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The Willingness to Pay of Industrial Water Users for Reclaimed Water in Taiwan

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1. Introduction

Water resource in Taiwan is mainly delivered through diversion from river, regulation of reservoir and groundwater extraction. Diversion from river is dependent on hydrological conditions on yearly bases. Reservoir regulation is unpredictable and subject to actual conditions of the watershed, and moreover, building a reservoir involves huge funding and takes a long time in addition to frequent confrontation of questioning and protests of environmental groups. As for groundwater extraction, land subsidence resulting from excessive groundwater extraction leads to national land conservation issues. Considering natural restrictions and environmental policies, wastewater reclamation has become an important topic when the government seeks for new water sources. Aiming to resolve the supply of water resource, the government is progressively promoting the wastewater reclamation industry and exploiting the corresponding market. With provision of statutes that favor the development of wastewater reclamation industry as well as financial setup that supports relevant technologies, the government expects to counsel the private sector to participate in establishing a wastewater reclamation industry that conforms to the trend of green ecology.

Taiwan has had a wastewater reclamation industry of the produce/use model instead of the produce/supply model. The produce/use mode is the situation that the supplier and user of the reclaimed water are the same. The reduce/supply mode is the situation that the supplier and user of the reclaimed water are different. The main reason is that the government has encouraged the industry to achieve "process recycle ratio" and "total plant recycle ratio" for more than 10 years, and there have been operators in Taiwan engaged in wastewater reclamation plants of "produce/use" model. However, wastewater reclamation plants of the "produce/supply" model still remain in the Model Plant stage and require successive fostering. Even in advanced countries such as EU, USA or Japan, there had been a number of barriers hindering the promotion of wastewater (sewage) reclamation; one of them is the dominant insufficiency of user confidence over quality and safety of the reclaimed water. In

Taiwan, except adopting the produce/use model - in which factories who promote water saving within the industrial park reclaim their own wastewater for reuse, the environmental assessment requires that wastewater or sewerage within a building to be reclaimed by the building, or a wastewater/sewage treatment plant reclaims a portion of its own effluent for in-plant miscellaneous use - no other industrial development or application reference has been seen. Furthermore, affected by the lacking of experience and the rather low water price, the willingness to use reclaimed wastewater has been fairly low.

The Hydraulic Planning and Experimental Institute made a preliminarily research in 2009 and found that potential candidates for the use of reclaimed water include: 1. Water for secondary livelihood use: using effluent of urban wastewater/sewage treatment plant for watering nearby golf courses, to enhance flexibility of the local supply of water resources. 2. Water for agricultural use: treating effluent from the urban wastewater/sewage treatment plant to meet the standard of "water quality for irrigation" and using the reclaimed water for agricultural irrigation in areas having a water shortage. 3. Water for conservation: using water reclaimed from urban wastewater/sewage treatment plants for groundwater recharge, for artificial recharge of disaster prevention purposes, for agricultural use in substitution for the groundwater which would have originally been extracted, so as to alleviate groundwater extraction. And 4. Water for industrial use. Organizations that may increase water consumption in the future include: Hsinchu Science Park Yilan Base, Taoyuan Aviation City, Taipower Letzer Industrial Park Power Plant, Taipei Harbor Power Plant, Expansion Project of Dragon Steel Corporation, Middle Taiwan Science Park Taichung Base and Houli Base, Taichung Harbor Proprietary Areas (including power plant, petrochemical and industrial areas), Hsinchu Science Park Phase IV Tongluo Base, Yunlin Offshore Fundamental Industrial Park, Taiwan Petroleum Corporation Third Naphtha Cracker Renovation Project, Tainan County Great Hsinyin Industrial Park Development Project, Southern Taiwan Science Park Phase II, Development Project of Southern Taiwan Science Park LCD TV District (Tree Valley Park), Tinnan Industrial Park, and China Steel Corporation. The study carries out questionnaire interview with industrial water users to comprehend their willingness towards paying for the reclaimed water as well as their methods to use the same.

2. Method

2.1 The theoretical model

The study use Contingent Valuation Method (CVM) to analyze the "willingness to pay (WTP)" of future industrial water users for using reclaimed water. The CVM method surveys user valuation over non-existing transactions of goods or services in the market by way of a direct questionnaire designed basing on hypothetic conditions in the market, therefore is a valuation method over non-market resources. The major feature of the CVM model is the forward-looking (ex ante) decision which evaluates a future event in advance. The price and quality level of the reclaimed water supply mechanism are presumed by the study without actually putting into operation; they are preliminary assumptions of the future supply mechanism of the reclaimed water which may be applicable to the existing factories of the industrial and science parks, for further understanding the WTP level of users regarding water price and the quality level.

