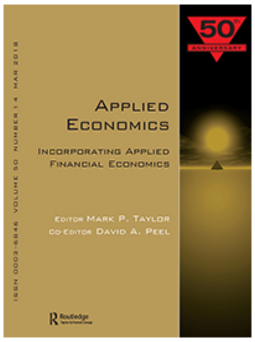

Applied Economics

ISSN: 0003-6846 (Print) 1466-4283 (Online) Journal homepage: www.tandfonline.com/journals/raec20

The public value of improving a weather forecasting system in Korea: a choice experiment study

Sun-Young Park & Seung-Hoon Yoo

APPLIED ECONOMICS, 2018
VOL. 50, NO. 14, 1644–1658
https://doi.org/10.1080/00036846.2017.1368995

The public value of improving a weather forecasting system in Korea: a choice experiment study

Sun-Young Park [a] and Seung-Hoon Yoo [b]

[a]Department of Economics, Korea University, Seoul, Republic of Korea; [b]Department of Energy Policy, Graduate School of Energy & Environment, Seoul National University of Science & Technology, Seoul, Republic of Korea

ABSTRACT
The Korean government plans to improve the quality of its weather forecasting system in order to increase its public utility. The benefits arising from the implementation of this plan should be measured. To this end, this study applies a choice experiment to four attributes: the update frequency of both short- and medium-range forecasts, and the accuracy of both. A survey of 1000 randomly selected households was undertaken in Korea. In the study results, the marginal willingness-to-pays, respectively, for one more update of the short-range forecast per day, for a 1% increase in the accuracy of the short-range forecast, for changing the update frequency of the medium-range forecast from once a day (reference level) to twice a day, and for a 1% increase in the accuracy of the medium-range forecast as a result of improving the weather forecast service were estimated to be KRW 499.3 (USD 0.45), 108.3 (0.10), 346.5 (0.31), and 80.9 (0.07) per household per month. The findings can provide policy-makers with useful information for both evaluating and planning improvements in the weather forecasting system.

KEYWORDS
Weather forecast service; choice experiment; willingness to pay; multinomial logit model

JEL CLASSIFICATION
D60; H41; Q55

I. Introduction

The number of natural disasters caused by severe weather conditions is increasing rapidly (NASA Langley Research Center 2013). Severe weather events such as heavy snow, extreme drought and heavy rain are becoming more frequent, powerful and erratic (World Economic Forum 2014). Preparing for such events is as important as taking measures afterwards, and this requires a weather forecasting service so that people have time to escape from a disaster area or minimize their losses. Thus, weather information partially reduces the effects of natural disasters. Weather forecasting plays a significant role in preparing for and providing relief from disaster damage, especially in the modern information-oriented and high-technology society in which most things are interrelated so that a small change in weather conditions can cause disaster.

Almost all weather forecasts in Korea are freely produced and distributed by the government, on the basis that weather forecasts are public goods[1] and should be supplied to a desirable level (Teisberg, Weiher, and Khotanzad 2005). In Korea, the Korea Meteorological Administration (KMA) has been the exclusive provider of weather forecasts and has provided daily weather forecasts since 1964. Despite some inaccurate forecasting, the Korean weather forecast service has been provided continuously and has received international praise.

Improving the quality of the KMA's weather forecasting system in Korea will require a large quantity of public funds to enhance the accuracy and frequency of the forecasts and thereby produce high-quality weather forecasts. Effective decision-making on the extent of investment in improving the weather forecasting system in Korea will require an evaluation of whether or not public investment in the quality of weather forecasting is worthwhile, because limited public funds should be spent in an efficient way. Clearly, it is valuable to study whether the incremental value of improved forecasting capabilities exceeds its cost. Therefore, this study attempts to ascertain the public value of improving the weather forecasting system in Korea.

CONTACT Seung-Hoon Yoo shyoo@seoultech.ac.kr Department of Energy Policy, Graduate School of Energy & Environment, Seoul National University of Science & Technology, 232 Gongreung-Ro, Nowon-Gu, Seoul 01811, Republic of Korea

[1]Public goods are defined as goods or services that are non-rivalrous and non-excludable. Non-rivalrous means that one person's consumption of the good cannot prevent the potential consumption of others. Non-excludable means that no-one can be excluded from enjoying such goods.

The value of improving weather forecasting that this article analyses can be a ground for government investments in public sector. When the government spends money for the public project, they require information on public needs. The marginal willingness to pay (WTP), which this article reports, can be read as the level of burden user can accept. Moreover, there is rarely found the information about the value of weather forecasting enhancement in Korea. The results in this study will be a basis of assessing weather forecasting and its enhancement hereafter.

One popular method through which decision-makers can measure the economic value of predictions about weather conditions is a cost/loss model. The model utilizes a simple 2 × 2 matrix comprising the predicted probabilities of adverse events and of protective action that avoids loss. For the case of weather forecasting services, the decision-makers can use this method in the following way: if the monthly cost for a household is less than the expected cost to that household of not taking a certain weather forecast into account (in other words, its expected loss), such a weather forecast should be provided. Although this method has been used since the 1950s (see Lee and Lee 2007) because it gives a simple and useful framework for analysing the use and value of weather information, we introduce a regression analysis for the Korean weather forecasting system for the first time.

The economic value of a weather forecasting service can be perceived using two different concepts. The first perspective is related to usual forecasts, including those for precipitation, temperature, cloud cover, sunshine, wind, etc. The second point of view is associated with extreme weather events (EWE) and high impact weather (HIW) such as extreme heat, intense rainfall, hurricanes, unusually strong winds or severe or unseasonal weather, that lead to huge disasters for human society. When a weather forecasting system is evaluated, these EWEs, and HIW, affect the public value of the weather forecasting service as much as the usual forecasts.[2] In this article, we focus on the usual forecasts in Korea because we want to consider ordinary people living in Korea rather than particular people in relation to a particular industry or region.

There is extensive literature on the value of weather forecasts in many parts of the world (e.g. Anaman and Lellyett 1996; Lazo and Chestnut 2002; Rollins and Shaykewich 2003; Considine et al. 2004; Lee and Lee 2007; Keith and Leyton 2007; Emanuel, Fondriest, and Kossin 2012; von Gruenigen, Willemse, and Frei 2014). However, relatively few studies have investigated the economic value or monetary benefits of improved weather forecasts. Lazo and Chestnut (2002) studied the benefits for United States households of a better weather forecast service. The study found that the average economic value of a certain level of enhancement to four attributes of the weather forecast service – Frequency of updates: from 4 to 12 times per day, Accuracy of One-day Forecasts: from 80 to 95%, Accuracy of Multiday Forecasts: from 05 days to 14 days, Geographic Detail: from 30 miles to 3 miles – was USD 16 per household per year. Moreover, Predicatori et al. (2008) and Lee et al. (2014) investigated, respectively, the value to farmers of enhancements in the agricultural weather information in Italy and the economic value of improvements in the pollen forecast system in Korea. Considine et al. (2004) valued a simulated 50% improvement in 48-h hurricane forecast accuracy for oil and gas producers and concluded that the value of forecasts for oil and gas extraction increases more than the amount by which the accuracy improves.

