Economic Evaluation for Meteorological Information Services: the 2018 Survey for Farmers in Taiwan

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Abstract

The meteorological information services in Taiwan are provided by Central Weather Bureau (CWB), the Ministry of Transportation and Communications (MOTC). CWB provides various weather forecasts in Taiwan, and most of those information services are free for the general public with accuracy and efficiency through many communication sources. This study use contingent valuation method (CVM) to estimate the economic values of meteorological information services in Taiwan for agricultural farmers. With the assistance of Directorate General of Budget, Accounting and Statistics (DGBAS), we have conducted a national face-to-face survey for 1,150 registered farmers in 235 municipals in Taiwan. The data consists of seven major agriculture production growers (including rice, coarse grain, special crops, ornamental plants, vegetables, mushrooms, and fruits). In addition to protest responses and the incomplete observations, the response rate is 72%, 830 out of 1,150. We have found that the independent variables which are statistically significant for agricultural producers' WTP include Respondent's subjective score for the weather forecast accuracy, education, farm size, annual income, dummy variable for mushroom farmers, and first bid price. Based on our empirical testing analysis, the average adjusted WTP for every agricultural household each year with a 95% confidence interval is 3,774 NT dollars. The preliminary inferred annual economic values for CWB's meteorological information services for agricultural farmers in Taiwan are between 360 million NT dollars and 587 million NT dollars. From those latest results from field survey, it suggests that if CWB can improve 1% of farmers' subjective perception for the weather forecast accuracy, those involved actions or policies can increase 230 NT dollars of respondent's annual WTP, which implies a 6% increase of farmer's WTP. In addition, we have found that the top three potential economic benefits for improved weather information services in the agriculture category can be created in the group of fruits, vegetables, and rice farmers.

Keywords: Meteorological Information Services, Agricultural Farmers, Economic Valuation, Willingness to Pay, Contingent Valuation Method

1. Introduction

The meteorological information services in Taiwan are provided by Central Weather Bureau (CWB), the Ministry of Transportation and Communications (MOTC). CWB provides various weather forecasts in Taiwan, and most of those information services are free for the general public with accuracy and efficiency through many communication sources. In addition, the Taiwan government currently requires public agencies and institutions to collect the information of costs and benefits for the services and investments provided by the public sector in order to allocate government budgets in a more efficient way. Thus, it is necessary to investigate the economic value of meteorological information services and establish a model that can monetize and quantify the benefits created by meteorological information services.

The World Meteorology Organization (WMO) has suggested four priority areas for global concerns in its Global Framework for Climate Services (GFCS), including agriculture and food security, disaster risk reduction, health, and water (WMO, 2012). There is a saying in Taiwan that what farmers can harvest and eat totally depends on the weather challenges they encounter. Needless to say, weather conditions are vital to agriculture, and most agricultural productions are exposed to the natural environment without any in-door protection facilities. Applying the contingent valuation method (CVM) in this study, we conduct a national survey in Taiwan to measure agricultural producers' willingness to pay (WTP), which is the value of a good to someone what that person is willing to pay for it, for meteorological information services for the purpose of estimating the economic value of meteorological information services for agricultural producers in Taiwan.

2. Methodology: Contingent Valuation Method

In general, there are three ways to investigate the benefits or the value of meteorological information services, which include prescriptive decision-making model, descriptive behavioral response model, and CVM. This study chooses CVM as a method with first-hand data derived by conducting a survey and the application of the estimation of statistical or econometric models.

In Taiwan, meteorological information services are viewed as public goods; however, they are not normal tradable goods in the market. They can be categorized as non-market goods in the field of environmental economics. The total value yielded by meteorological information services come from two major sources: the use value (e.g. the value from people using the information to enhance agricultural production), and the non-use value (e.g. the value stemming from people's desire that those services exist). Theoretically, when we begin to evaluate the economic value of such types of goods, the aggregate price that people are willing to pay for those services can be measured as their economic value. Applying CVM can estimate the value of both use value and non-use value at the same time, there are several successful CVM case studies on the valuation of weather information (Kenkel and Norris, 1995; Rollins and Shaykewich, 2003; Drake and Eriksson, 1997; Weiher et al., 2002). Thus, CVM is the method we choose for this evaluation study on the meteorological information services for agricultural producers.