The major difference of the CVM approach contrasting with a direct valuation approach is that CVM is specific in combining the survey practice with theories. Popular use of the CVM approach began in 1970's when the Forest Act of UK and the presidential directive #12291 were promulgated; a number of researches were seen conducted with the CVM approach over economic benefits of natural resources. During the Exxon tanker oil spoil incident in 1989, the federal court of USA ordered compensation to be paid by Exxon appraised with the CVM approach, enhancing the authenticity of the same. By 1993, since the US government extensively used CVM to make public policies that concern natural resources, the National Oceanic and Atmospheric Administration (NOAA) therefore promulgated guidelines on the use of the CVM approach, regulating the use of Contingent Valuation Surveys. Research papers show that CVM is applicable to offering a rational valuation over public goods or environmental goods (Smith, 1993). Hutchinson, et al.(1995) also pointed out that as long as the questionnaire is duly designed, CVM is a highly credible means for price evaluation.

The CVM appraisal can be conducted with a Random Utility Model (Hanemann, 1984) or an Expenditure Function (Cameron, 1988). However, Cameron(1988) uses Censored dichotomous choice model to directly estimate the parameter of the Expenditure Function, it directly and easily obtaining the WTP of the public over environmental goods. The microeconomic theory also demonstrates that the indirect utility function has a dyadic relationship with the Expenditure Function; therefore it can also represent the utility preference of the consumer. In order to prevent excessive biases and to make adequate use of all the data acquired from the questionnaire survey, the study employs a close-ended dichotomous choice method design for the questionnaire, and uses the Expenditure Function model (proposed by Cameron (1988) and Cameron & James (1987)) for calculating the WTP function of the reclaimed water.

This study use the questionnaire survey in determining the price level that the factories are willing to pay for the reclaimed water, and to provide incentives for the factories becoming willing to use the reclaimed water, a hypothetic market must be conceptually established for the factories, to create a bidding function based on individual social and economical characters and the level of bidding prices. The main method is to estimate the acceptable price by way of Cameron's expenditure function model based on the WTP of the questionnaire and the percentage of factories that are willing to pay or willing to accept. Follow the defined of resource value by Freeman (1993). We set up the empirical model of reclaimed water as follows:

$$Y(Q0,Q1,U0,S) = E(Q1,U0,S) - E(Q0,U0,S) \tag{1}$$

Y(Q0,Q1,U0, S) is the bidding function of the factories for the reclaimed water;
E(Q0,U0,S) and E(Q1,U0,S) are the Expenditure Function.
In the formula,
Q0 is the situation that the factory do not get reclaimed water;
Q1 is the situation that the factory got reclaimed water;
U0 is the utility function of the factory;
S is the price vector of market goods and individual social and economic characteristics vectors.

If the price suggested by the CVM questionnaire is T,

$$Y(Q0,Q1,U0,S) \geq T \tag{2}$$

the probability for the interviewee to check this bid can be expressed by formula (3):

$$Pr=Pr[Y^*(Q0,Q1,U0,S)-T>u] \tag{3}$$

Where Y* is observable component, u is observable random component, as shown in Formula (4):

$$Y(Q0,Q1,U0,S)=Y^*(Q0,Q1,U0,S)+u \tag{4}$$

The Bidding Function can be estimated based on the probit model by Cameron & James(1987) as shown below:

Ii=1 if Yi >Ti
= 0 otherwise

$$\begin{aligned} Pr(Ii=1) &= Pr(Yi>Ti) = Pr(ui>TI-Xi'B) \\ &= Pr(ui/\sigma > (TI-Xi'B)/\sigma) \\ &= 1-\phi((Ti-Xi'B/\sigma) \end{aligned} \tag{5}$$

where Xi'B is exclaiming variable, ϕ is accumulated probability of intensity function, then the interviewee's bidding valuation can be shown as formula (6) :