More recently, Lazo et al. (2010) investigated the value of improved hurricane forecast information. They used a choice experiment (CE) to determine the public worth of improved forecasts. The marginal WTP of four attributes (Time of expected landfall, Max wind speed, Projected location of landfall, Expected storm surge) were USD 2.18, 0.26, 0.23, and 2.04, respectively. Nguyen and Robinson (2015) elicited respondents' values of an improved cyclone warning service in Vietnam by using the CE approach. They concluded that there were three sorts of values: use, altruistic, and bequest. Nurmi, Perrels, and Nurmi (2013) applied a different method, called weather service chain analysis, to measure the benefits of high-quality forecasts in Finland. It is difficult to find studies on the value

[2]This is particularly so as these EWEs and HIW frequently cause great damage to our society and their frequencies have an upward trend, so interest in evaluating EWEs and HIW is increasing.

of weather forecast service improvements in Korea, although policy-makers are quite interested in acquiring information on the economic value of improvements to the weather forecast service.

The accuracies of short- and medium-range weather forecasts in 2011, which were updated every 3 h and once a day, respectively, were estimated to be 90 and 65%, respectively. For this reason, the government wanted to improve the quality of the weather forecast service (both its accuracy and the frequency with which forecasts were updated) in order to increase the public benefit. The government would benefit from qualitative analysis or information when deciding on the extent of efficient investment. Thus, this study applies CE to assess the most cost-effective investment for improving the Korean weather forecasting system by considering four attributes: the update frequency and the accuracy of both short- and medium-range forecasts, as detailed in Section III. The CE survey verifies the trade-offs between price and these four attributes, and derives each attribute's marginal WTP (MWTP) when the respondents choose the most preferred alternative.

The remainder of the article is divided into five parts. Section II delivers an overview of the weather forecasting system in Korea in 2011. Section III explains the CE approach adopted in this article and discusses the methodological issues. Section IV presents the theoretical and statistical models used to obtain the WTP for improving the weather forecasting system. Section V includes the estimation results, the MWTP, and the value of certain scenarios for improving the weather forecasting system. The final section presents some concluding remarks.

II. A brief overview of the weather forecasting system in Korea in 2011

Since Korea started making modern meteorological observations in 1904, the weather forecast service has been developed by using meteorological satellite data, introducing a super computer, and applying an advanced numerical weather prediction system. The KMA conducts weather observations and analyses meteorological phenomena and earthquakes on land and sea. It also produces weather data, including weather forecasts, warnings, and industrial meteorological information. The KMA has developed a national service, including a weather forecasting service and a severe weather warning service. The KMA's supercomputer system was updated twice before 2011, and a fourth supercomputer system is presently under discussion. The KMA is also trying to develop a numerical prediction system. This system had been a Japanese model until 2009, when it was changed to a British model. The KMA's own numerical prediction system is still under development.

The KMA issues many kinds of weather forecasts: short-, medium-, and long-range weather forecasts, typhoon forecasts, and severe weather warnings. This weather information is available in real time to the general public through the Internet (www.kma.go.kr), a weather call centre (+82–131), and an internet broadcasting system called Nalsee-ON. The short-range weather forecast is provided every 3 for the next 2 days for each 5 km grid square, whereas the medium-range weather forecast is issued twice a day for the next week, and the long-range weather forecast three times a month for the next 30 days, or once a month for the next three months. The short-range weather forecast in Korea, also known as the Digital Forecast Service (DFS) or Dong-Ne forecast, which is a forecast for the local neighbourhood, is the forecast that is most frequently and widely used by the public (Korea Meteorological Administration 2012) and it was launched in October 2008.

The DFS offers twelve types of weather information – spot temperature, maximum and minimum temperatures, precipitation type, probability and amount of precipitation, snow depth, sky cover, humidity, wind direction and speed, and significant wave height (i.e. the top one third of wave heights within a period) – in a variety of forms such as graphics, tables, text, and audio files. All weather elements of the DFS, except for precipitation amount and snow depth, are issued eight times per day (from 2 a.m. to 11 p.m.) for the following 48 h, and are available free and online anytime through the KMA's website and through social networking sites such as Facebook and Twitter; hence, weather information is easily accessed by the public.

The increase in weather information has promoted a demand for more specific and faster weather forecasts. The short-range weather forecasting system had a 3-h update interval and 90% accuracy in 2011. Since unexpected weather phenomena such as localized heavy rain lasting for a few minutes or a few hours have often occurred in Korea in recent times, a 3-h interval is too long for predictions. People want to obtain more than two weather reports in 3 h. As stated above, the accuracy of the medium-range forecast was 65% in 2011. Improving this accuracy will help people to prepare for weather damage and to plan ahead. Although the medium-range forecast was issued once a day in 2011, it did not include changes to weather conditions within the day. This inconvenience for the public led to calls for improvement in the quality of weather information. Furthermore, the Korean government agreed that the forecasts should be more frequently updated and more reliable. This study aims to provide a quantitative assessment of this improvement in weather forecasting in order to respond to the public demand and provide preliminary data for government investment in the weather forecast service.

III. Methodology

Choice experiment

Choice experiment (CE) is a multi-attribute preference-driven technique that is widely used to assess new products before introduction and to plan new markets for well-known products (Garrod and Willis 1997; Ida, Kinoshita, and Sato 2008; Ida 2012). When compared to other evaluation methods, CE is good at evaluating environmental goods with multiple characteristics (Madden and Simpson 1997; Baarsma 2003; Banfi, Filippini, and Horehájová 2012; Tarfasa and Brouwer 2013). The contingent valuation method also uses a survey to estimates people's utilities and is popular in estimating the economic value of non-market goods, while CE measures goods with several distinguishing characteristics and has often been used as an alternative to the contingent valuation method.[3]

CE is an attractive approach. First of all, when measuring the value of each attribute embedded in an environmental good, CE gives the results in an easy and simple way. This is a powerful merit for policy-makers; in most cases policy-making is more related to changing attribute levels than to varying the level of the good as a whole (Hanley, Wright, and Adamowicz 1998). Second, it shows the relationships among several environmental attributes or whether there can be trade-offs between environmental and non-environmental elements. In the trade-off process, the respondents may rethink their behaviour and researchers can test the consistency of the responses (Johnson and Desvousges 1997).

