Estimation of VSL Based on WTA for Increase of Heat Stress Mortality Risk Due to Global Warming

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Abstract: In this study, the value of a statistical life (VSL) has been calculated, by estimating the willingness to accept compensation (WTA) for allowing an increase of heat stress mortality risk by conducting the contingent valuation (CV) survey, and by dividing this WTA by the amount of risk reduction. There we have conducted a closed-type CV survey for adult men and women aged 20 to 69 throughout the country through a web research company. Based on 3,501 response data obtained there, we estimated WTA and VSL by each prefecture of Japan. As a result, we have estimated some values of WTA for an increase of heat stress mortality risk; the values in the nearer future till 2050 are 1,798 to 5,850 JPY/year; the values in the further future till 2100 are 7,476 to 13,289 JPY/year. Based on these WTA, we have calculated some values of VSL; the values in the nearer future till 2050 are 68.81 to 677.23 million JPY; the values in the further future till 2100 are 41.08 to 254.60 million JPY.

JEL classification: I18, J17, Q54

Keywords: *global warming, heat stress mortality risk, willingness to accept, value of a statistical life, contingent valuation method*

1. Introduction

According to the Japan Meteorological Agency (2013), the annual average temperature of the future climate of Japan is estimated to rise by about 3 degrees Celsius from the present, especially the northern Japan temperature rise is expected to be large. Also, according to the Intergovernmental Panel on Climate Change (IPCC), the world average temperature is reported to rise from 0.3 degrees Celsius (RCP 2.6) to 4.8 degrees Celsius (RCP 8.5) by 2100 [Japan Meteorological Agency, 2014].

In this way, the rise in temperature in the future climate of Japan is an inevitable situation, there is concern about the impact on people's health, especially death from heat stress. The Ministry of the Environment (2014) has stated that the mortality risk of heat stress increases due to global warming, and in almost all prefectures unless implementation of adaptation measures, it will be more than doubled risk regardless of age.

In response to such circumstances, it is desirable to make public investment that reduces the mortality risk of heat stress, but in such case the cost-benefit analysis is required to examine the adequacy of public investment. In measuring benefits of public investment that reduces such mortality risk, the value of a statistical life (VSL) is used, which is calculated by dividing the amount of willingness to pay (WTP) for reducing the mortality risk by the amount of mortality risk reduction [Ministry of Land, Infrastructure, Transport and Tourism, 2009a].

In this study, we estimate the amount of willingness to accept compensation (WTA) for allowing an increase of heat stress mortality risk by conducting the contingent valuation (CV) survey, and the VSL is calculated by dividing the amount of WTA by the amount of mortality risk increase.

2. WTP and WTA

As the monetary scale of the environmental change, the equivalent surplus (ES) and the compensating surplus (CS) are defined as follows.

<Equivalent Surplus: ES>

1) In the case of environmental improvement:

Under the condition that the utility level in the case of environmental improvement is maintained, the ES is the minimum compensating amount that households want the government to compensate in order to give up the environmental improvement

2) In the case of environmental deterioration:

Under the condition that the utility level in the case of environmental deterioration is maintained, the ES is the maximum payment amount that households consider to be worth paying for avoiding the environmental deterioration.

<Compensating surplus: CS>

3) In the case of environmental improvement:

Under the condition that the utility level in the case of no environmental improvement is maintained, the CS is the maximum payment amount that households consider to be worth paying for acquiring the environmental improvement.

4) In the case of environmental deterioration:

Under the condition that the utility level in the case of no environmental deterioration is maintained, the CS is the minimum compensating amount that households want the government to compensate in order to accept the environmental deterioration.

Among the definitions of 1) to 4) above, the WTP used for calculating the VSL is based on the definition of 3). According to the guidelines for the CV survey in the practice of public project evaluation, since the WTA has a possibility of estimating benefits excessively, the estimation of benefits based on WTP is recommended [Ministry of Land, Infrastructure, Transport and Tourism, 2009b]. Therefore, the estimation of WTP based on the definition of 3) is reasonable both in theory and practice.

In this study, for the purpose of economic evaluation of global warming (as the environmental deterioration; increase of heat stress mortality risk) and adaptation policy (as the environmental improvement; reduction of heat stress mortality risk), we have gained the estimated values of heat stress mortality risk in 2000, 2050 and 2100. The estimated values in 2000 are at the base case; assuming the case without global warming and adaptation policy. The estimated values in 2050 and 2100 are in the future case; assuming some cases with global warming and with / without adaptation policy. Therefore, in the CV survey, it is possible to ask the subject the WTP while referring to the estimated value of heat stress mortality risk based on the definition of 3), but it is difficult for the subject to understand such situation setting, since it is necessary to evaluate based on the future condition. The same applies to the definitions of 1) and 2). In contrast, in the definition of 4), it is enough to evaluate with the current state as a reference, so it is probably a situation setting that is easy for the subjects to understand. In this study, the priority is given to the simplicity of the CV survey, and the estimation by the WTA based on the definition of 4) is adopted.

3. Interview survey

(1) Overview of CV survey

The CV survey in this study was conducted on Japanese people who were aged 20 - 69 years old, through a questionnaire survey company, at 8 - 10 March 2016. There are three types of web survey in quantitative analysis; the open type, the closed type, and the semi closed type. This survey is the closed type of web survey. Since the subject is a general person registered in advance to the questionnaire survey company, it is possible to grasp various personal attributes. As a result, 3,501 responses were obtained, and the attribute distributions (gender, age, region, occupation, and annual income) of respondents are shown in Table 1.