$$Yi = Xi'B+ui \tag{6}$$

Yet standard binary probit model shall be

Ii=1 if Yi>0
=0 otherwise

$$\begin{aligned} Pr(Ii=1) &= Pr(Yi>0i) = Pr(ui>-wi'\delta) \\ &= Pr(zi>-wi'\delta/v) \\ &= 1-\phi(-wi'\delta/v) \end{aligned}$$

at this time,

$$Yi = wi'\delta + ui$$

using the following transformation

$$-(Ti, Xi')\begin{bmatrix} -1/\sigma \\ B/\sigma \end{bmatrix} = -wi'\delta$$

$$\delta^* = (\alpha,\gamma) = (-1/\sigma, B/\sigma)$$

we obtain

$$\begin{aligned} B &= -\gamma/\alpha \\ \sigma &= -1/\alpha \\ Yi^* &= Xi'B \end{aligned} \tag{7}$$

Where Yi* is the price of reclaimed water estimated by the supplier under the standard binary probit model; this can be used for the calculation of a reasonable price for the reclaimed water.

Assuming *u* to be the logistic distribution, the empirical result can be calculated based on the logistic model by Cameron(1988).

$$P(Y)=[1+e-[Yi-Ti]]-1$$

Similar to the probit model appraoch, we can obtain

$$Yi^* = Xi'B \quad (8)$$

Where Yi* is the price of reclaimed water estimated by the supplier under the logistic model; this can be used for the calculation of a reasonable price for the reclaimed water.

2.2 Questionnaire design

To the demand end, quality and price of the reclaimed water are the major concern. We detail as follows: Water reclaimed from effluent of large scale wastewater treatment plant by reverse osmosis: capable of reaching quality standard of Taiwan Water Works. For the selection of questionnaire valuation method, the study employs the most easy-to-operate and time saving "Single-bounded dichotomous choice elicitation method" (Boyle & Bishop, 1988) to carry out interviews based on NOAA suggestions.

The scenario of this study is as follow: We assumption that "the government guarantees that quality of reclaimed water conforms with city water specifications, no interruption of supply 365 days a year with assured quality and loss indemnification on supply interruption," and that "dedicated pipeline to be installed for reclaimed water delivery, plus with free-of-charge pipe connection," and that "50% deduction on wastewater treatment charge if total consumption of reclaimed water exceeds 40% of total industrial water consumption of the company". Than we ask the manager or boss of the factory " Are you willing to pay for the reclaimed water for the "T" price we suggested on the questionnaire[1] under the assumption scenario?"

The value of reclaimed water depends on its water quality. The quality of "city water" is just the basic requirement of the customer when comparing with more expensive and better quality of "soft water, 1μS/cm". Besides, the assumptions of the following are not yet done but they are the requests of the factories. So we set up the approximate realistic assumption of the scenario.

The selection of the price we suggested on the questionnaire, i.e. "T" in formula(2) in each questionnaire of the scenario is determined based on the current city water price in Taiwan and the costs for reclaiming the wastewater. Furthermore, one or several extreme and median values are set to meet theoretical requirements of the Contingent Valuation Method, the scenario having 12 kinds of "T" prices as shown in Table 1. In another word, the study employs 12 different questionnaires, Q_A through Q_L, with different assignment of the "T" prices for each type of questionnaires scenario.

[1] we give different "T" price in different type of questionnaires which shows on Table1.

No. of Questionnaire	Scenario
A	3
B	5
C	7
D	9
E	11
F	12
G	13
H	15
I	16
J	18
K	20
L	24

Table 1. The price "T" we suggested on the questionnaire (in NT$/ton)

2.3 Sampling design

The study takes industrial and science parks having a higher water consumption as survey objects, including factories in Hsinchu Industrial Park, Chungli Industrial Park, Taichung Industrial Park, Linyuan Industrial Park, Hsinchu Science Park, Central Taiwan Science Park and Tainan Technology Industrial Park. The above industrial and science parks comprise the sampling zone of the study. For industrial parks, factories having a water consumption exceeding 200CMD are selected as survey objects, a total of 347 factories are included. Then, we call factories one by one to verify their water consumption and exclude those having a low water demand or those lacking willingness to participate our survey. After verification, a total of 205 factories are included in the survey. The survey schedule covers September and October of 2009.