Choice-based approaches can be divided into three methods: contingent choice, contingent ranking, and contingent rating (Merino-Castello 2003). The contingent choice method shows the respondent a questionnaire, which consists of two or more hypothetical alternatives, and obtains the respondent's preferred decision, whereas the other two methods require the respondent to record his or her opinion on each alternative. In a contingent ranking survey, the respondents rank their preferences from the most preferred to the least preferred (Cuccia and Cellini 2007). The contingent rating method has different answers: the respondents must give their preference for, or rate the importance of, the alternatives by giving each a minimum of one point and a maximum of ten points.

Among the three CE methods, we applied the contingent choice method because choosing one alternative is simpler than ranking or rating a list of alternatives. It would have been burdensome for the interviewees to consider all the alternatives in every choice set, and this would have led to insincere replies.[4] Reducing the burden on respondents helps them to express their preferences or opinions sincerely. We tried to take advantage of this as data reliability is essential to questionnaire analysis.

A choice system is also similar to people's behaviour in the real world. Most purchase behaviour is the selection of one item from two or more similar items, or the selection of the best item. Consumers rarely rank all items or rate all of them, as this is irritating and makes them likely to give up answering all the questions or to answer them carelessly, which would generate erroneous study data. Thus, we used a contingent choice method in order to reduce respondents' resistance and the number of refusals. Although the CE

[3] For more details, refer to Carson (2011).
[4] If the respondents are required to make too many choices, it troubles them and they make their choices carelessly.

format was unfamiliar to the interviewees, they easily understood how to respond to the questionnaire: answering the questionnaire is like their usual activities.

Attributes

The weather forecast service as it relates to the daily life of households in Korea consists of short- and medium-range forecasts. A short-range forecast in Korea refers to DFS, which predicts weather information such as temperature, precipitation, sky conditions, wind direction and relative humidity for each village. These data are produced for every 5 km by 5 km square and are given for each district at 3-hourly intervals. Whereas the forecasts of the daily weather conditions are issued eight times a day, medium-range forecast information such as temperature, precipitation probability and wave height for the forthcoming week is provided once a day.

This study considered all the possible attributes of the hypothetical policies for the improvement of the weather forecast service. First, possible characteristics were selected from the literatures. For instance, Lazo and Chestnut (2002) used frequency of updates, forecasting periods, correctness of forecasts, geographic details for estimating public value of weather forecast. Both Considine et al. (2004) and Nurmi et al. (2013) proposed forecast accuracy, while Nurmi et al. (2013) additionally presented ability to respond timely and effectively. After several candidates were chosen, we adjusted them for our research purpose.

Without loss of generality, we selected preliminary characteristics of the two types of forecasts, and reviewed them based on economic theory and practical guidelines. Three criteria were used to decide on the final attributes: the independence of the attributes, the minimum number of attributes that is comprehensible, and the inclusion of important aspects (Phelps and Shanteau 1978; Yoo, Kwak, and Lee 2008). No two attributes should overlap with each other. Fewer than six attributes are preferred because respondents find it difficult to understand the complexity of attributes when too many are introduced together. Finally, the exclusion of scientifically meaningful and significant characteristics produces wrong conclusions.

One necessary and useful process is several interviews and consultations with specialists work in KMA. We have reflected the opinions of practitioners as much as possible so that our research can gain realistic implications later on. We met to exchange opinions about attributes of the weather forecasting service at every step. We reviewed literatures and selected characteristics among candidates together. This cooperation helps reliability and reality of our study.

Based on these three screening criteria and a discussion with weather experts in the KMA, we chose four attributes: the update frequency and the accuracy of the short- and the medium-range forecasts. Data transmission size was excluded from the chosen attributes because the public benefits from the segmentation of the transmission size overlap with those from faster update intervals or more accurate forecasts. Further, the data transmission size is not easy for the public to perceive when they consider improvements in weather forecasts. Table 1 describes the definition and levels of the final attributes.

Table 1. Descriptions and levels of the five chosen attributes.

Attributes	Descriptions	Levels
Frequency_short	The update frequency of the short-range forecast (Unit: update frequency)	Every 3 h (8)[a] Every 2 h (12) Every hour (24)
Accuracy_short	The accuracy of the short-range forecast (Unit: %)	90%[a] 93% 95%
Frequency_medium	The update frequency of the medium-range forecast (Unit: update frequency)	Once a day[a] 2 times a day 4 times a day
Accuracy_medium	The accuracy of the medium-range forecast (Unit: %)	65%[a] 70% 75%
Price	An increase in household monthly tax resulting from more frequent or accurate forecasts (Unit: Korean won)	0[a] 500 (USD 0.45) 1000 (USD 0.89) 1500 (USD 1.34) 2000 (USD 1.79)

[a]Indicates the reference level of each attribute. Figures in parenthesis of the frequency levels of short-range forecast represent the total number of updates in a day.

The baseline for weather forecast improvement in this study was the status quo of short-and medium-range forecasts in 2011. The short-range forecast has a three-hourly update system and is given for the following 48 h; the data are correct at a 90% accuracy level. On the other hand, the KMA updates the medium-range forecast once a day and it is given for the following seven days; the data are correct at the 65% level. Price (except for zero) refers to an additional payment in monthly tax that households must pay for more frequent or accurate forecasts. Price 0 (zero) means that no taxation is required other than what is paid for the current weather forecasting system (i.e. the reference level).

Design of choice sets

CE applies statistical design theory to set up choice sets in order to collect useful data with as low a bias as possible. Among various designs, such as the C-optimal, D-optimal and efficient designs, we used the orthogonal main effects design, which is effective at obtaining solely individual effects in the choice sets. This orthogonal design has the power to simplify the main effects, even though the attributes might be correlated in the real world. The SPSS 12.0 package was used to apply the orthogonal main effects method (SPSS 2005).

The CE questionnaire comprised two improvement alternatives and a status quo alternative. We had a sequence of $3^4 \times 5$ alternative groups in order to make each choice set. In order not to impose too heavy a burden on the respondents, we narrowed this number down to 16 alternatives, resulting in four selections for each person. Table 2 shows a list of the choice sets and the status quo choice set we used in the survey. These 16 choice sets were classified into two blocks, each comprising eight choice sets. Each respondent was asked to select one of three alternatives four times. Figure 1 is an example of choice card we present to the respondents.

Survey

The survey questionnaire was categorized into three types of questions: general, WTP, and socio-demographic. We measured the respondents' general views on weather forecast services in order to familiarize them with the weather forecasting system and help them evaluate its improvement. Pictures of the current weather forecasting system and of weather damage, such as heavy snow, strong winds and heavy rain, were shown to the respondents to enhance their understanding. The next part was designed to derive the respondents' WTP for weather forecasting system improvements, to estimate the economic value of the four attributes and price, and to determine the relationships between price and the other four attributes of the forecast improvements. The last part asked the respondents' income, age, education level, occupation and place of residence.

