Economic Assessment of Meteorological Information Services for Aquaculture: A Case Study in Taiwan

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Abstract

The main purpose of this study is to evaluate the economic value of the meteorological information service provided by the Central Meteorological Administration (CWB) for use in Taiwan's aquaculture fisheries. This study apply the contingent valuation method (CVM) to elicit the subjective evaluation of the meteorological information services provided by CWB by the fishery fisheries practitioners through the in-person survey. Based on the data collected by CVM, total economic value of the meteorological information service from the application of aquaculture fisheries was inferred. In order to clarify the main factors affecting the willingness-to-pay (WTP) of different respondents, this study applied the quantile regression model (QR model) to conduct an empirical evaluation of the bid function. According to the preliminary empirical results, the main factor affecting the WTP is the "subjective scoring of influence to production behavior" of the meteorological information services. When the respondents believe that the current meteorological information service provided by CWB has a higher positive effect on the decision-making of aquaculture production activities, the WTP will be higher for meteorological information services. Aside from that, by observing different bidding levels, the influence of the "subjective scoring of influence to production behavior" is different. The overall trend of influence of "subjective scoring of influence to production behavior" is to increase as the bidding level being higher. The median WTP estimated by the bid function is 753.4 NTD per month each household. As a result, the total economic value of meteorological information services applied to aquaculture fisheries is 285.38 million to 340.96 million NTD per year, accounting for 0.77%~0.93% of the total output value of the aquaculture fishery industry in 2017.

Keywords: climate information services, aquaculture fishery, economic value, contingent valuation method, quantile regression model

1. Introduction

Meteorological information services (MIS hereafter) is the basis of fisheries practitioners for operational planning and management, and to increase revenue or reduce losses. Therefore, MIS is also an important decision-making factor for fishery production management. However, the provision of MIS requires considerable infrastructure investment and is primarily supported by the budget of public sector. In order to improve the efficiency of budget usage, it is necessary to correctly measure the economic value of MIS for fishery applications.

According to the statistics announced by Fishery Agency, Council of Agriculture, Executive Yuan (2015), Taiwan's fishery production value is ranked according to the type of operation, with the highest production value of offshore fishery (about 43.6 billion NTD), accounting for 41.52% of the total fishery output; followed by inland aquaculture (about 36.8 billion NTD), accounting for 35.04% of the total fishery output value; the last is offshore fishery (about 14.3 billion NTD), accounting for 3.90% of the total fishery production value. In the inland aquaculture fishery, according to the classification of farmed fish, the grouper has the highest output value (about 8.3 billion NTD), accounting for about 22.59% of the inland aquaculture production value; followed by the milkfish (about 5.1 billion NTD), accounting for about 13.84% of the aquaculture fishery production; quahog ranks third (about 4.9 billion NTD), accounting for 13.44% of the value of inland aquaculture fishery; Tilapia fish is the fourth, with an output value of about 3.8 billion NTD, accounting for 10.29% of the output value of inland aquaculture fishery. Among these types of fisheries, the inland aquaculture industry has a high proportion of production value, and the MIS required are mainly provided by the Central Weather Bureau of Taiwan (CWB) due to the geographic consideration. Therefore, this study focuses on the total economic value evaluation of inland aquaculture.

In terms of evaluation methodology, most existing studies use the Contingent Valuation Method (CVM) to elicit the willingness to pay (WTP) for MIS through a hypothetical market, and as a basis for measuring economic value (Lee et al., 2014; Park et al., 2016; Anaman et al., 2017; Ouédraogo et al., 2018; Lin et al., 2019). Therefore, this study also adopts CVM, applying questionnaires to obtain empirical data as the basis for the estimation of the economic value of MIS applied to fisheries. In addition, in order to capture the influence of each factor on WTP bidding behavior, this study established a bid function for WTP and used a quantile regression model (QR model) for empirical evaluation. Using this model, it is possible to estimate the marginal effect of each factor of WTP under different WTP levels, and lead to more policy insights and implications (Koenker & Hallock, 2001; Koenker, 2005).