2.1 Setting up a hypothetical market

In the CVM hypothetical scenario, we ask the respondents to answer their value or WTP for a non-market good by utilizing CVM. In real life, the respondents do not have the experience of buying or trading this type of good in the market. Investigators need to construct a hypothetical market for the good and ask the valuation question of respondents' willingness to pay. The good in this study is identified as meteorological information services provided by the CWB in Taiwan. We use survey questions to construct a hypothetical market for those services, so the respondents could perceive the hypothetical market when they are interviewed.

For the purpose of having respondents successfully develop a perception of the hypothetical market, we use three surveying steps. First, we focus on the "forecast accuracy" issue of the meteorological information services accessed in their everyday life, and ask the respondents their rating scores on the subjective accuracy of weather forecasts. Second, we ask respondents how they apply weather information in their agricultural production activities. Finally, we ask them to answer their monthly WTPs in their minds for the meteorological information services provided by the CWB.

2.2 Sampling Design

The purpose of this study is to evaluate how agricultural producers perceive the economic value of using meteorological information services in Taiwan by CVM. Therefore, we select farmers those who produce seven major agricultural products (including rice, coarse grains, special crops, ornamental plants, vegetables, mushrooms, and fruits) in the 2015 National Agricultural Census in Taiwan as our major research population. With the assistance of the Directorate General of Budget, Accounting and Statistics (DGBAS), DGBAS randomly gives a sample of 1,068 registered agricultural households with another 5,340 replacement samples in case our investigators could not locate the sampled farmers or the selected respondents refuse to take the survey.

With Neyman allocation sampling method, we use farm size as a criterion for categorize each agricultural product type to determine the size of the subsample in each selected type of farmer candidates. The final allocation of our successful 1,150 door-to-door surveys is illustrated in Table 1 and Figure 1.

Table1. Door-to-Door Survey Sample Allocation

Region	Counties/Cities	Sample Size
North	Yilan County	18
	Taipei City	3
	New Taipei City	15
	Taoyuan City	17
	Hsinchu City	1
	Hsinchu County	14
Central	Miaoli County	27
	Taichung City	101
	Nantou County	98
	Changhua County	144
	Yunlin County	189
South	Chiayi City	3
	Chiayi County	111
	Tainan City	110
	Kaohsiung City	113
	Pingtung County	145
East	Taitung County	27
	Hualien County	14
Total		1,150

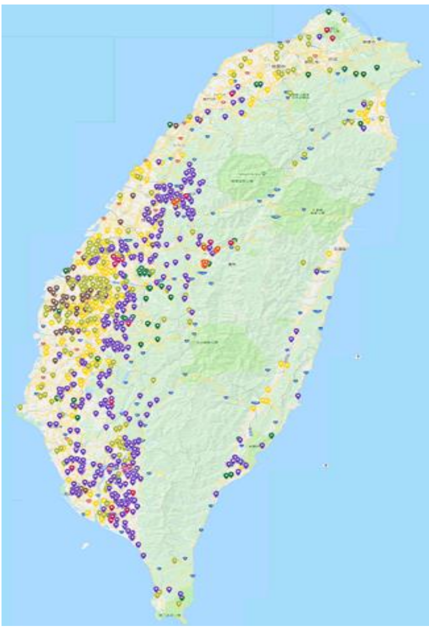

Figure 1. Geographic Allocation of the Survey

2.3 Valuation Question

To increase the response rate, we adopt the dichotomous choice model with an open-ended question for WTP valuation. Respondents are given the first bid as the "bid_1" shown in Figure2. They need to consider whether his/her real value is higher than the value of the first bid, and answer Yes or No. Then, this process is repeated. Respondents who answered "Yes" are given a new value (bid_2) which is higher than the first bid, while those who answer "No" are given a new value (bid_3) which is lower than the first bid. After finishing the second stage, the investigators ask the respondent what value is the maximum WTP for him or her.

The advantage of using this method is to offer a bargaining process, as we usually buy a normal commodity with a market price in a traditional market. For those who may not have a certain amount of value in mind, they would be able to figure out the economic value of meteorological information services they might expect in the end of their interviews. In other words, this valuation question design makes the bidding process easier, and it is more convenient for both respondents and investigators to understand the valuation question.