The survey was administered to 1000 randomly selected households from the national population with person-to-person interviews.[5] Despite the high expense of person-to-person interviewing, this method was used because it gives reliable answers. CE surveys are not familiar to the public; if we had used an internet-, telephone-, or mail-based survey, we may have decreased the respondents' understanding, yielding incorrect answers because with these methods it is not possible to check whether an interviewee understands the question correctly. The practical survey procedure was conducted by Research Prime, Inc., which is a professional polling firm in Seoul. They employed well-trained interviewers and used random sampling to guarantee the representativeness of the sample and prevent biased sampling. The respondents were evenly distributed across the 15 provinces of Korea.

Survey responses

As mentioned above, person-to-person interviews were conducted by well-trained interviewers with 1000 people in September 2011. Among total 4000 answers, a few choices have insufficient information on socio-demographics and missed choices were also found. We deleted those answers; thus the response rate is 97.3%. If we analysed the data from 4000 answers including the missing observations, we would get a different result from the result from analysing the data from 3892 answers because 108 responses would cause bias.

[5]The respondents spent an average of eight minutes completing the questionnaire.

Table 2. List of sixteen choice sets and the status quo choice set.

	Frequency_short	Accuracy_short	Frequency_medium	Accuracy_medium	Price
1	Every 3 h	95%	4 times a day	70%	500 (USD 0.45)
2	Every 2 h	90%	Once a day	75%	500 (USD 0.45)
3	Every 3 h	90%	Once a day	65%	2000 (USD 1.79)
4	Every 2 h	90%	4 times a day	65%	1500 (USD 1.34)
5	Every 2 h	93%	Once a day	70%	1000 (USD 0.89)
6	Every 3 h	93%	Once a day	65%	1500 (USD 1.34)
7	Every 3 h	90%	2 times a day	75%	1000 (USD 0.89)
8	Every hour	90%	4 times a day	65%	1000 (USD 0.89)
9	Every hour	95%	Once a day	75%	1500 (USD 1.34)
10	Every 2 h	95%	2 times a day	65%	2000 (USD 1.79)
11	Every hour	93%	2 times a day	65%	500 (USD 0.45)
12	Every 3 h	95%	Once a day	65%	1000 (USD 0.89)
13	Every hour	90%	Once a day	70%	2000 (USD 1.79)
14	Every 3 h	90%	Once a day	65%	500 (USD 0.45)
15	Every 3 h	93%	4 times a day	75%	2000 (USD 1.79)
16	Every 3 h	90%	2 times a day	70%	1500 (USD 1.34)
Status quo	Every 3 h	90%	Once a day	65%	0

	Alternative A	Alternative B	Status quo
Frequency of one-day forecasts updates	Every 3 hours a day (8 times a day)	Every 2 hours a day (12 times a day)	Every 3 hours a day (8 times a day)
Accuracy of one-day forecasts	95%	90%	90%
Frequency of multiday forecasts updates	4 times a day	Once a day	Once a day
Accuracy of multiday forecasts	70%	75%	65%
Additional income tax per month per household	KRW 500	KRW 500	KRW 0
Check with √ the only available alternative that you prefer among Alternative A, B or the status quo.	□ **A**	□ **B**	□ **Status quo**

Figure 1. A sample choice card used in this study.

This is an example of the choice card we present during the survey. After they read the description of each attribute with visual cards, they look the card over and compare three alternatives including status quo. The final step is to choose A, B, or Status quo.

Before completing the CE survey, the respondents were asked the questions in the general category about the importance of the weather forecast service and whether an accurate service was critical to their daily lives.[6] Nearly 90% of those surveyed (88.8%) thought that weather information is important, and

[6]We presented the same questionnaire about general opinion on weather information to all the respondents.

about 80% (83.6%) stated that a correct weather forecast is essential to their life. These responses indicate a strong desire to obtain and utilize accurate weather forecasts.

IV. Model

Random utility model

The random utility model is a well-known model in CE studies. In this study, we obtained the respondents' choices from three available alternatives; a multinomial logit (MNL) model (McFadden 1973) was adopted. The random utility model explains the consumer's utility in the form of an indirect utility function. The indirect utility function (I_{ij})[7] is divided into two parts: a deterministic part, D_{ij}, and a stochastic part, e_{ij}.

$$I_{ij} = D_{ij}(X_{ij}, C_i) + e_{ij}, \tag{1}$$

where X_{ij} has the attributes in alternative j and C_i is the characteristic set of the respondent i.

The respondent i who chooses alternative j from choice set S_i gains more utility than he or she does from choosing another alternative k; that is, $I_{ij} > I_{ik}$ for $j \neq k$ in S_i. His or her probability can be written as:

$$\begin{aligned}\Pr(j|S_i) &= \Pr(D_{ij} + e_{ij} > D_{il} + e_{il}) \\ &= \Pr(D_{ij} - D_{il} > e_{il} - e_{ij}).\end{aligned} \tag{2}$$

If the unobservable effects e_{ij} are independently and identically distributed with a Type I extreme value distribution, the probability is:

$$\Pr(j|S_i) = \frac{\exp(D_{ij})}{\sum_{l \in S_i} \exp(D_{il})}. \tag{3}$$

Each respondent answers with the preferred alternative among the four choice sets. Each choice set consists of the status quo alternative and two other alternatives; j ranges from 1 to 3. Now we have a data of the respondents' indirect utility function. The equations have different values depending on their choice (j). As mentioned above, we showed four types of choice cards to the respondents; thus indirect function changes according to the type. This is why the indirect utility functions have a subscribe i and j, which means indirect utility function has different value from the respondent i and the alternative j.

To obtain the estimates of parameters, we applied MNL model. It constructs the log-likelihood function which includes the deterministic part, D_{ij}, of the indirect utility function. When y_{ij} is a dummy variable for a chosen alternative and N is the total number of respondents, the log-likelihood function is given by:

$$\ln L = \sum_{i=1}^{N} \sum_{j=1}^{3} (y_{ij} \ln[\Pr(j|S_i)]), \tag{4}$$

To analyse the above function, we used maximum likelihood estimation (MLE) which find out parameters to maximize the log-likelihood function. Note that $\Pr(j|S_i)$ is a function of parameters β and regressors X and y_{ij} takes 1 only as the respondents choose j (Cameron and Trivedi 2005). The first-order conditions for the MLE $\hat{\beta}$ are that it solves

$$\frac{\partial L}{\partial \beta} = \sum_{i=1}^{N} \sum_{j=1}^{3} \frac{y_{ij}}{\Pr(j|S_i)} \frac{\partial \Pr(j|S_i)}{\partial \beta} = 0_{ij} \tag{5}$$

WTP model

As mentioned above, the deterministic part (D_{ij}) of the indirect utility function is explained by the attributes X_{ij}. We set up the attributes in a linear functional form. The attribute vector is defined as follows: $(X_1, X_2, X_3, X_4, X_5)$ = (Update frequency of short-range forecast, Accuracy of short-range forecast, Update frequency of medium-range forecast, Accuracy of medium-range forecast, and Price). Two alternative-specific constants (ASCs) were added to the deterministic part to estimate the effect of a missed series of attributes (Adamowicz, Louviere, and Williams 1994).

$$\begin{aligned}D_{ij} = ASC_j + \beta_1 X_{1,ij} + \beta_2 X_{2,ij} + \beta_3 X_{3,ij} \\ + \beta_4 X_{4,ij} + \beta_5 X_{5,ij}\end{aligned} \tag{6}$$

[7]Indirect utility function can be interpreted as welfare because it gives the consumer's maximal attainable utility when faced with a specific price and income.

