Study on Environmental Benefit of Shallow Groundwater Resource Conservation by Deep Water Irrigation in Paddy Field

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ABSTRACT

After a certain degree of industrialization many countries find that agricultural production appears to result in negative economic profits due to the substantial opportunity cost of keep land in use for agriculture. The value of the land in non-agricultural uses rises considerably with industrialization. This process is especially acute in small, densely populated countries, such as Taiwan. However, the profitability of agricultural production may be underestimated if the positive externalities associated with farmland are not included. A proper accounting for these positive externalities casts agricultural production in a more favorable light. This paper focuses on paddy rice fields in Taoyuan County. A double-bounded dichotomous Contingent Valuation Method (CVM) is combined with the selection-bias-correction procedure to estimate the extent of the positive externalities. The evidence suggests that the externalities of paddy rice fields are recognized by the majority of people in Taoyuan. Each household is willing to pay (WTP)on average about $2208 NT annually to sustain the rice fields' shallow groundwater resource conservation function, the total WTP is $1.062 trillion NT annually which is about 0.49 folds of the intrinsic economic value of rice. Thus, the rising opportunity costs of retaining land in agricultural production is not yet sufficient to justify a reallocation of this resource from agriculture to other uses. The policy prescription favors retention of the land in agricultural production. In fact, if efficiency is the goal of policy makers, then more than half of the rice fields recently converted to other uses should have remained rice fields.

Key Words：environmental benefit, deep water irrigation, the Contingent Valuation Method(CVM)。

1. INTRODUCTION

Land and water are basic natural resources of use in virtually all industries. When industries become the mainstream in a country's development, land allocated to agriculture declines. This decline is particularly dramatic in small, densely populated countries such as Taiwan, Singapore, and Switzerland.[2] The move towards free trade in recent decades has facilitated the decline in the extent of agricultural lands in these countries by making low priced agricultural imports available. This further motivates efforts to convert farmland to industrial uses.

The reallocation of land from lower-valued use to a higher valued use appears to be efficient. However, consideration of farmland's role in environmental protection and maintaining watersheds suggests that there is a significant positive externality associated with agricultural production. For purposes of environmental protection purposes, farmland is irreplaceable by the high-valued industrial parks. Because there is no existing market for the external benefits gained from farmlands, attempts to estimate the value of the external benefits arising from farmland production directly pose a significant challenge. This paper uses a contingent valuation method (CVM) to investigate that to what extent farmland provides value other than agriculture production to residents of the economy. A double-bounded dichotomous choice questionnaire was thus employed for the purposes of this study. The estimated value of the externality will then be added to the value of the agriculture products to be the final worth of paddy fields. This paper thus contributes to policy discussions by providing the first estimates of the value of agricultural production that include the externalities arising from farming activities on Taiwan.

This paper is organized as follows: Section 2 provides the theoretical foundations of the employed methodology for the externality estimation. Section 3 explains the data sources and collecting process for the empirical study. The empirical results are presented in the 4th section. The last section concludes the paper and makes some final remarks.

2. RESEARCH THEORY

Over the past few decades, several methods have been developed in the field of environmental studies to evaluate environmental externalities (Davis 1963, Field 1994, Brookshire and Coursey 1987). This paper employs CVM due to its popularity for evaluating immeasurable economic benefit (Mitchell and Carson, 1989). Similar studies applied to environmental and non-environmental issues have been previously conducted include air quality, preservation of wildlife, and the value of programs designed to reduce the risks of respiratory diseases.[3] In this paper we use a double-bounded dichotomous contingent valuation method to investigate the external benefit of farmland. Respondents are asked a series of questions with numerical values provided

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[2] According to Food and Agricultural Organization of United Nation, the falls in agricultural land area for the small open economies are evidential. For example, in the past three decades, the drop of agricultural land area is 27.3% in Switzerland, 7.08% in UK, 12.9% in Sweden, 7.3% in Netherlands, 14.4% in South Korea, 12.9% in Italy, 8.3% in Germany, 8.2% in France, 16.7% in Belgium, 12.1% in Austria, and 90% in Singapore.

[3] See Bowker and Stroll(1988),Carson and Mitchell(1993), and Krupnick and Cropper(1992), Boyle and Bishop(1987), Greffle et at. (1998), Brookshire and Coursey(1987), Ready and Berger (1997), Schulze et al. (1983) for details.

by the survey to induce the willingness-to-pay without losing much information (Boyle and Bishop, 1988). The formal theory follows.