The content of this paper is organized as follows: the second part describes the data source and the preliminary preview of data; the third section explains the specification of the bidding function; the fourth part introduces the empirical estimation results of bid function and estimations of the total economic value of MIS application in aquaculture; the last part is the conclusion.

2. Preview of data

This study employs CVM to obtain the empirical data needed for analysis through questionnaires followed the principle proposed by Arrow et al. (1993). In the design of the questionnaire content, there are three parts: (1) the demand and cognition of MIS; (2) WTP of MIS; and (3) the socio-economic background information of respondents. The survey target of questionnaire are the practitioners whose products include oysters, quahog, alfalfa, grouper, tilapia, milkfish, and shrimp. Through the assistance of the cooperation partners such as the "Changhua Fishman's Association", "Association of Tainan Nanxun Aquaculture Production Association", "Yung-An Fishman's Association", and "Mituo Fishman's Association", the survey were carried out. The regional distribution of survey sample is showed as **Figure. 1**.

The total number of questionnaires completed in this study is 202, of which 8 were "protest samples", accounting for 4% of the total sample, and 25 "uncertain samples", accounting for 12.4% of the total sample. After excluding the "protest samples" and "uncertain samples", there are 170 samples can be used for follow-up WTP estimation, defined as "effective samples", accounting for 83.7% of the total sample.

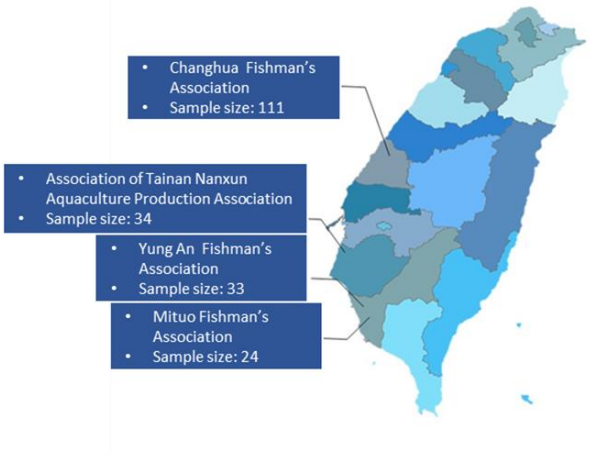

Figure.1: Regional distribution of survey sample

In the questionnaire, respondent is asked to score the impact of MIS on production management (1-10 grades). The higher the score, the higher the impact (subjective cognition) of the MIS on production

management. According to the results of the survey, 95% of the respondents believe that the weather forecast (one product of the MIS) has significant influence on the production management of the aquaculture fishery. The average score is about 7 grades when asked about the magnitude of the influence of MIS. However, since oysters are cultured in shallow seas, it is less able to carry out effective measures to prevent climate disasters compared to inland aquaculture. As a result, the proportion for Oyster practitioners believing in the importance of MIS on production is lower than that of others, and the average scores are lower as well (shown as **Figure. 2**).

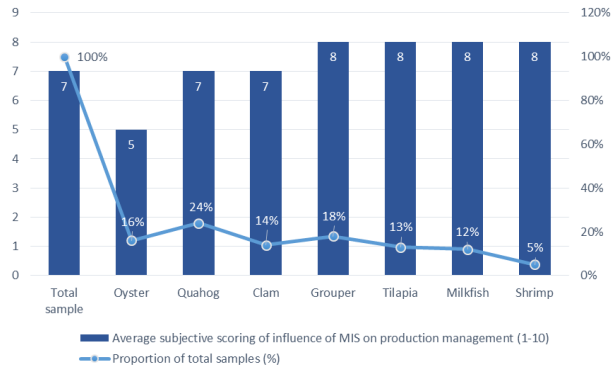

Figure.2 Subjective scoring of influence of MIS on production management

In terms of WTP of MIS, the mean value of whole sample is about 943 (NTD/monthly) and the median value is about 800 (NTD/monthly)(see **Figure. 3**).