By differentiating D_{ij} with respect to X_{ij}, MWTP is given by:

$$
\begin{aligned}
MWTP_{Z_1} &= -(\partial D/\partial X_1)/(\partial D/\partial X_5) = -\beta_1/\beta_5 \\
MWTP_{Z_2} &= -(\partial D/\partial X_2)/(\partial D/\partial X_5) = -\beta_2/\beta_5 \\
MWTP_{Z_3} &= -(\partial D/\partial X_3)/(\partial D/\partial X_5^{)} = -\beta_3/\beta_5 \\
MWTP_{Z_4} &= -(\partial D/\partial X_3)/(\partial D/\partial X_5) = -\beta_4/\beta_5
\end{aligned}
\tag{7}
$$

The β's are the estimated coefficients of each attribute, and the combinations in Equation (7) represent the trade-off between the price and each attribute. They can also be interpreted as the marginal rate of substitution between them.

V. Results

Socio-demographics of the sample

We report the socio-demographics of the sample in Table 3 and compare them to those of the general population. The numbers of male and female respondents are similar. Although the sample proportion of people in their twenties is smaller than the proportion in the population as a whole, the proportions of the other age groups in the sample are not different from the respective proportions in the whole population. High school graduates and college graduates form more than 80% of the sample, and the percentage is the same in the whole population. The average monthly household income of the sample is KRW 3.80 million, which is similar to that of the whole population, KRW 3.84 million. The number of household members in the sample is 3.49 on average, which is a little bigger than that in the whole population, but not very different. Generally, the sample represents the population well, which supports the extension of the estimation results from the sample to the whole population.

Estimation results of the model

To identify the effects of the socio-demographic variable in the model, we added them to the status quo equation in Equation (5).[8] Before showing the table of the estimation results, the descriptive statistics of the socio-demographic variables and definition and statistics of the alternative specific constant are presented in Tables 4 and 5. The average age is 45.14, the proportion of male respondents is 0.51, the respondents spent 13.32 years on education on average, the average income is 3.80 million Korean won. In addition, almost all the respondents know the KMA.

We introduce ASCs to capture the average effect on utility of unobserved factors in the model. There are three rooms to insert ASC; if we have three ASCs we have a problem to interpret it. To prevent this,

Table 3. Socio-demographics of the sample and population.

		Sample	Population[a]
Gender (%)	Male	50.9	50.3
	Female	49.1	49.7
Age (%)	20~24	1.0	9.7
	25~29	3.9	11.3
	30~34	7.7	11.8
	35~39	15.7	13.1
	40~44	18.6	13.2
	45~49	20.5	13.0
	50~54	15.7	12.1
	55~59	9.8	8.8
	60~64	7.1	7.0
Final education level (%)	No education	0.1	0.8
	Elementary school	1.9	6.0
	Middle school	6.6	8.5
	High school	46.7	35.6
	College	41.7	44.3
	Graduate school	3.0	4.8
Monthly average household income (million Korean won)		3.80	3.84
Average household size (number of household members)		3.49	3.28

[a]Monthly household income comes from the Household Income and Expenditure Survey of the Korean Statistical Information Service (www.kosis.kr) and the other statistics come from the Population Census 2010 of the Korean Statistical Information Service (www.kosis.kr).

[8]Note that the socio-demographic variables were embodied only in the status quo equation.

Table 4. Descriptive statistics of the socio-demographic variables in the model.

Variables	Descriptions	Mean	Standard deviation
Age	The respondent's age	45.14	9.18
Gender	The respondent's gender (0 = female; 1 = male)	0.51	0.50
Education	The final education level of the respondent in years (0 = no education to 20 = post graduate)	13.32	2.53
Knowledge	Dummy for the respondent's being aware of the existence of the Korea Meteorological Administration before the survey (0 = no; 1 = yes)	0.99	0.10
Income	Total monthly household income before tax deduction (Unit: 10,000 Korean won)	379.75	215.35

Table 5. Definition and statistics of the alternative specific constant.

Variables	Definition	Sum	Mean	Standard deviation
ASC_A	Constant specific to alternative A (1 = when alternative A is chosen, 0 = otherwise)	706	0.18	0.38
ASC_B	Constant specific to alternative B (1 = when alternative B is chosen, 0 = otherwise)	287	0.07	0.26

normally at most $(n-1)$ ASCs can be entered when J alternatives are presented. In this article, we included two ASCs in the model. Only status quo alternative do not have ASC, which means reference to other alternatives. The respondents who choose alternative A are 706 of 3893 and alternative B are 287 of 3893 (refer to Table 5).

Table 6 presents the model estimation results. All the coefficient estimates are statistically significant at the 1% level. Four of the attributes (but not price) have positive coefficient estimates, indicating that the frequency and accuracy of both short- and medium-range forecasts are valuable for the respondents. Therefore, people are more likely to agree to pay a certain bid amount if this would produce a more accurate or more frequently updated weather forecasting system.

The last column of Table 6 is the result from the MNL model with socio-demographic variables. The estimates of four attributes are much similar, even their t-values. The sign of ASCs are different from the results with and without covariates. The coefficient estimates for three variables such as Age, Education, and Gender are not statistically significant; their effects are not different from zero. Knowledge and Income have a negative effect on utility function. This means that if the other conditions are the same, people who know the KMA prefer the current state rather than the alternative (improved one with additional payment), and they have less utilities than those who do not know. This is because people with complaints or distrust of the KMA will know, of course, its existence and they will also prefer to current state.

Unlike the signs of the other attributes, the sign of the price coefficient is negative and statistically significant: the probability that a respondent would select the choice with a higher price decreases as the price increases. This is explained by the fact that the weather forecast service is a non-marketable good that is a kind

Table 6. Estimation results of the multinomial logit model.