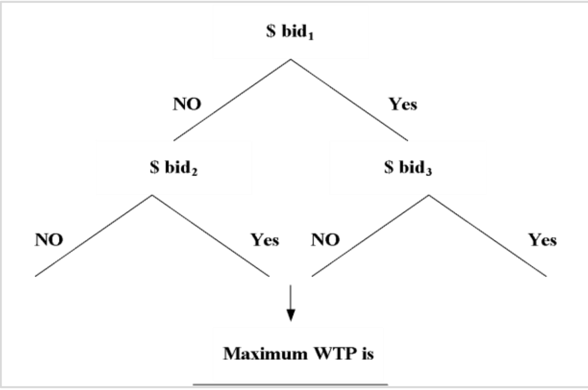

Figure 2. Dichotomous Choice Model with an Open-ended Elicitation Method

3. Descriptive Statistics of Survey Data and Empirical Model

The survey was pre-tested extensively by trained interviewers. From our previous research experience, we find that questions in the survey needed to be clarified further, and the language skills of interviewers are in great need of improving mutual understanding between the interviewers and respondents. Interviews with 1,150 respondents as shown in Table 2 were completed door-to-door by the trained interviewers in each selected agricultural household in 2018. In the 148 cases of the total interviews, respondents gave a zero for their WTP and refused to pay any amount of money even though they perceived meteorological information services provided by the CWB as valuable for their agricultural activities. Moreover, they believed that meteorological information services are supposed to be provided free by the public sector. In 163 interviews, respondents were not very certain about their perceived value of the meteorological information services. Therefore, 830 interviews were identified as the successful sample and were used to estimate WTP in this study.

3.1 Descriptive Statistics of Survey Data

Table 3 shows the average monthly WTP by using 830 valid responses in different categories. It is found that the top three groups giving higher value of WTP are fruit farmers, mushroom farmers, special crop farmers and vegetable farmers. The result implies that fruit farmers may have relatively high-value products and fruits are easily withered by bad weather. As a result, those farmers would be more sensitive to the weather conditions. Compared to other farmers, mushroom farmers in this study have expressed greater needs for meteorological information, and that may be the reason why they are willing to pay more than others.

In this study, we also find that respondents who are in the group of self-study and with junior high school degree tend to pay more than others. The result also indicates that farmers who had experiences of agricultural loss because of heavy rain and chilling injury are more likely to pay more, as shown in Table 3.

Based on our analysis presented in the previous content, we have generated a general look at how seven groups of farmers perceive the value of meteorological information. However, what the key factors influencing WTP value are still not clear. Besides, it is critical to have a second analysis to verify the result from the first analysis. Therefore, we have developed a valuation function model to serve as the second analyzing tool.

Table 2. Statistics of Total 1,150 interviews

Categories	Total	Rice	Coarse Grain	Special Crops	Vegetables	Fruits	Mushroom	Ornamental Plants
Sample	1,150	272	77	66	237	465	11	22
Percentage	100	24	7	6	21	40	1	2
Variable								
Gender (%)								
Male	74.00	74.63	72.73	84.85	69.62	74.41	72.73	77.27
Female	26.00	25.37	27.27	15.15	30.38	25.59	27.27	22.73
Region (%)								
North	5.91	6.99	0.00	13.64	10.97	2.37	0.00	13.64
Central	48.61	52.57	77.92	46.97	52.74	38.71	100.00	40.91
South	41.91	36.03	22.08	21.21	35.44	55.70	0.00	45.45
East	3.57	4.41	0.00	18.18	0.84	3.23	0.00	0.00
Average Age	61.82	65.81	64.30	58.70	59.87	61.11	49.73	54.95
Average Working years in Agriculture	35.76	42.37	37.94	33.65	33.08	24.00	24.00	26.18
Education (%)								
Illiterate	8.28	13.6	22.37	4.55	6.78	4.74	0.00	0.00
Self-study	0.61	1.10	1.32	0.00	0.85	0.00	0.00	4.55
Elementary	33.91	41.54	31.58	34.85	33.05	31.25	9.09	22.73
Junior High	19.62	17.28	17.11	15.15	25.00	19.18	18.18	22.73
Senior High Vocational	26.94	19.49	14.47	30.30	25.00	33.19	45.45	31.82
Junior College	6.19	3.68	7.89	10.61	4.66	7.11	9.09	13.64
University	3.92	2.94	5.26	4.55	4.24	3.88	9.09	4.55
Graduate school	0.52	0.37	0.00	0.00	0.42	0.65	9.09	0.00