The double-bounded model of CVM survey involves asking an individual if she/he would pay a specified amount to secure a given improvement in environmental quality with two bids. The level of the second bid is contingent upon the response to the first bid. If the individual responds "yes" to the first bid, the second bid (to be noted as B_i^H is some amount greater than the first bid if the individual responds "no" to the first bid, the second bid (B_i^L) is some amount smaller than the first bid ($B_i^L < B_i < B_i^H$). Thus, there are four possible outcomes with the likelihoods as π^{YY}, π^{NN}, π^{YN}, and π^{NY}. Under the assumption of a utility-maximizing respondent (Hanemann, 1984), the formulas for these likelihoods are as follow (Hanemann, Loomis, and Kanninen, 1991).

$$\pi^{YY}(B_i, B_i^H; \theta) = P_r\{ B_i^H \le WTP \} = 1 - G(B_i^H ; \theta) \qquad (1.1)$$

$$\pi^{NN}(B_i, B_i^L ; \theta) = G(B_i^L ; \theta) \qquad (1.2)$$

$$\pi^{YN}(B_i, B_i^H ; \theta) = G(B_i^H ; \theta) - G(B_i ; \theta) \qquad (1.3)$$

$$\pi^{NY}(B_i, B_i^L ; \theta) = G(B_i ; \theta) - G(B_i^L ; \theta) \qquad (1.4)$$

where $G(B ; \theta)$ is some statistical distribution function with parameter vector θ and can be interpreted as a utility-maximization response within a random utility context where is $G(B ; \theta)$ the cumulative density function of the individual's true maximum WTP. Also suppose that G is logistic distributed, and $G(B ; \theta) = \frac{\exp(B - X\beta)}{1 + \exp(B - X\beta)}$, where X is the explanatory variables, and $\theta = \beta X$, is the correspondent coefficients of X.

With N respondents, where B_i^L, B_i, B_i^H are the bids used for the ith respondent, the log-likelihood function takes the form

$$\ln L(\theta) = \sum_{i=1}^{N} \{ d_i^{YY} \ln \pi^{YY}(B_i, B_i^H; \theta) + d_i^{NN} \ln \pi^{NN}(B_i, B_i^L; \theta) + d_i^{YN} \ln \pi^{YN}(B_i, B_i^H; \theta) + d_i^{NY} \ln \pi^{NY}(B_i, B_i^L; \theta) \} \qquad (2)$$

where d_i^{YY}, d_i^{NN}, d_i^{YN}, and d_i^{NY} are the binary-valued indicator variables and the formulas for the corresponding response probabilities are as mentioned above. Applying the maximum likelihood (ML) method, we obtain the aforementioned estimation parameters of the dichotomous model. That is, we estimate $\frac{\partial \ln L(\hat{\theta})}{\partial \theta} = 0$ to obtain θ the coefficients.

The estimating model is now $WTP_i = X_i \beta + \varepsilon_i$, where WTP_i is the willingness to pay of the ith individual. Differing from B_i^L, B_i, and B_i^H that are with observable discrete values, WTP_i is an unobservable continuous series. We assume that ε is normally distributed with zero mean and $\sigma^2 I$ as the standard errors, $\varepsilon \sim N(0, \sigma^2 I)$.

When a survey method is employed to collect the data the problem of non-responses is encountered. If the values of environmental amenities to the individual that do not respond is different from the value of these amenities to those that do respond, then use of the survey data can result in biased estimates. To account for the potential selection problem, the Heckman two-stage selection bias correction procedure is used. Thus the estimated model becomes:

$$WTP_i = X_{1i}\beta + \sigma_{12}/(\sigma_{22})^{0.5}\lambda_i + v_i \qquad (3)$$

where $\sigma_{12}/(\sigma_{22})^{0.5}$ is the inverse Mill's ratio and v_i is the residual. With the Heckman two-step procedure, if the estimated coefficient of λ_i is a positive number, the unadjusted regression may give an overestimated result. If it is negative, the unadjusted regression then tends to underestimate the impacts of the variables.