Variables[a]	Model without covariates	Model with covariates
ASC_A	2.2693** (19.21)	−3.5732** (−4.89)
ASC_B	0.6408** (7.37)	−4.2135** (−5.79)
Frequency_short	0.2790** (6.79)	0.2782** (6.77)
Accuracy_short	0.0605** (3.19)	0.0603** (3.16)
Frequency_medium	0.1936** (6.85)	0.1942** (6.86)
Accuracy_medium	0.0452** (4.60)	0.0454** (4.61)
Price	−0.0005** (−8.36)	−0.0005** (−8.41)
Age		−0.0010 (−0.21)
Education		−0.0080 (−0.45)
Male		−0.1258 (−1.64)
Knowledge		−1.516* (−2.50)
Income		−0.0093** (−1.20)
Number of observations	3893	3893
Wald-statistic (p-value)	2171.29** (0.04)	2151.18** (0.00)
Log-likelihood	−2716.61	2708.98

[a]The variables are defined in Tables 1, 4, and 5. *, ** indicate statistical significance at the 5%, 1% level, respectively.

Table 7. Estimates of the marginal willingness to pay (MWTP) and the confidence intervals for the model.[a]

Attributes	MWTP[b,*]	t-Values[c]	95% confidence intervals
One more update for frequency_short	KRW 499.3 (USD 0.45)	5.32	KRW 337.2 to −708.5 (USD 0.30 to −0.63)
Increasing accuracy_short by 1%	KRW 108.3 (USD 0.10)	2.90	KRW 41.7 to −193.7 (USD 0.04 to −0.17)
One more update for frequency_medium	KRW 346.5 (USD 0.31)	5.32	KRW 231.3 to −495.1 (USD 0.21 to −0.44)
Increasing accuracy_medium by 1%	KRW 80.9 (USD 0.07)	4.49	KRW 54.9 to −121.3 (USD 0.05 to −0.11)

[a]The MWTPs were calculated using Equation (7). [b]The unit is Korean won per month. USD 1.0 was approximately equal to 1118 Korean won from the average of the exchange rates in September 2011. Refer to Korea Exchange Bank website (fx.keb.co.kr/FER1101C.web). [c]The *t*-values are computed by the use of the delta method. *Indicates statistical significance at the 1% level.

of commodity that follows the law of demand. It is natural that a higher payment lowers the utility, which implies that the survey was reasonably implemented.

MWTP estimates for each attribute

The increases in marginal benefits from choosing the preferred level of attributes are shown in Table 7. The MWTP for each attribute of the improved weather forecasts was calculated on the basis of Equation (7).[9] For example, one more update for short-range forecasting can be calculated from the equation −0.279/(−0.0005) by hand regardless of its standard error (refer to Equation (7)). The value of MWTP for short-range forecasting frequency becomes KRW 558 which lies in the 95% confidence intervals.

The monthly MWTP for an increase in the short-range forecasting frequency is KRW 499.3 (USD 0.45). Its *t*-value was computed as 5.32, indicating that this MWTP is not zero within a 99% significance level. The monthly MWTP for improving the accuracy of the short-term forecasts was computed as KRW 108.3 (USD 0.10). Similarly, the MWTPs for medium-range forecasting frequency and accuracy are KRW 346.5 (USD 0.31) and KRW 80.9 (USD 0.07), respectively. The MWTPs for these three attributes are significant at the 1% level.

The importance of the four attributes can be inferred from a comparison of their MWTPs. The MWTP result does not of itself reveal the importance level, but instead indicates the increase in value provided by the improvement to the weather forecast service. Arranging these values in ascending order reveals their relative importance. People believed that a fast update interval is more useful than greater accuracy, because the MWTPs for increasing the frequencies of short- and medium-range forecasts were much higher than those for increasing the accuracy. Furthermore, the two MWTPs for the short-range weather forecast lie above the two values for the medium-range weather forecast, suggesting that short-range term forecasting is more important than medium-range forecasting. This is because information about the near future has a stronger influence on people's daily lives than information that looks further into the future.

We report the confidence intervals for the MWTP of each attribute, rather than its point estimates only, in order to allow for the uncertainty involved in the MWTP estimates (Park, Loomis, and Creel 1991) and to lessen the risk of errors; point estimates have a high error risk. Since a report on interval information reduces the probability of an incorrect prediction, it is more reliable and beneficial for use in a development policy for the weather forecast service. In this article, we used the Monte Carlo simulation method (Krinsky and Robb 1986) to obtain 95% confidence intervals for the MWTPs. The MWTPs for the four attributes and their 95% confidence intervals are shown in Table 7.

Scenarios of improved weather forecasts

Policy implications can be drawn from various scenarios for improved weather forecasts that are combinations of these attributes. In addition, the benefits of the scenarios were calculated by using the estimated MWTPs of the attributes. This application uses the power of the CE method to overcome the

[9]The coefficients presented in Table 7 mean the average effects of attributes to indirect utility function. In addition, the indirect utility function, I_{ij}, includes the various type of choice card and its answer.

Table 8. Scenarios of weather forecast investment.

Attributes	Scenario A	Scenario B	Scenario C
Frequency_short	Every hour	Every hour	Every 2 h
Accuracy_short	92%	95%	95%
Frequency_medium	Four times a day	Twice a day	Twice a day
Accuracy_medium	75%	70%	73%
Monthly WTP per household	KRW 10,054 (USD 9.03)	KRW 9281 (USD 8.36)	KRW 3532 (USD 3.17)
Yearly WTP per household	KRW 120,647 (USD 108.36)	KRW 111,376 (USD 100.32)	KRW 42,389 (USD 38.04)
Aggregate value per year	KRW 2134 billion (USD 1917 million)	KRW 1970 billion (USD 1774 million)	KRW 750 billion (USD 673 million)
95% confidence intervals	KRW 1,427 to −3,061 billion (USD 1,276 to −2,725 million)	KRW 1,297 to −2,845 billion (USD 1,159 to −2,530 million)	KRW 473 to −1,118 billion (USD 427 to −995 million)

USD 1.0 is approximately equal to 1118 Korean won, which was the average of the exchange rates in September 2011. Refer to Korea Exchange Bank website (fx.keb.co.kr/FER1101C.web).

changeability of policy planning. We were able to compute the WTP for the proposed scenarios and rank these WTPs, and thus prioritize the scenario with the highest WTP. This ranking helps to evaluate the benefits of each potential scenario, even though it contains preliminary information. This study considers three scenarios for improved weather forecasts. The specification of the scenarios and the resulting benefits are indicated in Table 8.

The detailed calculation process is as follows. For scenario A, the monthly benefit of improving the update frequency from every 3 h (8 times per day) to every 1 h (24 times per day) is KRW 7988.8 (USD 7.2), that is, 16 times KRW 499.3 (USD 0.45), which is the MWTP for a higher update frequency for the short-range forecast. The monthly benefit of enhancing the accuracy of the short-range forecast by 2 percentage points is KRW 216.6 (USD 0.2), i.e. two times KRW 108.3 (USD 0.1). The monthly benefits of enhancing the update frequency and accuracy of the medium-range forecasts are calculated in the same way.