Areas \ Count	Selected as survey objects	Send after verify their water consumption and exclude those having a low water demand or those lacking willingness to participate our survey	Return
Hsinchu Industrial Park	20	12	5
Chungli Industrial Park	13	8	2
Taichung Industrial Park	1	1	0
Tainan Technology Industrial Park	6	3	2
Linyuan Industrial Park	8	4	4
Hsinchu Science Park	245	145	26
Central Taiwan Science Park	54	32	8
Total	347	205	47
Return Ratio		22.93%	

Table 2. Statistics on questionnaire count of sampling zone factories

Questionnaire via fax or mail is adopted for the survey. Every returned questionnaire is checked for completion; in case of miss or obvious mistake of key items, a telephone re-check will be made against the particular factory. For factories that fail to return the questionnaire, urging telephone calls will be made. The study sends out a total of 205 questionnaires and receives 47 returns of which 2 are null; the return ratio is 22.93%. Table 3 shows questionnaire distribution of the sampling zone. For further understanding of the scenario, Table 3 is compiled to statistically manifest the WTP selected for the scenario, and the percentage of factories that are willing to use the reclaimed water at different WTPs corresponding to respective questionnaires of the study.

Scenario \ Questionnaire No		A	B	C	D	E	F	G	H	I	J	K	L
Scenario	T price	3	5	7	9	11	12	13	15	16	18	20	24
	Return Count	3	7	3	3	4	4	1	6	4	6	2	2
	Ratio of Willingness	67	71	33	67	75	50	0	33	50	33	0	0
Total number of questionnaire		29	29	29	29	29	29	29	29	29	29	29	28

Note: Data of null questionnaires are not included in this table. Unit of T: NT$/ton. Ratio of Willingness is in %.

Table 3. Return ratio of difference type of questionnaires

3. Results

For empirical analysis of factories' Willingness to Pay (WTP), the study employs the valuation method developed by Cameron & James (1987) and Cameron (1988) using the software called LIMDEP. In order to avoid influences from extreme sample values, Logit Model is used to establish the valuation formula of WTP (Willingness to Pay); Approximation of Newton's method and maximum likelihood estimation (MLE) are used to evaluate the WTP; accuracy of the prediction exceeds 75% although the number of sample is small. Table 4 shows results of WTP:

	Scenario
WTP of factories (NT$/ton)	13.97
Accuracy of the prediction model	82.22%

Note: The estimation models are under the 0.5% significant level

Table 4. Results of WTP of factories

Under the assumption that "the government guarantees that quality of reclaimed water conforms with city water specifications, no interruption of supply 365 days a year with assured quality and loss indemnification on supply interruption," and that "dedicated pipeline to be installed for reclaimed water delivery, plus with free-of-charge pipe connection," and that "50% deduction on wastewater treatment charge if total consumption of reclaimed water exceeds 40% of total industrial water consumption of the company", factories are willing to purchase the reclaimed water at an average price of 0.48$/ton (13.97NT/ ton), reclaimed water demand is 131,000 Cubic Meter per Day (CMD[2]), 22.8% of factories in the sampling zone are willing to use reclaimed water, and a ratio of 47% of the

[2] Cubic Meter per Day (CMD) is the flow rate of water

returned effective samples. Average consumption of reclaimed water per factory is 291.55CMD, 48.86% to the total consumption of industrial water. Table 5 shows statistics of potential usage and consumption of reclaimed water by factories.

Application of reclaimed water	Average ratio of factories willing to accept	Average potential maximum consumption of reclaimed water per factory (CMD)
Process Water	24%	160
Boiler Feed Water	20%	50
Cooling Water	76%	65.75
Washing Water	58%	10.6
Firefighting Water	51%	5.2
Total consumption of reclaimed water		291.55

Note: Average potential maximum consumption of reclaimed water per factory = Total potential consumption of reclaimed water / number of factories that are willing to accept

Table 5. Statistics of potential reclaimed water application and consumption by factories

Table 6 shows values of model parameters of the Scenario. In which MAA indicates surveyed "T" price (N.T.D./ton); MAW indicates the product of ratio of maximum reclaimed water to total industrial water acceptable to the factory multiplied by the total consumption of industrial water in 2008(CMD); MAN indicates the amount of washing water the factory is willing to use(CMD). If the MAA coefficient is negative and MAW and MAN coefficients are positive, the theoretical expectation is deemed met.