Table 1: Basic statistics of respondents

Gender	Proportion
Male	50.1%
Female	49.9%
Total	100.0%

Age	Proportion
20-29	15.9%
30-39	19.5%
40-49	22.9%
50-59	19.2%
60-69	22.5%
Total	100.0%

Region	Proportion
Hokkaido/Tohoku	13.4%
Kanto	21.9%
Hokuriku	6.3%
Chubu	11.7%
Kinki	17.1%
Chugoku	9.4%
Shikoku	6.6%
Kyushu/Okinawa	13.5%
Total	100.0%

Occupation	Proportion
Company employee	33.7%
Self-employed person	7.4%
Profession	3.1%
Public official	4.6%
Student	3.4%
Housewife/husband	19.7%
Part-time worker	14.5%
No occupation	11.8%
Others	1.9%
Total	100.0%

Annual income	Proportion
No income	16.9%
under 1 million JPY	17.8%
1-2 million JPY	14.0%
2-4 million JPY	23.3%
4-6 million JPY	14.9%
6-8 million JPY	7.3%
8-10 million JPY	3.3%
over 10 million JPY	2.5%
Total	100.0%

(2) Contents of CV survey

The title of CV survey is “the survey on mortality risk associated with global warming", and the questions are as follows.

Q1: Recognition of general mortality risk.

Q2: Residential region (prefecture).

Q3: Minimum compensating amount that households want the government to compensate in order to accept an increase of the heat stress mortality risk (at first time).

Q4: Reasons for accepting the increase of mortality risk even if the minimum compensating amount is 0 JPY annually (at first time).

Q5: Reasons not for accepting the increase of mortality risk even if the minimum compensating amount is 100,000 JPY annually (at first time).

Q6: Minimum compensating amount that households want the government to compensate in order to accept an increase of the heat stress mortality risk (at second time).

Q7: Reasons for accepting the increase of mortality risk even if the minimum compensating amount is 0 JPY annually (at second time).

Q8: Reasons not for accepting the increase of mortality risk even if the minimum compensating amount is 100,000 JPY annually (at second time).

Specific contents of the above questions are as shown in Table 2. First, question Q1 is set up in order to confirm whether the subject correctly recognized the degree of mortality risk.

In question Q2, the residential region (prefecture) of the subject is asked, then the heat stress mortality risks (X / 100,000 annually) at the prefecture in 2000 are indicated, and the mortality risks (Y / 100,000 annually) in the future (2050 and 2100) are also indicated. These values of heat stress mortality risk were estimated in the sub-theme S-8-1 (7) "Effects on health by global warming: elaboration of evaluation method and construction of countermeasure (Representative: Yasushi Honda)"; the main-theme S-8 "Comprehensive study on impact assessment and adaptation policy on global warming (Representative: Nobuo Mimura)" which was supported by the Environment Research and Technology Development Fund of the Ministry of the Environment, Japan.

In questions Q3 to Q8, we presented "the question about minimum compensating amount that households want the government to compensate in order to accept an increase of the heat stress mortality risk" which is the main question of this survey. In question Q3, we assumed that the heat stress mortality risk in the nearer future (2050) was set at the present time, and indicated the subject the minimum compensating amount and asked him/her accept or not. If the subject selected "Yes, I can accept the increase of mortality risk", the question (bid price game) was ended. On the other hand, if the subject selected "No, I cannot accept the increase of mortality risk", we indicated a further amount and asked him/her accept or not again. Here, as the minimum compensating amount to be indicated, we prepared 0 JPY, 100 JPY, 300 JPY, 500 JPY, 700 JPY, 1,000 JPY, 3,000 JPY, 5,000 JPY, 7,000 JPY, 10,000 JPY, 30,000 JPY, 50,000 JPY, 70,000 JPY, and 100,000 JPY annually. Yamamoto and Oka (1994) adopts the binary selection method (single bound method) and the bid price game system in the CV survey, and in particular there is no possibility of the starting point bias; where the result would change depending on the amount indicated at the starting point. Therefore, in the bid price game of this survey, we indicated all subjects the same price "0 JPY annually" as the starting point.

In question Q6, we assumed that the heat stress mortality risk in the further future (2100) was set at the present time, and indicated the subject the minimum compensating amount and asked him/her accept or not, in the same way as in question Q3. That is, one subject was asked twice for the minimum compensating amount by changing the increase of the mortality risk.

In questions Q4 and Q7, we asked the reason why the subject responded "Yes, I can accept" even if the minimum compensating amount is 0 JPY annually. On the other hand, in question Q5 and Q8, we asked the reason why the subject responded "No, I cannot accept" even if the minimum compensating amount is 100,000 JPY annually.

Here, in question Q3 and Q6, we asked the subject that he /she could accept or not accept an increase of the mortality risk on the assumption that the heat stress mortality risk in the future were set at the present time. However, in the free description fields of "Others" in Q4, Q5, Q7 and Q8, there are descriptions such as "I cannot live until such future". This is misunderstanding of the subjects who image that the assumption to occur in the future. In the analysis of this study, such kind of reply which includes a misunderstanding is regarded as an invalid reply, but there is a possibility of being latent in an effective reply. I would like to make this a future subject.

Table 2: Main questions in the contingent valuation survey

Q1:

(1) Can you see that the mortality risk of cancer (258.3 / 100,000 annually) is higher than the mortality risk of traffic accidents (6.4 / 100,000 annually) from the list of mortality risk of various causes of death? Please select one applicable answer.

1. Yes.
2. No.

(2) Can you see that the mortality risk of heat stroke (0.4 / 100,000 annually) is 100 times the mortality risk of food poisoning death (0.004 / 100,000 annually) from the list of mortality risk of various causes of death? Please select one applicable answer.

1. Yes.
2. No.

(3) How do you think about the mortality risk of such heat stress? Please select one applicable answer.