Other things being equal, a household's monthly WTPs for Scenarios A, B, and C are KRW 10,054 (USD 9.03), KRW 9281 (USD 8.36), and KRW 3532 (USD 3.17), respectively. A household's annual WTPs for improved weather forecast services are about KRW 120,647 (USD 108.36), KRW 111,376 (USD 100.32), and KRW 42,389 (USD 38.04), respectively. The total values for each scenario are obtained from a simple computation. Calculating the aggregate value for a certain scenario is helpful in predicting the resulting public benefits. Measuring and comparing the aggregate value of the various scenarios is useful in choosing between many scenarios.

The annual WTP for all households in Korea was calculated by multiplying the annual WTP by the 17,687,001 Korean households in 2011 (according to the Korean Statistical Information Service: www.kosis.kr). The last row of Table 7 shows the total WTP for each scenario. For Scenario A, the total WTP for enhancing certain attributes of the weather forecast service to certain levels is KRW 2134 billion (USD 1917 million). In this scenario, the short-range forecast is updated every hour (24 times in a day) to give 92% accuracy and the medium-range forecast is updated four times a day to give 75% accuracy. Similarly, we measured the value of Scenarios B and C. The value for Scenario B is KRW 1970 billion (USD 1774 million), which would mean updating the short-range forecast every hour to give 95% accuracy and updating the medium-range forecast twice a day to give 70% accuracy. Scenario C was valued at KRW 750 billion (USD 673 million), and would mean updating the short-range forecast every 2 h to give 95% accuracy and updating the medium-range forecast twice a day to give 73% accuracy.

Next, these scenarios were assessed. Scenario A had the highest value, followed by Scenarios B and C in order. Hence, Scenario A would be recommended under the assumption that it would cost the same to improve the weather forecast service in each scenario. Scenario analysis is excellent for determining investment efficiency. Moreover, the scenarios are customizable and flexible, so this analysis is easily applied to the evaluation of improvements to the weather forecast service.

VI. Concluding remarks

In daily life, many personal decisions are related to the weather. People choose their clothes, and increase or decrease their consumption of weather-sensitive goods like ice-cream and air conditioners, according to the weather. Industrial decisions of the energy markets and aviation companies are also affected by the weather. Inaccurate or outdated weather information causes unpleasant situations such as being caught without an umbrella in the rain. People want high quality weather forecasts to reduce such risks. Better-informed decisions not only reduce the risk but also increase opportunities (Frei 2009). More accurate weather forecast services and more frequent forecast updates allow people to make better decisions.

Although any investment in improving a weather forecasting system will increase its accuracy, such an investment will require public funding and hence increase taxes. The merits of investment are relevant to the incremental benefits obtained from the investment in improving the accuracy and update frequency of the weather forecast services. The incremental benefits from each attribute of the weather forecasting system are used to assess the benefits from investments in improving these attributes. Therefore, an evaluation of the economic benefit obtained by enhancing the weather forecasting system versus its cost would be useful information for such public investment.

The monthly MWTPs for one more short-range forecast update every day and a 1% improvement in the accuracy of the forecast were estimated at KRW 499.3 (USD 0.45) and KRW 108.3 (USD 0.10), respectively. Similarly, the monthly MWTPs for an additional medium-range forecast update every day and a 1% increment in the accuracy of the forecast were estimated at KRW 346.5 (USD 0.31) and KRW 80.9 (USD 0.07), respectively. These results imply that the two attributes of short-range forecasts were valued more highly than those of medium-range forecasts. The expected total benefit of the scenarios for a weather forecasting system that provided short-range forecasts every hour with 95% accuracy and medium-range forecasts twice a day with 70% accuracy was approximately KRW 1.97 trillion (USD 1.77 billion).

This study aimed to provide quantitative information on weather forecast investment in Korea to assist policy-makers in determining the most effective investment level for improving the weather forecast service. To this end, CE and the MNL model were applied. In detail, the marginal value of improving each attribute of the Korean weather forecasting system was estimated, and the economic value of potential scenarios was calculated. In the CE procedure, the survey elicited the value of improvements to the weather forecasts. Most respondents' choices were made consistently and rationally, and the MWTP estimates of the four attributes were statistically positive.

This article would encourage further research on weather forecasting service and its improvement. Until now, there is not much information about weather forecasting service and its improvement in Korea. Many government officers and many persons concerned can make use of these results to make a government budget plan and design the weather forecast service because the findings can tell where to go. It is expected that related research will increase in line with the demand for meteorological service research.

Our findings can be used in policy-making decisions. When deciding the policy to be followed to improve the weather forecast service, the benefits estimated herein can be used for further cost–benefit analysis. Moreover, our study results suggest that the public is willing to shoulder additional taxes to improve the weather forecasting system. These results can be used as baseline data for the financial cost of the improvement. Our results present a preliminary indication of the benefits of such weather forecast service policies.

The weather forecast service in Korea has continuously been developed: the update interval of the medium-range forecast was reduced from 24 to 12 h in 2012, and its forecasting period was extended to 10 days in October 2013 so that medium-range forecasts now cover three more days; the short-range weather forecast period was extended to three days in April 2014, when previously only one-day forecasts had been provided. The present study results could be applied to evaluate these changes or improvements in the weather forecasting system and to assess the benefits arising from the current high-quality weather information. Our conclusion could be used to justify these improvements and to set the proper direction for the further development of the weather forecast service in terms of public welfare.

Disclosure statement

No potential conflict of interest was reported by the authors.

ORCID

Sun-Young Park http://orcid.org/0000-0002-4950-0909
Seung-Hoon Yoo http://orcid.org/0000-0001-5048-219X

References

Adamowicz, W., J. Louviere, and M. Williams. 1994. "Combining Revealed and Stated Preference Methods for Valuing Environmental Amenities." *Journal of Environmental Economics and Management* 26 (3): 271–292.

Anaman, K. A., and S. C. Lellyett. 1996. "Contingent Valuation Study of the Public Weather Service in the Sydney Metropolitan Area." *Economic Papers: A Journal of Applied Economics and Policy* 15 (3): 64–77.

Baarsma, B. E. 2003. "The Valuation of the Ijmeer Nature Reserve Using Conjoint Analysis." *Environmental and Resource Economics* 25 (3): 343–356.

Banfi, S., M. Filippini, and A. Horehájová. 2012. "Using a Choice Experiment to Estimate the Benefits of a Reduction of Externalities in Urban Areas with Special Focus on Electrosmog." *Applied Economics* 44 (3): 387–397.

Cameron, A. C., and P. K. Trivedi. 2005. *Microeconometrics: Methodsand Applications*. New York: Cambridge University Press.

Carson, R. T. 2011. *Contingent Valuation: A Comprehensive Bibliography and History*. Cheltenham: Edward Elgar Publishing.

Considine, T. J., C. Jablonowski, B. Posner, and C. H. Bishop. 2004. "The Value of Hurricane Forecasts to Oil and Gas Producers in the Gulf of Mexico." *Journal of Applied Meteorology* 43 (9): 1270–1281.