Variable explain	Variable Name	Coeff.	Std.Err.	t-ratio	P-value
Intercept	ONE	0.170238	1.04835	0.162387	0.871001
The surveyed "T" price (N.T.D./ton)	MAA	-0.20879	0.099374	-2.10108	0.035634
The amount of washing water the factory is willing to use (CMD)	MAN	2.73873	1.01492	2.69846	0.006966
The product of ratio of maximum reclaimed water to total industrial water acceptable to the factory multiplied by the total consumption of industrial water in 2008 (CMD)	MAW	0.005193	0.002371	2.19045	0.028491

Table 6. Value of model parameters of Scenario

4. Discussion and conclusions

The study assumed the scenario "the government guarantees that quality of reclaimed water conforms with city water specifications, no interruption of supply 365 days a year with assured quality and loss indemnification on supply interruption," and that "dedicated pipeline to be installed for reclaimed water delivery, plus with free-of-charge pipe connection," and that "50% deduction on wastewater treatment charge if total consumption of reclaimed water exceeds 40% of total industrial water consumption of the company", factories are willing to purchase the reclaimed water at an average price of 0.48$/ton. The Scenario mach the policy that Taiwan government wants to promote to use of reclaimed water for new water source other than diversion from river, reservoir water, building new reservoir or groundwater extraction.

The study results show the WTP under the Scenario exceed the existing price of city water indicate that the assumption of senior as about are the works if which need to be done in the future. We presume the reason behind this are that: 1) the factories that are willing to assist the survey had suffered from water shortage in the past operation and therefore are willing to procure the reclaimed water at a cost higher than the city water under the assumed scenario. 2) It appear to be under the changing climate, the Industrial water users are more concern about the stable water source. 3) We speculated that the Scenario of "50% deduction on wastewater treatment charge" have a great incentives to use reclaimed water.

5. Lessons learned

The result of this study implies that the appropriate water management policy design could really encourage the use of reclaimed water. In other word, appropriate water management policy design could change the structure of water use. Well water management policy or incentives mechanism, such of deduction on wastewater treatment charge, could bring about good water conservation patterns. Furthermore, the willing to pay for the reclaimed water price is higher than the city water also show that the wastewater reclamation industry have good future prospects. If there has appropriate water management policy, the reclaimed water could be good water source other than diversion from river, reservoir water, building new reservoir or groundwater extraction.

6. Acknowledgments

The article was extracted from detailed project "The Research on the Strategic Development of Specialists Training of the Wastewater Reclamation and Reuse Industry" that sponsored by the Water Resources Agency, Ministry of Economic Affairs, Taiwan (project code: Moeawra0980052) and "A game theory approach to evaluation the irrigation water transfer" that sponsored by the National Science Council, Taiwan (project code: 100-2221-E-134-001). The authors would like to thank the anonymous reviewers and all the participants of this project for their efforts.

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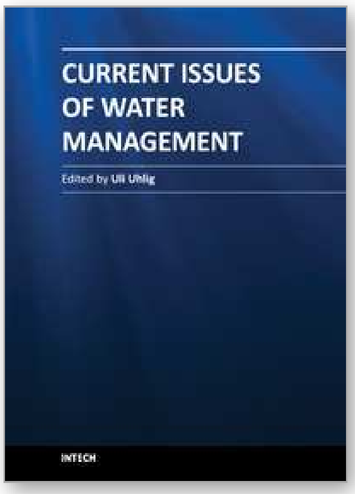

Current Issues of Water Management
Edited by Dr. Uli Uhlig

ISBN 978-953-307-413-9
Hard cover, 340 pages
Publisher InTech
Published online 02, December, 2011
Published in print edition December, 2011

There is an estimated 1.4 billion km3 of water in the world but only approximately three percent (39 million km3) of it is available as fresh water. Moreover, most of this fresh water is found as ice in the arctic regions, deep groundwater or atmospheric water. Since water is the source of life and essential for all life on the planet, the use of this resource is a highly important issue. "Water management" is the general term used to describe all the activities that manage the optimum use of the world's water resources. However, only a few percent of the fresh water available can be subjected to water management. It is still an enormous amount, but what's unique about water is that unlike other resources, it is irreplaceable. This book provides a general overview of various topics within water management from all over the world. The topics range from politics, current models for water resource management of rivers and reservoirs to issues related to agriculture. Water quality problems, the development of water demand and water pricing are also addressed. The collection of contributions from outstanding scientists and experts provides detailed information about different topics and gives a general overview of the current issues in water management. The book covers a wide range of current issues, reflecting on current problems and demonstrating the complexity of water management.