1. I want the mortality risk to decrease.
2. I want the mortality risk to increase.
3. I do not care.

<Explanation of virtual situation>

From here it is a virtual question. Please suppose that "If compensation was made for an increase in the mortality risk of heat stress". And suppose that

the mortality risk of heat stress increased from X / 100,000 annually to Y / 100,000 annually now, and

you can receive necessary minimum of compensation in order to maintain living standards of the current situation in order to accept the increase of mortality risk.

Q3 and Q6:
Can you accept the increase of mortality risk above if minimum compensation is T JPY annually?

1. Yes, I can accept the increase of mortality risk.
2. No, I cannot accept the increase of mortality risk.

Q4 and Q7:
What is the reason why you responded that "Yes, I can accept the increase of mortality risk" even if the minimum compensating amount is 0 JPY annually? Please select all that apply. In other case, please specify in the bracket (   ) concretely.

1. I think that it is better not to increase the mortality risk of heat stress, but think that there is no damage to receive compensation.
2. I think that there is no problem even if the mortality risk of heat stress increases.
3. I think I will never die by heat stress.
4. Other: (   )

Q5 and Q8:
What is the reason why you responded that "No, I cannot accept the increase of mortality risk" even if the minimum compensating amount is 100,000 JPY annually? Please select all that apply. In other case, please specify in the bracket (   ) concretely.

1. The Compensating amount is too low at 100,000 JPY annually.
   # If the compensating amount is (   ) JPY annually, I can accept the increase of mortality risk.
2. I cannot accept the increase of mortality risk absolutely.
3. I cannot trust whether this compensation can really be received.
4. I am against the idea of trying to solve the problem of increase of mortality risk with compensation.
5. I cannot judge with only such information.
6. Other: (   )

(3) Determination of effective reply

The effectiveness of reply in the CV survey was judged based on the following criteria.

C1: For people who chose "2" in question Q1 (1), we judge that they do not understand the magnitude relation of mortality risk and exclude the sample from the analysis data.

C2: For people who chose "2" in question Q1 (3), we judge that they do not understand the meaning of mortality risk and exclude the sample from the analysis data.

C3: For people who chose "2" to "4" in question Q4 or Q7 as reasons for accepting the increase of the mortality risk even if the minimum compensating amount is 0 JPY annually, we judge that they do not understand the purpose of this survey and exclude the sample from the analysis data.

C4: For people who chose "2" to "6" in question Q5 or Q8 as reasons not for accepting the increase in the mortality risk even if the minimum compensating amount is 100,000 JPY annually, we judge that they do not understand the purpose of this survey and exclude the sample from the analysis data.

C5: For the people who have a relation of "T (1ST)> T (2ND)" between the minimum compensating amount T (1ST) and T (2ND) which chose "1" first in questions Q3 and Q6 respectively, we judge that there is the internal scope violation (where the evaluation result decreases despite the scale of the evaluation object becoming larger) and exclude the sample from the analysis data.

By examining 3,501 replies obtained in this survey based on the above criteria C1 to C5, the valid replies are 1,429 samples. In addition, the internal scope violation in the strong sense as follows was also considered.

C6: For the people who choose "1" when "T = 0" in questions Q3 and Q6, we judge that there is the strong internal scope violation (where the evaluation result does not change despite the scale of the evaluation object changing) and excludes the sample from the analysis data.

By reviewing 1,429 samples above based on six criteria C1 to C6, 824 samples are obtained as the valid replies.

4. Method of analysis

(1) Specification of utility function

In order to estimate the WTA for accepting an increase of heat stress mortality risk, the utility function of an individual is specified by Equation (1). Equation (1) represents the difference between the utility level in the case of agreeing with the minimum compensating amount for accepting an increase of heat stress mortality risk and the utility level in the case of not agreeing; as the function of the compensating amount, the current mortality risk, the increase of mortality risk, and individual attributes.

$$V_{yes} - V_{no} = a + b \cdot \ln(t) + c \cdot \gamma_0 + d \cdot \ln(\gamma) + \sum_k e_k \cdot x_k \qquad (1)$$

where, V_{yes}: utility level in the case of agreeing with the minimum compensating amount for accepting an increase of heat stress mortality risk, V_{no}: utility level in the case of not agreeing, t: compensating amount, γ_0: current mortality risk (number of deaths per 100 thousand population annually), γ: increase of heat stress mortality risk from present to future, x_k: individual attributes, and a, b, c, d, e_k : unknown parameters.

The parameters of Equation (1) are estimated by the choice behaviors in questions Q3 and Q6. If we take the choice behaviors in the framework of random utility theory, the theoretical choice probability of each option is derived. Among the various probability models, the logit model with the highest operability is shown below.

$$\begin{aligned} P_{yes} &= \frac{\exp\left(w \cdot V_{yes}\right)}{\exp\left(w \cdot V_{yes}\right) + \exp\left(w \cdot V_{no}\right)} \\ &= \frac{1}{1 + \exp\left(-w \cdot \left(V_{yes} - V_{no}\right)\right)} \end{aligned} \tag{2}$$

$$P_{no} = 1 - P_{yes} \tag{3}$$

where, P_{yes}: theoretical probability of one's decision to agree with the minimum compensating amount for accepting an increase of heat stress mortality risk, P_{no}: theoretical probability of one's decision not to agree, and w: dispersion parameter of random utility (assuming w = 1 in general).

In this study, the compensating amount when the difference between the utility level V_{yes} with "an increase of heat stress mortality risk" and "a compensating amount" and the utility level V_{no} without both of them, that is ($V_{yes} - V_{no}$), becomes zero is defined as the individual WTA for accepting an increase of heat stress mortality risk. This WTA is given by the following equation.

$$WTA = \exp\left(-\frac{a + c \cdot \gamma_0 + d \cdot \ln(\gamma) + \sum_k e_k \cdot x_k}{b}\right) \tag{4}$$

Then, the VSL of heat stress is calculated by dividing the WTA by the increase of heat stress mortality risk. It is expressed by the following equation.

$$VSL \equiv \frac{WTA(\gamma)}{\gamma} \tag{5}$$

where, VSL: value of a statistical life, and WTA (γ): minimum compensating amount for accepting an increase of mortality risk γ.

