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# Willingness to Pay for a Highland Agricultural Restriction Policy to Improve Water Quality in South Korea: Correcting Anomalous Preference in Contingent Valuation Method

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**Abstract:** This study examines the willingness to pay (WTP) for the highland agriculture restriction policy which aims to stabilize the water quality in the Han River basin, South Korea. To estimate the WTP, we use a double-bounded contingent valuation method and a random-effects interval-data regression. We extend contingent valuation studies by dealing with the potential preference anomalies (shift, anchoring, and inconsistent response effects). The result indicates that after the preference anomalies are corrected, the statistical precision of parameter estimates is improved. After correcting the potential preference anomalies, estimated welfare gains are on average South Korean currency (KRW) 2,861 per month per household. Based on the WTP estimate, the total benefits from the land use restriction policy are around KRW 297.73 billion and the total costs are around KRW 129.44 billion. The net benefit is, thus, around KRW 168.29 billion. This study suggests several practical solutions that would be useful for the water management. First, a priority should be given to the valid compensation for the highland farmers' expected income loss. Second, it is necessary to increase in the unit cost of the highland purchase. Third, wasted or inefficiently used costs (e.g., overinvestment in waste treatment facilities, and temporary upstream community support) should be transferred to the program associated with high mountainous agriculture field purchase. Results of our analysis support South Korean legislators and land use policy makers with useful information for the approval and operationalization of the policy.

**Keywords:** double-bounded contingent valuation method; willingness to pay; random-effects interval-data regression; potential preference anomalies; benefit-cost analysis

## 1. Introduction

Degradation of water quality is an ongoing issue for water resource users between high- and lowland areas [1]. Due to leaching of agrochemicals and the export of sediments caused by agricultural intensification in the highland areas, water pollution is very common along the river basin in East and Southeast Asian countries [2–7]. This results in degrading water quality, threatening aquatic ecosystems in downstream areas [8,9].

In the highland areas of the Han River basin, South Korea which is the primary source of drinking water supply to the Seoul metropolitan area of South Korea, agriculture is dominated by vegetable (e.g., Chinese cabbage and radish) production and is characterized by a high level of chemical fertilizer inputs [10]. Because of the intensive use of agricultural chemicals, in particular nitrogen and phosphorous being the main pressures dominating the ecological status of the basin [11], they have been identified as hotspots of non-point pollution due to soil erosion accelerated by the monsoon climate, which causes deterioration of the important freshwater resources [12,13]. Even though several measures including the introduction of a water use charge (water users in downstream areas (Seoul, Incheon, and part of Gyeonggi_do) that are supplied with water from upstream water source protection zones (part of Gyeonggi_do, Gangwon_do, and Chungcheongbuk_do) of the Han River basin have to pay a water use charge, which has been increased from KRW 80 per cubic meter in 1999 to KRW 170 per cubic meter in 2012 [14] (KRW is the currency unit of South Korea and, at the time of the survey (year 2012), USD 1 equaled KRW 1,126.25) as an incentive to designate water source protection zones in upstream areas since 1975 have been implemented, water quality deterioration due to highland agricultural activities still continues. Thus, downstream water users have called for a highland agricultural restriction policy including the abolishment of highland vegetable cultivation [15]. However, such crop production is the main source of income for local farmers in the highland areas [16]. The current situation is that the Korean government and downstream residents support stopping agricultural activities susceptible to environmental problems, while highland farmers and local governments wish to continue these activities.

Within this context, a highland agricultural restriction policy was proposed and has been under extensive discussion in public media and among land use policy makers [15]. The aim of the policy is to prevent turbid water inflows to the Han River basin via the conversion of vegetable cultivation to other alternatives such as perennial crops or forest trees in the highland areas, i.e., trade-offs between benefits through water quality improvement and opportunity costs of abandoning current highland agriculture. Obviously, if the policy is approved, it puts limits on economic activities of residents in the upstream areas in order to protect or improve water quality, which means they are deprived of opportunity for potential economic benefits with respect to utilizing natural resources. Residents in down- and midstream areas are, on the other hand, provided with safe and clean water through the implementation of the policy, which means they gain more benefits from the water use [17]. To accomplish equal distribution of the benefits of using water resources between river basin stakeholders, there should be a financing mechanism to support highland farmers for the conversion in order to compensate for their expected income loss. Therefore, it is essential that the government should ensure adequate financing available to effectively manage water quality [18].