Table 3. Average monthly WTP among different categories

Categories	Total	Rice	Coarse Grain	Special Crops	Vegetables	Fruits	Mushroom	Ornamental Plants
Sample	830	192	55	55	184	320	7	17
Percentage	100.0	23.0	7.0	7.0	22 .0	38.0	1.0	2.0
Average monthly WTP	385	277	201	375	379	488	441	320
Variable					`			
Age								
18-45 Years	318	312	267	265	345	354	250	199
46-64 Years	371	317	195	500	415	372	585	179
65 Years & over	419	242	192	235	337	692	0	750
Gender								
Male	403	271	246	407	401	526	488	191
Female	328	300	69	161	323	379	380	630
Location (%)								
North	370	284	0	425	433	361	0	333
Central	405	293	206	454	419	537	441	244
South	354	219	182	225	298	446	0	450
East	386	421	0	332	50	453	0	0
Education								
Illiterate	146	113	125	50	274	185	0	0
Self-study	650	150	0	0	300	0	0	2,000
Elementary	307	303	220	390	367	270	0	500
Junior High	619	354	138	308	416	1074	270	263
Senior High								
Vocational	369	296	256	379	474	364	600	154
Junior College	331	178	400	683	171	374	100	90
University	325	211	167	217	128	596	300	200
Graduate school	472	0	0	0	10	667	350	0
Agricultural Loss								
Typhoon	279	198	144	306	294	339	269	259
Chilling Injury	321	215	146	311	311	414	300	170
Drought Injury	285	197	143	365	301	345	332	247
Heavy Rain	331	204	146	332	254	452	598	175
Others	304	345	429	393	339	236	260	264

3.2. Empirical Model

A testing and calibration model developed by Herriges and Shogren (1996) is used to reduce the starting point bias error. They suggest there is an anchoring effect coefficient (γ_1), and $0 \leq \gamma_1 \leq 1$. The value at the second stage (WTP_i^2) consists of the first bid price and the respondents' real WTP value with the adjustment by the anchoring effect coefficient, as shown in Equation (1). If γ_1 is closer to 1, it reveals that the real WTP value of the respondents is closer to the first bid price, and the anchoring effect coefficient will have a greater influence on valuation estimation. Otherwise, if γ_1 is closer to zero, the values from the respondents' answers are very close to their true WTP values. Meanwhile, the effect of the anchoring effect coefficient on estimation is insignificant.

$$WTP_i^2 = (1-\gamma_1)WTP_i + \gamma_1 Bid_i^1 \quad (1)$$

With Equation (1), we can estimate γ_1. We can then use Equation (2) to adjust the average WTP value to the true WTP_i value.

$$WTP_i = (WTP_i^2 - \gamma_1 Bid_i^1)/(1-\gamma_1) \quad (2)$$

Besides, the correction model built in this study is based on the Tobit model due to the characteristics of our censored data. In terms of functional form of the WTP bid function, this study adopted the trial and error process, and finally selected the form with better explanatory power for empirical analysis. As a result, the empirical model of WTP bid function is expressed as in the Equation (3).

$$lnWTP_i = \beta_0 + \beta_1 * effect + \beta_2 * indegree + \beta_3 * insur + \beta_4 * sex + \beta_5 * age + \beta_6 * exp + \beta_7 * edu + \beta_8 * area + \beta_9 * lninc + \beta_{10} * lninc^2 + \beta_{11} * full + \beta_{12} * region2 + \beta_{13} * region3 + \beta_{14} * region4 + \beta_{15} * crop2 + \beta_{16} * crop3 + \beta_{17} * crop4 + \beta_{18} * crop5 + \beta_{19} * crop6 + \beta_{20} * crop7 + \beta_{21} * lnBid \quad (3)$$

The definition of each variable in equation (3) is illustrated in Table 4.