(2) Estimation method of utility function

For the estimation of the utility function, a joint probability function (likelihood function) of the choice result set was constructed by using the theoretical choice probabilities of Equations (2) and (3). Then, the data obtained by the CV survey was applied and the parameters of the utility function were estimated by the maximum likelihood method. Here, the was adopted in the CV survey on the minimum compensating amount, but it was replaced by the double bound system as described later in the estimation of the utility function. In the double bound method, a compensating amount T1 is presented at the beginning, and when the subject agrees, a lower compensating amount TL than T1 is indicated, and we ask about agree or not again. On the other hand, when the subject does not agree, a higher compensating amount TU than T1 is indicated, and we ask about agree or not again. Four cases are considered for such two indications, and these probabilities are represented by Equations (6) to (9) [Kuriyama, 1998].

1) Probability to answer "agree" at the both stages:

$$\begin{aligned}\Pr.[T1 \geq WTA, TL \geq WTA] &= P_{yes}[TL \geq WTA] \\ &= P_{yes}[TL]\end{aligned} \tag{6}$$

2) Probability to answer "agree" at the first stage and "not agree" at the second stage:

$$\begin{aligned}\Pr.[TL < WTA \leq T1] &= P_{yes}[T1] - P_{yes}[TL] \\ &= P_{yes}[T1] + P_{no}[TL] - 1\end{aligned} \tag{7}$$

3) Probability to answer "not agree" at the first stage and "agree" at the second stage:

$$\begin{aligned}\Pr.[T1 < WTA \leq TU] &= P_{yes}[TU] - P_{yes}[T1] \\ &= P_{yes}[TU] + P_{no}[T1] - 1\end{aligned} \tag{8}$$

4) Probability to answer "not agree" at the both stages:

$$\begin{aligned}\Pr.[T1 < WTA, TU < WTA] &= P_{no}[TU < WTA] \\ &= P_{no}[TU]\end{aligned} \tag{9}$$

Based on Equations (6) to (9), the log likelihood function in the maximum likelihood method is specified by Equation (10).

$$\ln(L) = \sum_{i=1}^{n} \left\{ \begin{array}{l} d_i^{YY} \cdot \ln(P_{yes}[TL]) \\ + d_i^{YN} \cdot \ln(P_{yes}[T1] + P_{no}[TL] - 1) \\ + d_i^{NY} \cdot \ln(P_{yes}[TU] + P_{no}[T1] - 1) \\ + d_i^{NN} \cdot \ln(P_{no}[TU]) \end{array} \right\} \tag{10}$$

where, L: likelihood function, n: number of samples, d_i^{YY}: dummy variable when individual i answers "agree" at the both stages, d_i^{YN}: dummy variable when individual i answers "agree" at the first stage and "not agree" at the second stage, d_i^{NY}: dummy variable when individual i answers "not agree" at the first stage and "agree" at the second stage, and d_i^{NN}: dummy variable when individual i answers "not agree" at the both stages.

(3) Replacement from bid price game system to double bound system

Table 3 shows the replacement from the bid price game system to the double bound system. Here, the WTA in Table 3 represents the minimum compensating amount in the bid price game system. For the combination of presentation amounts T1, TU and TL, three consecutive amounts including the minimum compensating amount are selected among the amounts indicated in the bid price game system as follows.

Specifically, when the minimum compensating amount is 0 JPY and 100 JPY, the combination of the compensating amounts is set to 300 JPY for T1, 500 JPY for TU, and 100 JPY for TL. At this time, since one's WTA exists between 0 JPY and 100 JPY, he answers "agree with T1" and "agree with TL". When the minimum compensating amount is 300 JPY, the combination is set to 300 JPY for T1, 500 JPY for TU, and 100 JPY for TL. At this time, since one's WTA exists between 100 JPY and 300 JPY, he answers "agree with T1" and "not agree with TL". When the minimum compensating amount is 500 JPY, the combination is set to 300 JPY for T1, 500 JPY for TU, and 100 JPY for TL. At this time, since one's WTA exists between 300 JPY and 500 JPY, he answers "not agree with T1" and "agree with TU". When the minimum compensating amount is up to 100,000 JPY, the combination of T1, TU and TL is set as the same manner. When the minimum compensating amount is 100,000 JPY or more, the combination is set to 70,000 JPY for T1, 100,000 JPY for TU, and 50,000 JPY for TL. At this time, since one's WTA is 100,000 JPY or more, he answers "not agree with T1" and "not agree with TU".

Table 3: Replacement from the bid price game system to the double bound system

WTA (JPY/year)	Compensating amount (JPY/year)			Answer	
	T1	TU	TL	1st time	2nd time
0	300	500	100	T1: Yes	TL: Yes
100	300	500	100	T1: Yes	TL: Yes
300	300	500	100	T1: Yes	TL: No
500	300	500	100	T1: No	TU: Yes
700	500	700	300	T1: No	TU: Yes
1,000	700	1,000	500	T1: No	TU: Yes
3,000	1,000	3,000	700	T1: No	TU: Yes
5,000	3,000	5,000	1,000	T1: No	TU: Yes
7,000	5,000	7,000	3,000	T1: No	TU: Yes
10,000	7,000	10,000	5,000	T1: No	TU: Yes
30,000	10,000	30,000	7,000	T1: No	TU: Yes
50,000	30,000	50,000	10,000	T1: No	TU: Yes
70,000	50,000	70,000	30,000	T1: No	TU: Yes
100,000	70,000	100,000	50,000	T1: No	TU: Yes
over 100,000	70,000	100,000	50,000	T1: No	TU: No

5. Result of analysis

(1) Estimation of WTA and VSL without considering personal attributes

In this study, the parameters of the utility function were estimated by using "Environmental evaluation which can be done with Excel" by Kuriyama et al. (2013).