Since the benefits generated by water quality improvement are not traded in real markets [19], this requires the use of non-market valuation methods to estimate these benefits [20]. Among various non-market valuation methods, we used the double-bounded dichotomous choice contingent valuation method (CVM) to investigate the benefits associated with increase in water quality generated by a highland agricultural restriction policy. The double-bounded dichotomous choice CVM developed by Hanemann et al. (1991) [21] includes two payment questions, offering two different bids. If the first bid is accepted (rejected), a higher bid (a lower bid) is proposed in the follow-up question so that an individual can make a decision whether they agree to accept or reject the proposed bids. Since the individual's willingness of pay (WTP) can be below or above a bid amount or between the two bid amounts, the double-bounded model could have the potential to identify the WTP location more accurately, hence improving the estimates [22].

This method might, however, cause other undesirable response effects, known as shift [23], anchoring [24,25], and yea-saying effects [26–29]. Cameron and Quiggin (1994) [30] indicate that despite the high correlation between the WTP distributions signified by the first and second bids, the WTP distributions are not equivalent in the double-bounded model. This is because the variance from the second WTP estimate is larger than the first. The offer of the second bid could, in addition, surprise respondents due to their unfamiliarity with the institutional design of the double-bounded dichotomous choice CVM, thus causing diverse strategic answers (anomalous preferences) [31,32], and less precise WTP estimates [32].

A few studies have tried to identify and control these effects [23–25,27,28,30], but most of them show that controlling for biases in the double-bounded dichotomous choice format may lead to a loss in efficiency and estimate precision [22]. In this study, we further examine respondents' aberrant behavior by comparing the accepted bid amounts from the dichotomous choice question with the maximum WTP amounts from the open-ended question at the last stage of the contingent valuation survey. We assume that the inconsistent responses found from the comparison may include yea-saying, which shows more respondents' strategic behavior [26]. We thus consider the aberrant responses as the inconsistent response effects including the yea-saying bias in this study.

In this regard, our analysis aims: (1) to provide a robust way for the improvement of precision in model estimation by controlling shift, anchoring, and inconsistent response effects simultaneously in the double-bounded dichotomous choice CVM; (2) to examine households' willingness of pay (WTP) for the highland agriculture restriction policy in the Han River basin; and (3) to derive the monetary value of the total benefits generated by the water quality improvement policy, and to provide practical solutions that would be useful for the water management based on the benefit–cost analysis. This study makes two contributions to the literature on the impact of water quality management policy on households' preferences. In terms of methodological aspect, we use a double-bounded dichotomous choice CVM to identify the impacts of the land use restriction policy for water quality improvement and provide an empirical evidence of a statistically significant improvement in the double-bounded model fit by correcting potential preference anomalies. With respect to empirical aspect, we estimate the monetary value (benefits) which can be considered as an ecosystem service value derived from the improvement in water quality due to the implementation of the policy, conduct benefit–cost analysis, and provide practical solutions for the policy relevance.

Our paper is structured as follows. Section 2 presents the theoretical framework of the study, describing the CVM, random-effects interval-data regression models for the estimation of the welfare change associated with change in the environmental quality, and each of the preference anomalies in detail. Section 3 describes the study area, survey design, and administration. Empirical results and discussion are provided in Section 4. Based on the calculation of the benefits, benefit-cost analysis is conducted in Section 5. Conclusions and policy implications are summarized in Section 6.

Final focus of this study is in the Han River basin.