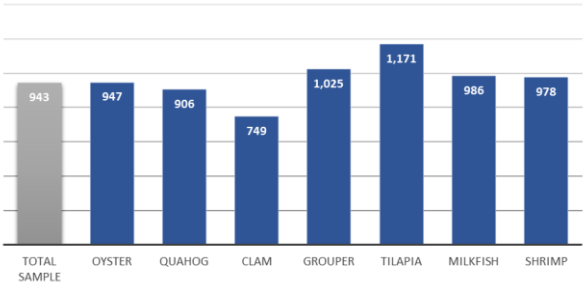

Figure.3 Mean WTP of MIS by product (NTD/per month)

Classified all the survey data according based on the response way of climate disasters, there are three types can be defined, including "not acting", "rush in the harvest", and "disaster prevention in advance". In general, those who "not acting" have the highest WTP (mean WTP=1,156 NTD/monthly), followed by "rush in the harvest" (mean WTP=1,019 NTD/monthly) and the last one is the "disaster prevention in advance" (mean WTP=935 NTD/monthly) (see **Figure. 4**).

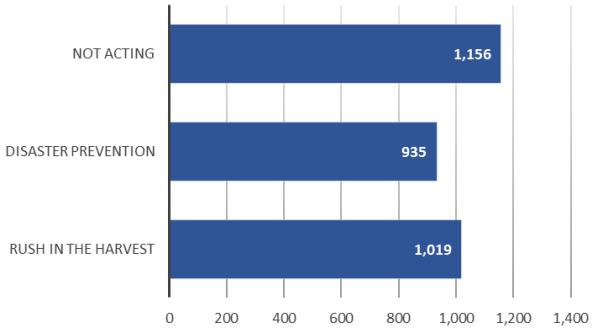

Figure.4 Mean WTP of MIS
(by respondent's reaction to climate disaster; NTD/monthly)

3. Design of the bid function

In the selection of explanatory variables used in the WTP bidding function of aquaculture fisheries, the study comprehensively considered the variables of socioeconomic background and of subjective perception of the respondents. Individual socioeconomic background variables include: the gender of respondents (*sex*), education level (*edu*), annual income (*income*), working experience in aquaculture fisheries (*workex*), and the numbers of family members work in aquaculture (*coworkers*). The subjective perception variables include: subjective scoring to influence of MIS on production activity management (*perception*), and the subjective accuracy score for MIS (*accuracy*). The definitions and descriptive statistics of these variables are shown as **Table 1**.

Table 1: Variable of WTP bid function

Variable	Definition	Mean (S.D.)
WTP	Willingness to pay for MIS (NTD/per month);	1,727.69 (6,550.27)
perception	Subjective scoring to influence of MIS on production activity management (1-10);	7.10 (2.72)
accuracy	Subjective scoring to accuracy of MIS (1-100);	76.62 (13.48)
sex	Dummy variable of gender, male=1, female=0;	0.83 (0.38)
edu	Level of education, no schooling=1, elementary school=2, junior high school=3, senior high school=4, college=5, graduate school=6;	3.39 (1.19)
workex	Working experience in aquaculture (years);	23.92 (14.63)
coworkers	Numbers of family members work in aquaculture (person);	2.58 (1.64)

yields	Number of fish rods owned;	7.45 (11.06)
income	Annual income from aquaculture (million NTD);	5.21 (8.52)
		Sample size: 170

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 designed as (1).

$$\begin{aligned}\mathrm{Ln}WTP_{\theta,i} = {} & \beta_{\theta,0} + \beta_{\theta,1}\ln(perception_i) + \\ & \beta_{\theta,2}\ln(accuracy_i) + \beta_{\theta,3}sex_i + \\ & \beta_{\theta,4}edu_i + \beta_{\theta,5}workex_i + \\ & \beta_{\theta,6}coworkers_i + \beta_{\theta,7}yields_i + \\ & \beta_{\theta,8}\ln(income_i) + \varepsilon_{\theta,i}\end{aligned} \quad (1)$$

Where, $\beta_{\theta,0}$ is the constant; $\boldsymbol{\beta}_\theta$ is the vector of estimated coefficient; θ represents the percentile of WTP, and $\theta = 0.1,0.2\ldots,0.9$. in this study; $\varepsilon_{\theta,i}$ is the random error term.