The result of estimation of Equation (1) without considering personal attributes is shown in Table 4. From Table 4, it is found that the t-values of estimated parameters are high and the null hypothesis can be rejected with the significance level of 1%. The results of the statistical analysis are overall good. Here, since the question about the minimum compensating amount was repeated twice for the subject while changing the increase of the mortality risk, the number of samples used for the analysis is twice as large as the number of effective replies (824).

Table 4: Estimated parameters of a model without any variables of personal attribute

Variable	Estimated parameter	t-value
Constant	-6.100	-31.150 ***
ln(Compensating amount)	0.737	42.436 ***
Present mortality risk	0.159	3.408 ***
ln(Increase of mortality risk)	-0.437	-6.962 ***
Number of samples	1,648	
Log-likelihood	-4,464	

Note) ***: significance level is 1%

By substituting the estimated parameters in Table 4 and the estimated values of mortality risk by prefecture into Equations (4) and (5), the WTA and the VSL by prefecture for the increase of heat stress mortality risk can be calculated. Here, although the estimated parameters of Equation (1) are common throughout the country, since the numerical value of mortality risk is set for each prefecture, the WTA and the VSL are calculated for each prefecture.

The results are shown in Figures 1 and 2. From Figure 1, it is found that the WTA for accepting the increase of the mortality risk from the current level (2000) to the nearer future level (2050) is 1,798 JPY/year (Okinawa) to 5,850 JPY/year (Nagasaki), and that the WTA for accepting the increase of the mortality risk from the current level (2000) to the further future level (2100) is 7,476 JPY/year (Okinawa) to 13,289 JPY/year (Nagasaki). From Figure 2, it is found that the VSL based on WTA for accepting the increase of the mortality risk from the current level (2000) to the nearer future level (2050) is 68.81 million JPY (Akita) to 677.23 million JPY (Okinawa), and that the VSL based on WTA for accepting the increase of the mortality risk from the current level (2000) to the further future level (2100) is 41.80 million

JPY (Akita) to 254.60 million JPY (Okinawa). In the previous study on VSL [Ohno et al., 2009], the VSL (90 million JPY to 105.5 million JPY) was calculated through estimation of the WTP (271 JPY/year to 2,849 JPY/year) for reduction of heat stroke mortality risk. We adopt the WTA with priority on easiness of the CV survey in this study, but the estimated WTA is larger than the estimated WTP in the previous study. However, the mortality risk of heat stroke used in the previous study is about 0.2 / 100,000 annually in 2000, but the mortality risk of heat stress used in this study is about 2.5 / 100,000 annually in 2000. Since the mortality risk used in this study is more than 10 times that of the previous study, it cannot be said that the WTA estimated in this study is excessive.

As shown in Figure 2, there is a tendency for the VSL of each prefecture to be higher in the VSL in the south (warm) region than the VSL in the northern (cool) region. The reason for this is that the WTA in each prefecture does not change so much, but the mortality risk decreases from the northern region to the southern region. That is, where the change of the mortality becomes large (small), the VSL becomes small (large); there is a negative correlation.

There is also a trend that the VSL based on the WTA for the further future is higher than the VSL based on the WTA for the nearer future. The reason for this is that the rate of increase of the mortality risk is greater than the rate of increase of WTA; the WTA will become only double, but the mortality risk will increase four-fold. As a result, the VSL based on the WTA for the further future will be about 1/2 times of the VSL based on the WTA for the nearer future.

The WTA in Okinawa is considerably smaller (about 1/4 times) than the WTA in other prefectures, but the VSL in Okinawa is considerably larger (about 4 times) than the VSL in other prefectures. The reason for this is that the increase of heat stress mortality risk in Okinawa is considerably small (about 1/15 times) compared with other prefectures, and the WTA function is concave. Meanwhile, Okinawa prefecture is originally a hot region, and Okinawa citizens are accustomed to a hot weather, so it is expected that measures against heat stress will be perfect. Therefore, it may be thought that Okinawa citizens die by the heat stress rarely. As seen in Japanese behavior when mad cow problems occurred, people tend to respond sensitively to the very low risk of death. So it is also understood that the VSL is large in Okinawa, where the mortality risk of heat stress is small.

On the other hand, at each period of 2050 and 2100, the WTA tends to be large as the increase of mortality risk become large. Generally, it is thought that the WTA becomes large as the increase of mortality risk becomes large. However, as for the results by prefecture in 2050 and 2100, the WTA tends to become small as the increase of mortality risk become large. There is a possibility of the external scope violation about this point, and I would like to make this a future subject.