## 2. Methodology

This study deals with the elicitation of the monetary values that people would trade off their income against the improvement of water quality induced by a land use policy such as the highland agricultural restriction program. The land use policy would lead to betterment of environmental condition in terms of water quality, for example, and consequently lead to a change in utility/welfare of individual water users. Therefore, the concept of WTP for changes in utility/welfare can be used to value the outcome of the policy [33–35]. This follows the principle that public policy should be based on the aggregation of individual preferences [20].

A CVM is one of the most prevalent approaches [36,37] to estimate the total value (use and non-use value of an environmental good or service [38–40]. Regulating the use of non-marketed goods and services would limit their use to a so-called indirect use (non-use), which means stakeholders might benefit from the goods and services regardless of their intention to use [41]. Stated choices regarding changes in the policy identified via survey reveal actual (or true) behavior. This stated behavior can help to understand the differentiated effects of the policy [42–44]. This method inquires respondent's WTP for the change in environmental quality (e.g., hypothetical improvements in water quality) through the survey instrument in assessing the impact of the policy change on individual welfare [26,45]. Given that the responses to a contingent valuation study are usually treated as random variables, a random component is incorporated into the individual's utility function and the probability of survey response is linked to the WTP distributions based on the assumption that a respondent maximizes his utility [38,46].

Among different WTP elicitation methods, the popular double-bounded dichotomous choice question format is applied in this study [32,47–53]. Efficiency in the elicitation of WTP can be increased if repeated bid questions are used [46]. Respondents are asked about their WTP for proposed changes from given bid values. If the response to the initial bid is positive, a follow-up bid, higher than the initial bid, is asked, whereas, if the answer is negative, a follow-up bid, lower than the initial bid, is asked. Therefore, the method can directly provide a monetary (Hicksian) measure of welfare associated with a discrete change in water quality [46,54]. In the dichotomous choice (or closed-ended) question format, the probability that their WTP is equal to or greater than a certain amount of money $(B)$ that the individuals would pay for water quality improvement is:

$$\Pr(\text{yes}) = \Pr(WTP \geq B) \equiv 1 - F_c(B), \tag{1}$$

where $F_C(B)$ denotes the cumulative distribution function of WTP. A random utility model is a basic framework for analyzing dichotomous contingent valuation responses. In this model, a respondent certainly knows his utility function. This preference is, however, not entirely observable and is treated as a random variable. The random component of preferences $(\varepsilon)$ is, thus, directly incorporated into the indirect utility function, $V$ (Q, Y, P, Z, ε), where (Q) represents the scalar for water being valued, (P) is the vector of the prices of the market goods, (Z) is the socio-demographic characteristics, and (Y) is the respondent's income, in order to obtain a WTP distribution. In the status quo, the utility function of the respondent is given by $V(\text{Q}^0, \text{Y}, \text{P}, \text{Z}, \varepsilon)$. When a change in water quality from the status quo $(\text{Q}^0)$ to the proposed alternative occurs, the utility function in the final state $(\text{Q}^1)$ is equal to $V(\text{Q}^1, \text{Y} - \text{B}, \text{P}, \text{Z}, \varepsilon)$. In this case, the compensating variation: $\text{C} = \text{C}(\text{Q}^0, \text{Q}^1, \text{Y}, \text{P}, \text{Z}, \varepsilon)$, which presents WTP of the individual for a welfare gain (WTP = C) is defined as $V_1(\text{Q}^1, \text{Y} - \text{C}, \text{P}, \text{Z}, \varepsilon) = V_0(\text{Q}^0, \text{Y}, \text{P}, \text{Z}, \varepsilon)$. It also yields the respondent's maximum WTP for the change from $(\text{Q}^0)$ to $(\text{Q}^1)$. If the respondents' maximum WTP for the change from the initially deteriorated $(\text{Q}^0)$ to finally improved $(\text{Q}^1)$ water quality state is greater than or equal to the bid proposed $(B)$, they will say "yes". Following the dichotomous choice approach, the probability of "yes" answer can be written as:

$$\Pr(\text{yes}) = \Pr\left\{\text{C}\left(\text{Q}^0, \text{Q}^1, \text{Y}, \text{P}, \text{Z}, \varepsilon\right) \geq B\right\} = \Pr\left\{V\left(\text{Q}^1, \text{Y} - \text{B}, \text{P}, \text{Z}, \varepsilon\right) \geq V\left(\text{Q}^0, \text{Y}, \text{P}, \text{Z}, \varepsilon\right)\right\} \equiv 1 - F_c(B), \tag{2}$$