4. Empirical results of bid function and the total economic value of MIS application in Taiwan aquaculture

The meaning of the coefficient vector $\boldsymbol{\beta}$ is the elasticity value defined in economics field. The value of β_j of specific variable j indicates that WTP will change by β% while the change of variable is 1%.

According to the empirical estimation results, it is found that the most significant variable affecting WTP is "perception", and the influence of other explanatory variables is relatively insignificant. This result indicates that the subjective perception of respondents whether MIS is beneficial for production management is crucial for WTP of MIS. Since the quantile regression model is adopted to measure the influences of explanatory variables in this study, the impact of "perception" under different WTP levels can be identified. Based on the estimation results, the magnitude of this variable's influence to WTP under each percentile ($\beta_{\theta,2}$), are presented in **Figure. 5**. Taking the coefficient of the median (θ=0.5) as an example, $\beta_{0.5,perception}$ =0.549, indicating that the WTP median will change by 0.549% when the variable of "perception" changes by 1%. According to the empirical results, while θ = 0.1, 0.2, 0.3, 0.4, the estimated β coefficients are not significant different from 0 statistically. Conversely, if θ > 0.4, the effect of β coefficients on WTP are significant.

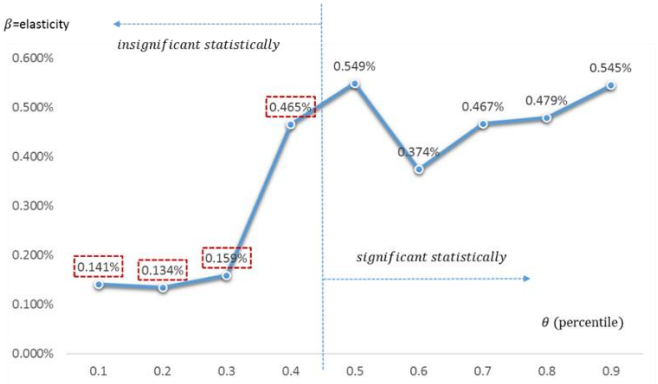

Figure.5 estimation results of elasticity of "perception" on each WTP percentile

Only keep the estimated coefficient results with θ>0.4, and the influences of per unit variation of "perception" on the WTP value are calculated. Those results can be as shown in **Figure. 6**. According to Fig. 6, when θ is increased from 0.5 to 0.6 (WTP value changes from 800 NTD to 1,000 NTD monthly), the influence of the variable "perception" on WTP is reduced from 61.81 (NTD/monthly) per unit to 52.69 (NTD/monthly). After θ>0.6, the effect on WTP is gradually increased for each unit of the variable "perception". At the 90th percentile of WTP, the WTP value can be increased by 184.16 (NTD/monthly) for each unit of the variable "perception". These results point out one policy insight that improving the fishermen's positive perception of MIS through education or promotion activities can increase the WTP. In addition, for respondents who have a higher WTP, the effect of perception on WTP is greater. Therefore, education and promotion activities can be designed for different target groups based on the average WTP.