Table 4. Variable definition

Variables	Definition	Mean	S.D.
bid	First bid price.	357.36	317.01
effect	Respondent's subjective cognition for the effect of weather information on crop production	4.1581	0.9123
degree	Respondent's subjective score for the weather information satisfaction (0~100)	73.6761	14.5584
insur	Dummy variable for agriculture insurance purchase (yes=1; no=0)	0.0219	0.1465
sex	Dummy variable for gender (male=1; female=0)	0.7637	0.4251
age	Respondent's age	60.4194	12.2915
exp	Experience in agricultural activities (in years)	33.2183	19.5615
edu	Education indicators (Illiteracy=0; Self-study=3; Elementary=6; Junior High=9; Senior High=12; Junior College=14;University=16; Graduate school=18)	9.0923	3.8002
area	Plantation area (in hectares)	1.4432	3.5590
inc	Annual agricultural revenue (in 1,000 NTD)	1,309.65	2,977.48
full	Dummy variable for agriculture as the main source of income (yes=1; no=0)	0.8247	0.3805
region1	Dummy variable for northern region	0.0798	0.2712
region2	Dummy variable for central region	0.5712	0.4953
region3	Dummy variable for southern region	0.2973	0.4574
region4	Dummy variable for eastern region	0.0516	0.2215
crop1	Dummy variable for Rice farmers	0.2379	0.4261
crop2	Dummy variable for coarse grain farmers	0.0516	0.2215
crop3	Dummy variable for special crop farmers	0.0673	0.2507
crop4	Dummy variable for vegetable farmers	0.2081	0.4063
crop5	Dummy variable for fruit farmers	0.4053	0.4913
crop6	Dummy variable for edible mushroom farmers	0.0094	0.0965
crop7	Dummy variable for ornamental plant farmers	0.0203	0.1413

4. Empirical Results

The results generated by using the valuation function in Equation (3) are summarized in Table 5. We have found that the independent variables which are statistically significant for agricultural producers' WTP include respondent's subjective score for the weather forecast accuracy (degree), education (edu), farm size (area), annual income (inc), dummy variable for mushroom farmers (crop6), and first bid price (bid).

Table 5. Estimation Results of Empirical Model

Variables	Coefficients	S.D.	t-value
ln bid	0.8355***	0.035	23.79
effect	-0.0333	0.040	-0.84
ln degree	0.7397***	0.196	3.77
insur	-0.3589	0.253	-1.42
sex	-0.0383	0.085	-0.45
age	0.0066	0.004	1.56
exp	-0.0011	0.002	-0.43
edu	0.0408***	0.013	3.15
area	0.0312**	0.015	2.14
ln inc	0.3909*	0.215	1.82
ln inc^2	-0.0320*	0.016	-1.95
full	0.0841	0.098	0.86
region2	-0.0460	0.132	-0.35
region3	-0.1578	0.141	-1.12
region4	0.0324	0.200	0.16
crop2	-0.2109	0.172	-1.23
crop3	-0.0231	0.173	-0.13
crop4	-0.0214	0.110	-0.20
crop5	-0.0497	0.098	-0.51
crop6	0.6742*	0.389	1.73
crop7	0.3755	0.268	1.40
constant	-3.9577***	1.168	-3.39
Sample size: 639			
Pseudo-R^2=0.3842			
Notes: 1. *,**, and *** represent significance levels at 0.1, 0.05, and 0.01 respectively. 2. In terms of analyzing data of type of crops and geographical region, it is required to drop a variable as a reference type to avoid multicollinearity. In this study, we choose rice farmers and northern region as a reference type.			

There are seven statistically significant variables in our model. In terms of respondent's subjective score for the weather forecast accuracy (eg. ln degree), we find that its coefficient is 0.7397, implying that agricultural producers who are willing to give a higher score for the accuracy of weather forecasts are more likely to have a higher WTP value. Based on our preliminary estimates, it suggests that if CWB can improve 1% of farmers' subjective perception for the weather forecast accuracy, those involved actions or policies can increase 230 NT dollars of respondent's annual WTP, which implies a 6% increase of farmer's WTP.