Let $\mu_{WTP}$ = E[WTP($Q^0$, $Q^1$, Y, P, Z, ε)], $\sigma^2{}_{WTP}$ = Var[WTP(Q$^0$, $Q^1$, Y, P, Z, ε)] and F(·) be the cumulative distribution function of the standardised variate $\omega = (\text{WTP} - \mu_{WTP})/\sigma_{WTP}$. The probability function can be rewritten as:

$$\Pr(yes) = 1 - \text{F}\left[\frac{\text{B} - \mu_{WTP}}{\sigma_{WTP}}\right] \equiv 1 - \text{F}(-\alpha + \beta B), \tag{3}$$

where $\alpha = \mu_{WTP}/\sigma_{WTP}$ and $\beta = 1/\sigma_{WTP}$. Equation (3), where the answer to the dichotomous choice question is a function of a monetary amount, is consistent with an economic model of maximizing utility (WTP) if it can be understood as the survivor function of a WTP distribution [38,46]. The econometric model used for WTP estimation is determined by the form of cumulative distribution function of WTP (C), $F_c(B)$, and the distributional assumption of the random component of the utility function [55]. If $F_c(B)$ follows a probit standard distribution and the model is linear, the expected mean WTP is:

$$E_\varepsilon(WTP/\alpha, \beta, \text{Z}) = \frac{\alpha \text{Z}}{\beta}, \tag{4}$$

where α denotes the vector of parameters, Z the vector of characteristics of the respondent, and β the coefficient on the bid level representing the estimated marginal utility of income.

In the double-bounded dichotomous choice CVM, a respondent $(j)$ is presented with the first bid amount $(B_1)$, and the second $(B_2)$ for the water quality improvement program. There are, thus, four possible responses: (1) both "yes" and "yes" responses ($WTP_j \geq B_2$); (2) a "yes" followed by a "no" ($B_1 \leq WTP_j < B_2$); (3) a "no" followed by a "yes" ($B_1 > WTP_j \geq B_2$); and (4) both "no" and "no" responses ($WTP_j < B_2$), which means that the set of observed bid responses (preferences) yields a set of intervals for estimating WTP [22]. Based on its structure, the researcher is provided with additional WTP intervals of respondents. Estimating the model that the additional information is incorporated into the likelihood function plays a crucial role in improving model accuracy [22]. In addition, decisions or choices within a range of intervals are common in daily life and are appropriate for the valuation practice where respondents are unacquainted with the environmental goods or services being valued [56]. It also makes it easy for respondents to reveal their true WTP [57,58]. With the double-bounded dichotomous choice data, we estimate the interval data probit model initially formulated by Hanemann et al. (1991) [21]. This is the format in which the double-bounded model provides the greatest efficiency gains, along with the least equivocalness [54].

The formulation of general econometric double-bounded model is $WTP_{ji} = \mu_i + \varepsilon_{ji}$, where $WTP_{ji}$ represents WTP of the *j*th respondent, and *i* = 1, 2 for the first and second responses, while $\mu_1$ and $\mu_2$ correspond to the means for the first and second responses, respectively. Under the assumption that $\mu = \mu_1 = \mu_2$, the WTP for the respondent (*j*) can be rewritten as $WTP_j = \mu + \varepsilon_j$. If the response is "yes-yes" in sequence ($B_2 > B_1$), the probability can be simplified as $\Pr\left(\mu + \varepsilon_j > B_1,\ \mu + \varepsilon_j \geq B_2\right) = \Pr\left(\mu + \varepsilon_j \geq B_2\right)$. If the response is "no-no" in sequence ($B_2 < B_1$), the probability can be simplified as $\Pr\left(\mu + \varepsilon_j < B_1,\ \mu + \varepsilon_j < B_2\right) = \Pr\left(\mu + \varepsilon_j < B_2\right)$. For "yes-no" and "no-yes" responses, the probability is that WTP falls in the interval. With the assumption that the random term is normally distributed, the respondent's contribution to the likelihood function is:

