum_h p_h^f FF_h - S^p - T^d), \quad \forall i \quad (\text{A.13})$$

- Export and import goods prices and the balance of payments

$$p_i^e = \varepsilon p_j^{We}, \quad \forall i \quad (\text{A.14})$$

$$p_i^m = \varepsilon p_i^{Wm}, \quad \forall i \quad (\text{A.15})$$

$$\sum_i p_i^{We} E_i + S^f = \sum_i p_i^{Wm} M_i \quad (\text{A.16})$$

- Alternative between imported goods and home goods

$$Q_i = \gamma_i (\delta m_i M_i^{\eta_i} + \delta d_i D_i^{\eta_i})^{\frac{1}{\eta_i}}, \forall i \quad (\text{A.17})$$

$$M_i = \left( \frac{\gamma_i^{\eta_i} \delta m_i p_i^q}{(1 + \tau_i^m) p_i^m} \right)^{\frac{1}{1-\eta_i}} Q_i, \forall i \quad (\text{A.18})$$

$$D_i = \left( \frac{\gamma_i^{\eta_i} \delta d_i p_i^q}{p_i^d} \right)^{\frac{1}{1-\eta_i}} Q_i, \forall i \quad (\text{A.19})$$

- Transformation between exported goods and home goods

$$Z_i = \theta_i (\xi e_i E_i^{\phi_i} + \xi d_i D_i^{\phi_i})^{\frac{1}{\phi_i}}, \forall i \quad (\text{A.20})$$

$$E_i = \left( \frac{\theta_i^{\phi_i} \xi e_i (1 + \tau_i^z) p_i^z}{p_i^e} \right)^{\frac{1}{1-\phi_i}} Z_i, \forall i \quad (\text{A.21})$$

$$D_i = \left( \frac{\theta_i^{\phi_i} \xi d_i (1 + \tau_i^z) p_i^z}{p_i^d} \right)^{\frac{1}{1-\phi_i}} Z_i, \forall i \quad (\text{A.22})$$

- Market equilibrium conditions

$$Q_i = X_i^p + X_i^g + X_i^v + \sum_j X_{i,j}, \forall i \quad (\text{A.23})$$

$$FF_h = \sum_j F_{h,j}, \forall h \quad (\text{A.24})$$

- Endogenous variables

$Y_j$ : composite factor,

$F_{h,j}$ : factor input,

$X_{i,j}$ : intermediate input,

$Z_j$ : output,

$X_i^p$ : household consumption,

$X_i^g$ : government consumption,

$X_i^v$ : investment demand,

$E_i$ : exports,

$M_i$ : imports,

$Q_i$ : Armington's composite good,

$D_i$ : domestic good,

$p_h^f$ : factor price,

$p_j^y$ : composite factor price,

$p_j^z$ : supply price,

$p_i^q$ : Armington's composite good price,

$p_i^e$ : export price in local currency,

$p_i^m$ : import price in local currency,

$p_i^d$ : domestic good price,

$\varepsilon$ : exchange rate,

$S^p$ : private saving,

$S^g$ : government saving,

$T^d$ : direct tax,

$T_j^z$ : production tax,

$T_i^m$ : import tariff,

- Exogenous variables

$FF_h$ : factor endowment,

$S^f$ : foreign savings in foreign currency,

$p_i^{We}$ : export price in foreign currency,

$p_i^{Wm}$ : import price in foreign currency,

- Subscripts

$i, j$ : industrial sector; AGR, MIN, HYD,

ELE, GAS, COM, FIN, REA, TRN,

TEL, PUB, SER and UNK,

$h$ : input factor; LAB and CAP.

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