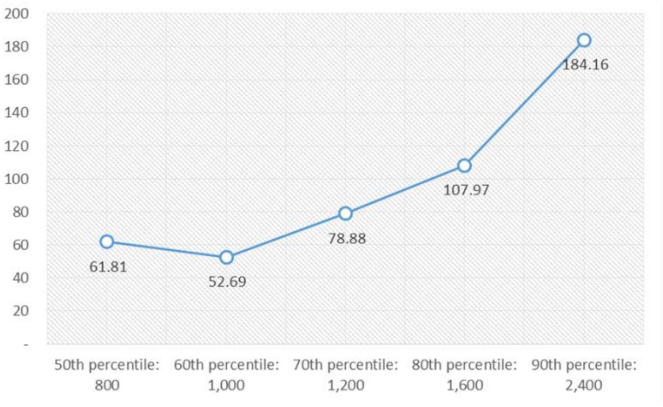

Figure.6 The rise of WTP for each unit increase of "perception" in every percentile (NTD/monthly)

Finally, the total economic value (TE) of MIS applied to Taiwan's aquaculture fisheries can be calculated based on the above WTP empirical estimates. The WTP median (θ = 0.5) is used to represent the WTP of

aquaculture fishery in Taiwan, and then multiplied by the number of aquaculture practitioners that they are willing to pay for MIS, the estimated value of the total economic value can be obtained. The calculation of TE is as (2).

$$\widehat{\mathrm{TE}_j} = \mathrm{N}_j * \widehat{WTP}_{\theta=0.5},\ \ j = S1, S2. \qquad (2)$$

In (2), N_j is the number of aquaculture practitioners they are willingness to pay for MIS in different scenario *j*. In this study, two scenarios are assumed. The first scenario defined as optimistic scenario (S1), assuming that all aquaculture practitioners in Taiwan are willing to pay for MIS, denoted as N_{S1}. The second scenario defined as conservative scenario (S2), assuming that the proportion of numbers of willing to pay for MIS is the same rate as that in survey sample, denoted as N_{S2}.

According to the statistics published by Council of Agriculture, Executive Yuan (2018), the number of aquaculture practitioners in Taiwan at 2017 is 30,228. The survey result shows that the proportion of willing to pay for MIS in whole sample is 83.7%. $\widehat{WTP}_{\theta=0.5} = 753.4\ (\mathrm{NTD/monthly})$. Based on those parameters mentioned above, in the optimistic scenario (S1), the annual total economic value (TE_{S1}) can be calculated as (3) and in the conservative scenario (S2), the annual total economic value (TE_{S2}) can be calculated as (4).

$$\widehat{\mathrm{TE}_{S1}} = (30{,}228 * (753.4 * 12))/1{,}000{,}000 \approx 340.96\ (\text{million NTD/annually}) \qquad (3)$$

$$\widehat{\mathrm{TE}_{S2}} = ((30{,}228 * 0.837) * (753.4 * 12))/1{,}000{,}000 \approx 285.38\ (\text{million NTD/annually}) \qquad (4)$$

As a result, the TE under S1 is estimated as 340.96 million NTD/annually and that under S2 is 285.38 million NTD/annually. Furthermore, the annual production value of Taiwan's inland aquaculture fishery is about 36,800 million NTD. The total economic value created by MIS each year accounts for 0.77%~0.93% of the annual output value.

5. Conclusions

Applying the contingent valuation method with an in-person survey, this study estimated the possible total economic value of meteorological information services of Taiwan's aquaculture fishery. The estimation result of the WTP bid function shows that the Subjective scoring to influence of MIS on production activity management (i.e. variable of "*perception*") dominates the WTP. Under the two scenarios setting up in this study, the annual total economic value of meteorological information services to aquaculture practitioners in Taiwan is about 285.38 million NTD~340.96 million NTD annually.

From the perspective of policy implications, the finding of this study can provide some insights both for public and private sectors. From the perspective of the public sector, how to increase the efficiency of government budgets usage under the limited budget and with growing public affairs is important. At present, the weather information in Taiwan is mainly provided by the Central Weather Bureau, and the funding resources come from official budgets. The results of this study can be used as a reference for subsequent decision-making on investment, including such items as the projects receiving funding, the scale of investment, and so on.

From the perspective of the private sector, the results of this study give a preliminary insight about the further construction of the weather information market. First, the total economic value estimation result can be regarded as a measurement of the market potential of meteorological information in Taiwan. In addition, if any private company intends to commercialize weather information, the results of this study can also serve as a reference for the pricing strategy of the relevant commodity.

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