$$L_j\left(\frac{\mu}{B}\right) = \Pr\left(\mu + \varepsilon_j \geq B_2\right)^{YY} \times \Pr\left(B_2 - \mu > \varepsilon_j \geq B_1 - \mu\right)^{YN} \times \Pr\left(B_1 - \mu > \varepsilon_j \geq B_2 - \mu\right)^{NY} \times \Pr(\mu + \varepsilon_j < B_2)^{NN} \quad (5)$$

where *YY* ("yes-yes") = 1 and 0 otherwise; *YN* ("yes-no") = 1 and 0 otherwise; *NY* ("no-yes") = 1 and 0 otherwise; and *NN* ("no-no") = 1 and 0 otherwise.

The primary independence assumption developed by Hanemann et al. (1991) [21] of the double-bounded dichotomous choice CVM is that a respondent's preference (WTP) remains the same over the first and second payment questions (i.e., true $WTP_{ji} = WTP_{j1} = WTP_{j2}$), which means since observations are independent across the answers to the initial and subsequent payment questions, the preferences of respondents remain the same over the two answers. The double-bounded model, however, undergoes the preference anomalies signifying that the respondents' answer to the second question might be influenced by the first bid proposed to them [23,24,28]. In other words, the response to the second bid is not always independent from the first bid, indicating that different WTP values could be derived from the same respondent. This can, consequently, lead to inconclusive results since it is unclear whether WTP is correct or not [22,30]. Among these potential anomalies violating the assumption above, the two most common are anchoring bias and shift effects.

The anchoring bias follows if respondents who have uncertain information (a poor perception or description given by researchers as a base) on the good valued presume that the first bid is information on the true value of the good [24,25,59]. The respondents may, thus, anchor the value they place on a good in the first bid [60–63]. Based on the first bid, the respondent's anchored preferences ($\gamma$) could be an adjustment of their previous WTP $\left(WTP_{j1}\right)$. The posterior WTP $\left(WTP_{j2}\right)$ generated by the adjustment is, accordingly, a weighted average $(1 - \gamma)$ of the true WTP $\left(WTP_{j1}\right)$ and the level of the first bid $(\gamma B_1)$ provided by the researcher: $WTP_{j2} = (1 - \gamma)\, WTP_{j1} + \gamma B_1$, where $0 \leq \gamma \leq 1$ [22]. The more the anchoring effect ($\gamma$) increases the closer $WTP_{j2}$ is to $B_1$, thus increasing bias in the WTP estimate.

Shift effects arise if respondents interpret the first bid as information on the true cost of the policy proposed. Under this perception, a respondent who accepts the first bid may regard the second bid as an offer of additional payment for the same object. Similarly, when a respondent refuses the first bid payment, the follow-up question could be interpreted as an offer for a lower quality level of the object [22,23]. In other words, the respondents' preferences shift between $WTP_{j1}$ and $WTP_{j2}$. Supposing a respondent's response to the first payment question $\left(WTP_{j1}\right)$ is based on his true WTP, then the response to the second payment question $\left(WTP_{j2}\right)$ is based on his true WTP plus the shift effect of a follow up question. The shift effect is taken through the addition of a structural shift parameter (δ): $WTP_{j2} = WTP_{j1} + \delta$, where $0 < \delta$ [23]. A negative sign of the shift parameter shows that the follow up increases respondents' probability of rejecting the second bid [29], thus leading to decline in the WTP [22].