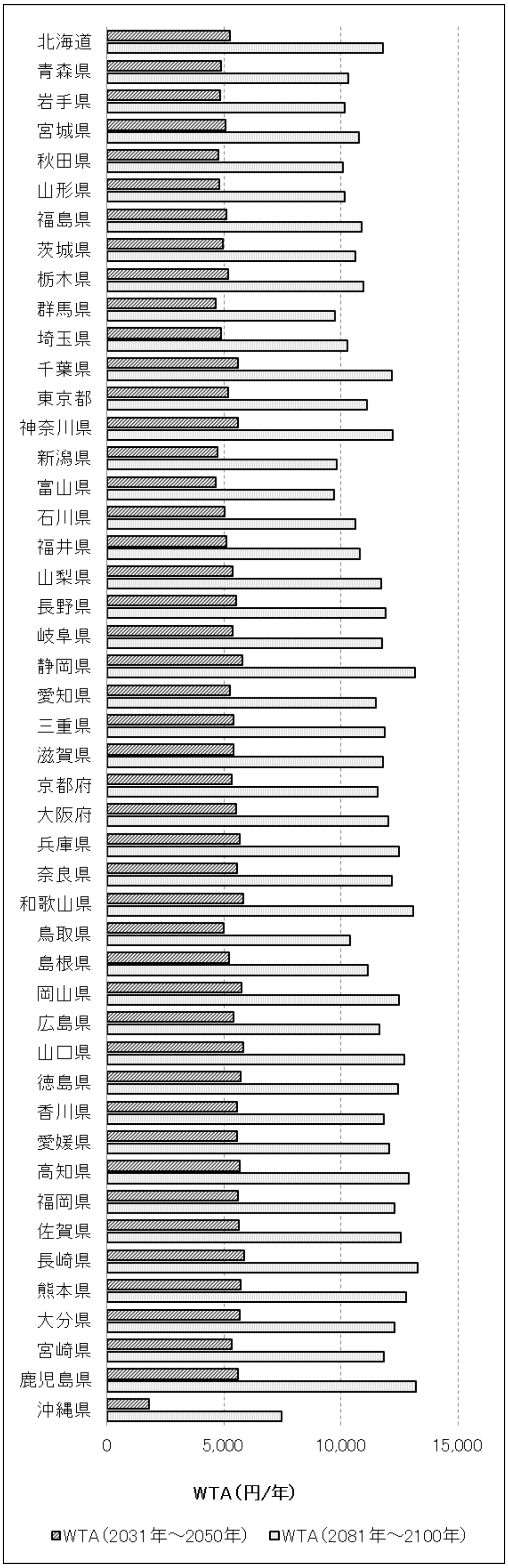

Figure 1: Estimated WTA for accepting an increase of mortality risk of heat stress

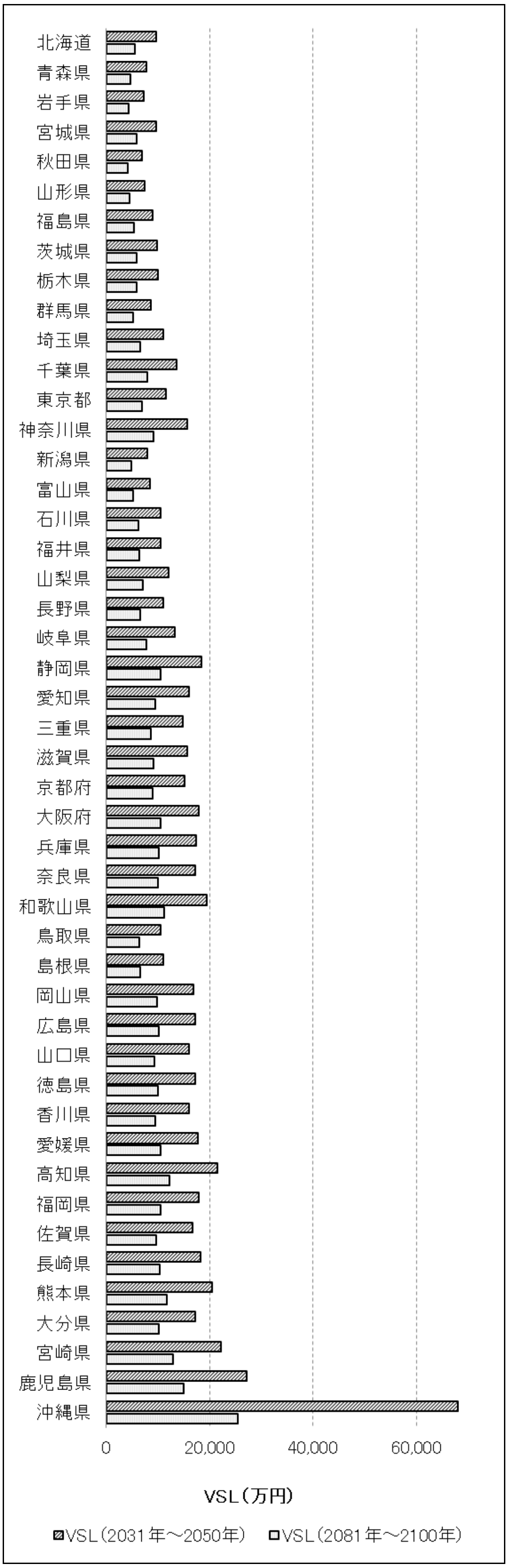

Figure 2: Calculated VSL based on WTA in Figure 1

(2) Estimation of WTA and VSL with considering personal attributes

The results of estimation of Equation (1) with considering personal attributes (age, occupation, and annual income) are shown in Tables 5 to 7. Table 5 shows the model with considering the dummy variables of age. We estimated the model incorporating all dummy variables of age at beginning, removed dummy variables with low significance level in order, and estimated the model again. It was finished when the null hypothesis on all variables could be rejected with a significance level of 10%. As a result, only the age group of 20's has the statistically significant.

Table 6 shows the model with considering the dummy variables of occupation. By the same procedure of estimation above, we have got a result that the public official group and the housewife/husband group have the statistically significant.

Table 7 shows the model with considering the dummy variables of annual income. By the same procedure of estimation above, we have got a result that the 6-8 million JPY group and the 8-10 million JPY group have the statistically significant.