Cuccia, T., and R. Cellini. 2007. "Is Cultural Heritage Really Important for Tourists? A Contingent Rating Study." *Applied Economics* 39 (2): 261–271.

Emanuel, K., F. Fondriest, and J. Kossin. 2012. "Potential Economic Value of Seasonal Hurricane Forecasts." *Weather, Climate, and Society* 4 (2): 110–117.

Frei, T. 2009. "Economic and Social Benefits of Meteorology and Climatology in Switzerland." *Meteorological Applications* 17 (1): 39–44.

Garrod, G. D., and K. G. Willis. 1997. "The Non-Use Benefits of Enhancing Forest Biodiversity: A Contingent Ranking Study." *Ecological Economics* 21 (1): 45–61.

Hanley, N., R. E. Wright, and V. Adamowicz. 1998. "Using Choice Experiments to Value the Environment." *Environmental and Resource Economics* 11 (3/4): 413–428.

Ida, T. 2012. "Beyond Mobile Number Portability: Measuring Consumer Preferences for Service Portability in Japan's Mobile Phone Market." *Applied Economics* 44 (26): 3357–3369.

Ida, T., S. Kinoshita, and M. Sato. 2008. "Conjoint Analysis of Demand for IP Telephony: The Case of Japan." *Applied Economics* 40 (10): 1279–1287.

Johnson, F. R., and W. H. Desvousges. 1997. "Estimating Stated Preferences with Rated-Pair Data: Environmental, Health, and Employment Effects of Energy Programs." *Journal of Environmental Economics and Management* 34 (1): 79–99.

Keith, R., and S. M. Leyton. 2007. "An Experiment to Measure the Value of Statistical Probability Forecasts for Airports." *Weather and Forecasting* 22 (4): 928–935.

Korea Meteorological Administration. 2012. *The Second Half of 2012, National Meteorological Service Satisfaction Survey*. Seoul: Korea.

Krinsky, I., and A. Robb. 1986. "On Approximating the Statistical Properties of Elasticities." *The Review of Economics and Statistics* 68: 715–719.

Lazo, J. K., and L. G. Chestnut. 2002. *Economic Value of Current and Improved Weather Forecasts in the US Household Sector*. US Department of Commerce, National Oceanic and Atmospheric Administration, Office of Program Planning and Integration. Boulder: Stratus Consulting. http://www.wmo.int/pages/prog/amp/pwsp/documents/STORM_Report.pdf.

Lazo, J. K., D. M. Waldman, B. H. Morrow, and J. A. Thacher. 2010. "Household Evacuation Decision Making and the Benefits of Improved Hurricane Forecasting: Developing a Framework for Assessment." *Weather and Forecasting* 25: 207–219.

Lee, J.-W., J. Jang, K.-K. Ko, and Y. Cho. 2014. "Economic Valuation of a New Meteorological Information Service: Conjoint Analysis for a Pollen Forecast System." *Weather, Climate, and Society* 6 (4): 495–505.

Lee, K.-K., and J.-W. Lee. 2007. "The Economic Value of Weather Forecasts for Decision-Making Problems in the Profit/Loss Situation." *Meteorological Applications* 14 (4): 455–463.

Madden, G., and M. Simpson. 1997. "Residential Broadband Subscription Demand: An Econometric Analysis of Australian Choice Experiment Data." *Applied Economics* 29 (8): 1073–1078.

McFadden, D. 1973. "Conditional Logit Analysis of Qualitative Choice Behavior." In *Frontiers in Econometrics*, edited by P. Zarembka, 105–142. New York: Academic Press.

Merino-Castello, A. 2003. "Eliciting Consumers' Preferences Using Stated Preference Discrete-Choice Models: Contingent Ranking versus Choice Experiment." University Pompeu Fabra Economics and Business Working Paper No. 705. http://www.econ.upf.edu/docs/papers/downloads/705.pdf.

NASA Langley Research Center. 2013. *More Extreme Weather Events Forecast*. Hampton: NASA Langley Research Center. http://www.nasa.gov/centers/langley/science/climate_assessment_2012.html.

Nguyen, T. C., and J. Robinson. 2015. "Analysing Motives behind Willingness to Pay for Improving Early Warning Services for Tropical Cyclones in Vietnam." *Meteorological Applications* 22 (2): 187–197.

Nurmi, P., A. Perrels, and V. Nurmi. 2013. “Expected Impacts and Value of Improvements in Weather Forecasting on the Road Transport Sector.” *Meteorological Applications* 20 (2): 217–223.

Park, T., J. B. Loomis, and M. Creel. 1991. “Confidence Intervals for Evaluating Benefits Estimates from Dichotomous Choice Contingent Valuation Studies.” *Land Economics* 67 (1): 64–73.

Phelps, R. H., and J. Shanteau. 1978. “Livestock Judges: How Much Information Can an Expert Use?” *Organizational Behavior and Human Performance* 21 (2): 209–219.

Predicatori, F., F. Giacomazzi, P. Frontero, and M. Bellodi. 2008. “Agriculture and Climate Change: An Evaluation of the Willingness to Pay for Improved Weather Forecasts.” Foralps Technical Report 12. Trento: UniversitàdegliStudi di Trento, Dipartimento di IngegneriaCivile e Ambientale. http://www.ing.unitn.it/dica/tools/download/Quaderni/Foralps_TR_12.pdf.

Rollins, K. S., and J. Shaykewich. 2003. “Using Willingness-To-Pay to Assess the Economic Value of Weather Forecasts for Multiple Commercial Sectors.” *Meteorological Applications* 10 (1): 31–38.

SPSS. 2005. *SPSS Conjoint 14.0*. Chicago: SPSS.

Tarfasa, S., and R. Brouwer. 2013. “Estimation of the Public Benefits of Urban Water Supply Improvements in Ethiopia: A Choice Experiment.” *Applied Economics* 45 (9): 1099–1108.

Teisberg, T., R. F. Weiher, and A. Khotanzad. 2005. “The Economic Value of Temperature Forecasts in Electricity Generation.” *Bulletin of the American Meteorological Society* 86 (12): 1765–1771.

Von Gruenigen, S., S. Willemse, and S. T. Frei. 2014. “Economic Value of Meteorological Services to Switzerland’s Airlines: The Case of TAF at Zurich Airport.” *Weather, Climate, and Society* 6 (2): 264–272.

World Economic Forum. 2014. *Outlook on the Global Agenda 2015*. Geneva: World Economic Forum. http://reports.weforum.org/outlook-global-agenda-2015/wp-content/blogs.dir/59/mp/files/pages/files/outlook-2015-a4-downloadable.pdf.

Yoo, S.-H., S.-J. Kwak, and J.-S. Lee. 2008. “Using a Choice Experiment to Measure the Environmental Costs of Air Pollution Impacts in Seoul.” *Journal of Environmental Management* 86 (1): 308–318.