Moreover, the coefficient estimates for "edu", "area", "ln inc", "ln inc2", and "crop6" are positive, meaning that agricultural producers who with higher education level, greater plantation area, higher income and those who are mushroom farmers will be more likely to have higher WTP.

In addition, "ln bid" is also a statistically significant variable, and the coefficient estimate is around 0.8355. This is consistent with what literature has suggested about the issue of starting point bias. This result also indicates that respondents will give their WTP value of weather information based on the given first bid price randomly in the survey. Because the respondents may not reveal their true WTP values when we ask them the WTP question, we need to use the function in Equation (4) to calibrate and make adjustment to the estimated value of WTP to reduce the effect of the starting point bias error.

$$\widehat{WTP}^{median} = exp^{\left[(\overline{lnWTP_l^2} - \widehat{\gamma_1} \overline{ln\ \ Bıd_l}\ ) / (1-\widehat{\gamma_1}) \right]} \tag{4}$$

Considering all these conditions, we use Equation (4) to estimate monthly WTP for each type of agricultural household. Based on the result from our valuation function model, the adjusted monthly WTP for every agricultural household is 314 NT dollars on median, and the annual WTP is 3,774 NT dollars on median.

We have tried to infer the aggregate values of meteorological information services for the seven selected agricultural household types in Taiwan by using the estimated WTP above, based on the number of households of agricultural producers in the national agricultural reports, and the sample of effective responses. The formula we use is described in Equation (5).

$$\text{TE} = \widehat{WTP}_i^{mdican} * N_i + \widehat{WTP}_j^{mdican} * N_j \tag{5}$$

where TE is total economic value of weather information per year; i is rice, coarse grains, special crops, ornamental plants, vegetables, and fruits; j is mushrooms; $\widehat{WTP}_i^{mdican}$ is the estimated median WTP per year of agricultural households producing rice, coarse grains, special crops, ornamental plants, vegetables, and fruits; $\widehat{WTP}_j^{mdican}$ is the estimated median WTP per year of agricultural households producing mushrooms; N_i is the total number of households producing rice, coarse grains, special crops, ornamental plants, vegetables, and fruits; N_j is the total number of households producing mushrooms.

The annual agricultural reports in 2015 have suggested that the total number of households for the seven types of agricultural producers is 155,735, including 29,097 households for rice farmers, 8,474 households for coarse grain farmers, 9,311 households for special crops farmers, 38,985 households for vegetable farmers, 65,865 households for fruit farmers, 3,063 households for ornamental plant farmers and 940 households for mushroom farmers. Assuming our selected sample can represent the whole population of agricultural producers in Taiwan, the preliminary inferred annual economic values for CWB's meteorological information services for agricultural farmers in Taiwan are between 360 million NT dollars and 587 million NT dollars. Moreover, we have found that the top three potential economic benefits for improved weather information services in the agriculture category can be created in the group are fruit farmers, vegetable farmers, and rice farmers.

5. Concluding Remarks

This study utilizes CVM methodology and conducts a national door-to-door survey. Based on our preliminary empirical analysis, the adjusted WTP for every agricultural household each year with a 95% confidence interval is 3,774 NT dollars. The inferred annual economic value of meteorological information services for agricultural producers in Taiwan is between 360 million NT dollars and 587 million NT dollars (eg. around 12~19 million US dollars).

This economic evaluation outcome can be discussed from two different perspectives: public sector and private sector. From the perspective of the public sector, how to improve the effectiveness of weather information and the communication with end users in the agricultural sector (i.e. farmers) will be the first priority. Nowadays, the CWB is the only government agency to issue all kinds of weather warnings for the country. This result not only can be used for conducting performance evaluation for relevant services provided by the CWB, but more importantly, can be used as a social benefit estimation reference for policymakers to decide public resource allocation including what government should invest or not.

Moreover, from the perspective of developing domestic weather information service industry. Actually, many different forms of weather information services have been developed to meet customer needs and are sold as commercial products. This result can serve as an evaluation of the size of the domestic weather information market from the farmer's perspective. More importantly, if the administrative agency is considering merchandizing weather information or building a business model to provide better services, then this result can serve as a reference for price-setting strategies.

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