Table 5: Estimated parameters of a model with the dummy variables of age

Variable	Estimated parameter	t-value
Constant	-6.205	-31.616 ***
ln(Compensating amount)	0.740	42.517 ***
Present mortality risk	0.160	3.433 ***
ln(Increase of mortality risk)	-0.439	-6.997 ***
Age dummy: 20's	0.369	3.459 ***
Number of samples	1,648	
Log-likelihood	-4,458	

Note) ***: significance level is 1%

Table 6: Estimated parameters of a model with the dummy variables of occupation

Variable	Estimated parameter	t-value
Constant	-6.050	-30.534 ***
ln(Compensating amount)	0.738	42.342 ***
Present mortality risk	0.158	3.381 ***
ln(Increase of mortality risk)	-0.437	-6.963 ***
Occupation dummy: Public official	-0.313	-1.378 *
Occupation dummy: Housewife/husband	-0.195	-1.874 **
Number of samples	1,648	
Log-likelihood	-4,461	

Note) ***: significance level is 1%, **: significance level is 5%, *: significance level is 10%

Table 7: Estimated parameters of a model with the dummy variables of annual income

Variable	Estimated parameter	t-value
Constant	-6.088	-31.045 ***
ln(Compensating amount)	0.738	42.519 ***
Present mortality risk	0.161	3.447 ***
ln(Increase of mortality risk)	-0.436	-6.952 ***
Annual income dummy: 6-8 million JPY	-0.296	-1.510 *
Annual income dummy: 8-10 million JPY	-0.399	-1.646 **
Number of samples	1,648	
Log-likelihood	-4,462	

Note) ***: significance level is 1%, **: significance level is 5%, *: significance level is 10%

By substituting the estimated parameters in Tables 5 to 7 and the estimated values of mortality risk by prefecture into Equations (4) and (5), the WTA and the VSL by prefecture for the increase of heat stress mortality risk by considering personal individual attributes can be calculated. The results are shown in Tables 8 to 10.

Table 8 shows the results of estimated WTA and VSL by age group. As for the WTA for accepting the increase of the mortality risk from the current level (2000) to the nearer future level (2050), the WTA of the 20's group is 1,212 JPY/year (Okinawa) to 3,945 JPY/year (Nagasaki), and that of other age group is 1,995 JPY/year (Okinawa) to 6,495 JPY/year (Nagasaki). As for the VSL based on WTA for accepting the increase of the mortality risk from the current level (2000) to the nearer future level (2050), the VSL of the 20's group is 46.41 million JPY (Akita) to 456.43 million JPY (Okinawa), and that of other age group is 76.41 million JPY (Akita) to 751.36 million JPY (Okinawa). As for the WTA for accepting the increase of the mortality risk from the current level (2000) to the further future level (2100), the WTA of the 20's group is 5,042 JPY/year (Okinawa) to 8,966 JPY/year (Nagasaki), and that of other age group is 8,301 JPY/year (Okinawa) to 14,763 JPY/year (Nagasaki). As for the VSL based on WTA for accepting the increase of the mortality risk from the current level (2000) to the nearer future level (2100), the VSL of the 20's group is 27.71 million JPY (Akita) to 171.70 million JPY (Okinawa), and that of other age group is 45.63 million JPY (Akita) to 282.71 million JPY (Okinawa). From the above, it is found that the WTA and the VSL of the 20's group are smaller than those of the other age group. However, since the 20's group will live longer than any other age groups, it seems that the 20's group require more compensating amount and the VSL of the 20's will bigger than any other age groups.

Table 9 shows the results of estimated WTA and VSL by occupation group. As for the WTA for accepting the increase of the mortality risk from the current level (2000) to the nearer future level (2050), the WTA of the public official group is 2,530 JPY/year (Okinawa) to 8,242 JPY/year (Nagasaki), and that of the housewife/husband group is 2,154 JPY/year (Okinawa) to 7,019 JPY/year (Nagasaki), and that of other occupation group is 1,655 JPY/year (Okinawa) to 5,392 JPY/year (Nagasaki). As for the VSL based on WTA for accepting the increase of the mortality risk from the current level (2000) to the nearer future level (2050), the VSL of the public official group is 97.48 million JPY (Akita) to 952.57 million JPY (Okinawa), and that of the housewife/husband group is 83.01 million JPY (Akita) to 811.24 million JPY (Okinawa), and that of other occupation group is 63.76 million JPY (Akita) to 623.11 million JPY (Okinawa). As for the WTA for accepting the increase of the mortality risk from the current level (2000) to the further future level (2100), the WTA of the public official group is 10,507 JPY/year (Okinawa) to 18,716 JPY/year (Nagasaki), and that of the housewife/husband group is 8,948 JPY/year (Okinawa) to 15,939 JPY/year (Nagasaki), and that of other occupation group is 6,873 JPY/year (Okinawa) to 12,243 JPY/year (Nagasaki). As for the VSL based on WTA for accepting the increase of the mortality risk from the current level (2000) to the further future level (2100), the VSL of the public official group is 58.16 million JPY (Akita) to 357.83 million JPY (Okinawa), and that of the housewife/husband group is 49.53 million JPY (Akita) to 304.74 million JPY (Okinawa), and that of other occupation group is 38.05 million JPY (Akita) to 234.07 million JPY (Okinawa). From the above, it is found that the WTA and the VSL are large, in the order of public official group, housewife/husband group, and other occupation group.