2.1 Design and enforcement of survey

There are many different types of agriculture fields and the environmental benefits provided by them differ one from the other. We select Taoyuan's paddy rice fields as our sample in this study since they are known for several environmental benefit: ground water storage and recharge, green field landscaping, polluted water purification, prevention for soil erosion, microclimate regulation, and habitats for wild animals, air purification, prevention of flood damage, and prevention of salty water involving ground water system (Tsai, 1993).

In this study, the function is classified – shallow groundwater resource conservation–that is to be focused and studied as the external benefits of paddy fields.

The survey was conducted from April to May in 2002 over the entire Toayuan of Taiwan (total 13 district areas). We apply the interviewing method to conduct the interview. The sampling method is random and uses computerized phonebooks provided by the local telephone company to select the base sample. The usual demographic questions are asked during the interview. To induce each individual's WTP, three groups of bids are designed based on a pretest of a 900 sample-size open-ended question survey result. The WTP are divided into 3 categories by its standard deviation. The result is presented in table 1.

Table 1 Alternative Bids for Paddy Fields (NT$)

Shallow Groundwater Conservation Function		
First round bidding	Second round bidding	
B	B^H	B^L
36	100	16
154	225	90
315	475	200

Each respondent is randomly assigned into one of the three groups. The result of the success rate is 52.6 percent.

The questions to induce the respondent households' WTP are based on a tax reallocation scheme. It is considered to be a more common means for financing environmental commodities and changes neither a disposable income nor a price of evaluated commodity. It does, however, reduce the amount of a household' tax money that has been spent on other public services. Thus, the following question is asked:

1. Given the paddy fields' ground water protection function, would you vote for the program if reduced the amount of your household's tax money[4] that spent on the other public services by $ B_W per year? Yes No
If the above answer is "Yes", then the same question is asked again by changing the $\$B_W$ to $\$B_W^H$.
If the answer is "No", the amount $\$B_W$ will be changed to $\$B_W^L$[5].

2.2 Empirical result

The statistical summary of the interviewed sample is presented in Table 2.

Table 2 Demographic summary

Variables	No. of obs	Mean	Standard Error	Min.	Max.
Age	471	41.01	14.06	20	89
Education	471	13.82	3.61	5	26
Family size	420	4.61	2.68	1	20
No. of working people in a family	457	2.65	1.83	0	18
Tenure	447	14.50	9.28	1	60
Average expense ($x10^4$)	316	71.24	37.28	30	200
Marriage status	460	0.74	0.42	0	1
Average income ($x10^4$)	420	104.74	48.24	41	210
Homeowner	474	0.69	0.41	0	1

[4] Yabe, Bergstorm, and Boyle (1999) compare the effects of two payment vehicles of a special tax and a tax reallocation on willingness to pay. In this study, we use the tax reallocation method meaning that the residents do not need to pay out of their own pockets to finance the environmental protection program. Instead, the tax money allocated to other public services will decline along with the increase amount of money allocated to the environmental protection program.

[5] The amount of B,B^H, and B^L are determined from pretest. They are presented in the table of next section.

Gender	474	0.51	0.50	0	1
Occupation:	No. of obs.	Percentage			
Public worker	52	11.09			
Business	84	17.91			
Farmers	57	12.15			
Self-employed	56	11.94			
Blue collar	84	17.91			
Staff	52	11.09			
Other	84	17.91			
Working position					
Owner of the business	186	47.21			
Manager	50	12.69			
Staff	158	40.1			

The monetary values from the questionnaire are denominated in New Taiwan Dollars (NT), which convert to US dollars at a ratio of 34 NT dollars to 1 US dollar. Table 3 presents the summary of participants' responses to the initial and the second bids.

Table 3 Participants' responses to the initial and second bids

For shallow groundwater resource conservation function			
Answer type		Second bid	
		Yes	No
First bid	Yes	217 (55.08%)	31(7.86%)
	No	12 (3.05%)	134(34.01%)

It shows that more than 65.99 percent of households think that paddy rice fields require some degree of public subsidy due to their shallow groundwater resource conservation function, respectively. The result of the maximum likelihood estimates of the respondents' double-bounded WTP is summarized in Table 4.

Table 4 Maximum likelihood estimates of the respondents' WTP

Variables	shallow groundwater conservation	Shallow groundwater conservation(modified)
Education	29.28 (14.14)	29.48*** (14.50)
Income	-24.38 (25.16)	-30.37*** (28.09)
Tenure	6.18 (3.41)	6.59*** (3.50)
Marital Status	7.01* (30.65)	7.54*** (32.66)
Gender	3.45 (23.41)	-0.15*** (26.41)
Urban	7.21 (24.56)	-18.51** (28.26)
Family size	-8.45** (4.69)	-9.47*** (5.41)
Manager	-20.54 (37.31)	-33.64 (35.65)
Farmer	49.65 (74.23)	84.51*** (79.17)
Businessman	-23.04 (33.08)	-27.64*** (33.81)
News	-4.15 (13.89)	-4.67 (14.98)
Mill's ratio	--	3405.16*** (1824.97)
Constant	187.52** (135.27)	-72.15*** (148.31)
Log likelihood	-664.58	-603.471
Number of obs	425	425
Model $chi^2(15)$	13.27	15.06
Prob > chi^2	0.5147	0.468
Medium WTP	2209.84	2208.15

Note :

1. 1, 5, and 10% level of significance are denoted by ***, **, and *, respectively.
2. standard errors are in the parentheses
3. Education, income, and tenure year are in natural logarithm form.
4. The variable "News" represents the number of news sources where the respondents obtain their environmental knowledge.

Column 1 is the results of the WTP estimation without the selection bias correction and column 2 contain the estimates incorporating Heckman's two-step correction. Since the estimated coefficient for the inverse Mill's ratio is significant at 5% level, it appears that the appropriate

estimates is this contained in columns 2. That is, incorporation of the selection bias correction is important.

The estimation results show that manager and income level have a negative significant impact on the respondents' WTP for both functions of paddy fields, and both are statistically significant at 1% level. Also, respondents with larger family sizes tend to pay less for both the paddy fields' environmental protection functions. Other variables that have negative impacts on the households' WTP toward paddy fields include businessman, respondents has more knowledge about paddy field's wildlife, and the respondents with flood experience. The latter two variables seem to give counterintuitive results. They are statistically insignificant, however. Male, married respondents, and farmers, and respondents who work in business sectors in general tend to pay higher for both type of paddy fields' function, and the results are statistically significant at 5% level.

The coefficients of the Mill's ratio in the estimate results is positive and statistically significant at 5% level meaning that the regression without selection-bias correction may be upward biased. The overall estimated WTP's for each regression function are shown at the bottom of Table 4 noted as medium WTP. They are estimated at the mean value of the explanatory variables. The results show that the average households in Toayuan are willing to reallocate their tax money from other public services to maintain paddy rice fields for their groundwater conservation function by the amount of $2208 NT (about $65) annually. With total 505,298 households in Toayuan area, the total amount of tax money needed to be reallocated for paddy fields maintenance is about $1.067 trillion NT, equivalent to 0.493 folds of the value of rice production at the same period.

3. CONCLUSION

In this study, the importance of the environmental protection function of farmlands is stressed and the value of these external benefits is estimated. Aside from the agriculture production purpose, farmlands are also recognized to be important in their environmental function. For simplicity, those benefits are roughly categorized into the type: shallow groundwater resource conservation function for further investigation in the paper. To evaluate the value of these external benefits, a double-bounded dichotomous contingent valuation method is employed.

The majority of survey respondents feel that paddy rice fields exert a significant positive effect on groundwater conservation. For groundwater conservation the associated percentage of positive WTPs exceed two-thirds, respectively. The total willingness to pay obtained from tax reallocation for the paddy fields is $1.067 trillion NT, which is equivalent to 0.493 folds of the market value of rice production in Toayuan. Also the WTP's are positively related to the respondents' tenure year, marital status, and male status. They are negatively related to the respondents' income level, family size, and manager status.

The results of this paper indicate that the majority of the households are aware of the external benefits of farmlands and are willing to pay certain amount of money out of their tax payment to maintenance them. With the technology improvement and the economic structural shifts, farming area is gradually shrinking especially in the small open economies, which even consider about abolishing agricultural production and mainly relying on imported products. In the ever

decreasing in size of farmland in today's societies, this paper calls attention that only look at the internal value of one sector is not enough. When evaluating the priority of the development of a nation, the external benefits of farmlands and the external costs of industries development need to be evaluated along with their internal value. It is hoped that this paper can serve as a useful reference to the agricultural authorities for future policy considerations.

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