Table 10 shows the results of estimated WTA and VSL by annual income group. As for the WTA for accepting the increase of the mortality risk from the current level (2000) to the nearer future level (2050), the WTA of the 6-8 million JPY group is 1,169 JPY/year (Okinawa) to 3,774 JPY/year (Nagasaki), and that of the 8-10 million JPY group is 1,017 JPY/year (Okinawa) to 3,286 JPY/year (Nagasaki), and that of other annual income group is 1,746 JPY/year (Okinawa) to 5,639 JPY/year (Nagasaki). As for the VSL based on WTA for accepting the increase of the mortality risk from the current level (2000) to the nearer future level (2050), the VSL of the 6-8 million JPY group is 44.05 million JPY (Akita) to 440.06 million JPY (Okinawa), and that of 8-10 million JPY group is 38.35 million JPY (Akita) to 383.11 million JPY (Okinawa), and that of other annual income group is 65.81 million JPY (Akita) to 657.48 million JPY (Okinawa). As for the WTA for accepting the increase of the mortality risk from the current level (2000) to the further future level (2100), the WTA of the 6-8 million JPY group is 4,837 JPY/year (Okinawa) to 8,554 JPY/year (Nagasaki), and that of the 8-10 million JPY group is 4,212 JPY/year (Okinawa) to 7,447 JPY/year (Nagasaki), and that of other annual income group is 7,228 JPY/year (Okinawa) to 12,780 JPY/year (Nagasaki). As for the VSL based on WTA for accepting the increase of the mortality risk from the current level (2000) to the further future level (2100), the VSL of the 6-8 million JPY group is 26.24 million JPY (Akita) to 164.77 million JPY (Okinawa), and that of 8-10 million JPY group is 22.84 million JPY (Akita) to 143.44 million JPY (Okinawa), and that of other annual income group is 39.20 million JPY (Akita) to 246.17 million JPY (Okinawa). From the above, it is found that the WTA and the VSL of the high income (6-10 million JPY) group are smaller than those of the low income (other annual income) group. Since the high income group has enough money to live, it can be understood that the high income group does not need to receive much compensating amount.

Table 8: Estimated WTA and VSL by age group

	case of nearer future (2050)		case of further future (2100)	
	WTA (JPY/year)	VSL (million JPY)	WTA (JPY/year)	VSL (million JPY)
20’s	1,212 - 3,945	46.41 - 456.43	5,042 - 8,966	27.71 - 171.70
Others	1,995 - 6,495	76.41 - 751.36	8,301 - 14,763	45.63 - 282.71

Table 9: Estimated WTA and VSL by occupation group

	case of nearer future (2050)		case of further future (2100)	
	WTA (JPY/year)	VSL (million JPY)	WTA (JPY/year)	VSL (million JPY)
Public official	2,530 - 8,242	97.48 - 952.57	10,507 - 18,716	58.16 - 357.83
Housewife/husband	2,154 - 7,019	83.01 - 811.24	8,948 - 15,939	49.53 - 304.74
Others	1,655 - 5,392	63.76 - 623.11	6,873 - 12,243	38.05 - 234.07

Table 10: Estimated WTA and VSL by annual income group

	case of nearer future (2050)		case of further future (2100)	
	WTA (JPY/year)	VSL (million JPY)	WTA (JPY/year)	VSL (million JPY)
6-8 million JPY	1,169 - 3,774	44.05 - 440.06	4,837 - 8,554	26.24 - 164.77
8-10 million JPY	1,017 - 3,286	38.35 - 383.11	4,212 - 7,447	22.84 - 143.44
Others	1,746 - 5,639	65.81 - 657.48	7,228 - 12,780	39.20 - 246.17

6. Concluding remarks

Regarding measurement of benefits of public investment to reduce the mortality risk, a method using the value of statistical life (VSL) calculated by dividing the willingness to pay (WTP) for reducing the mortality risk by the amount of risk reduction has been put to practical use in the western countries. In Japan, a value of approximately 30 million yen based on "medical fee + benefit loss + consolation money = total loss" provisionally has been used as "value of life" in practice. In addition, estimation of VSL based on WTP is also conducted, and since fiscal 2009 the value of 226.07 million JPY has been used for public project evaluation by the Ministry of Land, Infrastructure, Transport and Tourism, but research accumulation is not yet enough. In this study, VSL has been calculated, by estimating the willingness to accept compensation (WTA) for allowing an increase of heat stress mortality risk by conducting the contingent valuation (CV) survey, and by dividing this WTA by the amount of risk reduction. There we have conducted a closed-type CV survey for adult men and women aged 20 to 69 throughout the country through a web research company. Based on 3,501 response data obtained there, we estimated WTA and VSL by each prefecture of Japan.

As a result, we have estimated some values of WTA for an increase of heat stress mortality risk; the values in the nearer future till 2050 are 1,798 JPY/year (Okinawa) to 5,850 JPY/year (Nagasaki); the values in the further future till 2100 are 7,476 JPY/year (Okinawa) to 13,289 JPY/year (Nagasaki). Based on these WTA, we have calculated some values of VSL; the values in the nearer future till 2050 are 68.81 million JPY (Akita) to 677.23 million JPY (Okinawa); the values in the further future till 2100 are 41.08 million JPY (Akita) to 254.60 million JPY (Okinawa). From the result, we can see the difference by each prefecture of Japan; the values of VSL in the south (warm) region are higher than those in the north (cool) region.

On the other hand, in the previous study on the VSL [Ohno et al., 2009], the VSL was estimated 90.2 to 105.5 million JPY through estimation of the WTP for the reduction of heat stroke mortality risk. Here, the mortality risk of heat stroke in 2000 is about 0.2 / 100,000 annually, but the mortality risk of heat stress in 2000 is about 2.5 / 100,000 annually. In other words, since the heat stress mortality risk is more than 10 times the heat stroke mortality risk, we will be able to analyze the wide range relationship between of the mortality risk changes and the VSL.

And, when 3,501 samples obtained from this survey were carefully examined, the number of valid responses was 824, and the ratio of valid responses used for analysis (effective response rate) was 23.5%. It was not clear whether the cause of such a low effective response rate lies in the difficulty of understanding the contents of the question or whether it is in the characteristics of the web survey. I would like to consider these subjects in the next study.

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