In terms of yea-saying bias, respondents exaggerate their true WTP in order to accept researcher's offers. In other words, they accept any bids proposed from the researcher without considering the bids as information on environmental goods valued [21], consequently, overstating their true WTP [26–28]. One possible explanation for the overstatement of the true WTP is the presence of the warm glow effect, which is an important factor affecting an individual's decision to make a contribution to the goods [64,65]. The contingent valuation response may reflect the individual's WTP for the moral satisfaction derived from contributing to the goods, not just the economic value of the goods. Therefore, WTP could be changed by levels of the moral satisfaction, which changes by the size of the contribution [66]. There are many other factors influencing the decision to privately contribute to the environmental goods such as social pressure, guilt or sympathy. All of these factors including the warm glow bias may encourage a respondent to have a higher tendency to say "yes" to the contingent valuation survey question [26]. The yea-saying bias is mostly involved in ascending bid sequences, thus resulting in an upward bias in WTP [26,27,29].

In the last stage of the contingent valuation survey, respondents are asked the open-ended question associated with the maximum WTP in order to explore deviant responses to the dichotomous choice question. When facing open-ended question, respondents who are confident of their WTP in the dichotomous choice question may answer consistently. Respondents who overstate or understate their WTP in the dichotomous choice question may, on the other hand, answer inconsistently.

The key of the potential anomaly between WTP values over the survey is the presence of anchoring bias, shift, and inconsistent response effects. To confirm our hypothesis that the respondents' WTP over the survey will be significantly influenced by the potential preference anomalies, our CVM data are transformed into a panel data structure following Whitehead (2002) [25] in iterative valuation questions. The econometric model for respondent $j = 1, \ldots, N$, who is observed at several time periods $t = 1, \ldots, T$, can be formulated as:

$$WTP_{jt} = \alpha_t + \delta D_j + \gamma B_1 D_j + UWTP_{jmax} D_j + \varepsilon_{jt} \quad (6)$$

where α is the intercept. δ, γ, and $U$ are the shift, anchoring, and inconsistency parameters, respectively. $WTP_{jmax}$ is the maximum WTP amount from open-ended questions at the last stage of the survey. $\varepsilon_{jt} = u_t + \nu_{jt}$, where $u_t$ is the individual specific error term (random effect) which varies across respondents but is time invariant. It explains the WTP due to the respondent's unobservable characteristics. $\nu_{jt}$ is the random error term which varies across time and respondents. With the assumption that both error terms are independently and identically distributed with mean zero $\left(\mathrm{N}\left(0, \sigma_u^2\right), \mathrm{N}\left(0, \sigma_v^2\right)\right)$, $D_j$ in the observed $WTP_{jt}$ which is located in interval, lower and upper bounds, denotes a dummy variable with the value of one $\left(D_j = 1\right)$ with follow-up questions in the double-bounded contingent valuation survey and zero otherwise [25].

If the anchoring bias exists, the anchoring parameter $(\gamma)$ will be positive $(0 < \gamma < 1)$ and statistically significant. If the shift effect is present, the shift parameter $(\delta)$ will be negative $(\delta < 0)$ and statistically significant. If the inconsistent response effect exists, the inconsistency parameter $(U)$ will be positive $(U > 0)$ and statistically significant. The correlation coefficient between the answers $(\rho = \frac{\sigma_v^2}{\sigma_u^2 + \sigma_v^2})$ is a measure of the ratio of the variance of the panel-level variance component in the model. In this study, the random-effects interval-data regression models in Stata (command "*xtintreg*") are used with the panel data. To focus on the examinations of the preference anomalies, socio-demographic variables are not included in the model.

# 3. Study Area, Survey Design and Administration

## 3.1. Study Area

The Han River basin lies on five administrative districts, namely Seoul, Incheon, Gyeonggi_do, Gangwon_do, and Chungcheongbuk_do. The basin includes Paldang Lake, Bukhan River and Namhan River (Figure 1). The area of the basin is 24,988 km$^2$ and accounts for 69.6% of the total area of these five administrative districts (35,927 km$^2$). The population of the basin is about 20 million, accounting for 71.5% of total population in the five administrative districts (approximately 29 million). Regarding land uses, forests cover the greatest area (69.1%) of the five administrative districts, followed by rice paddy fields (7.9%) and highland crops fields (7.7%) (Table 1). Some areas of the Han River basin are designated as water source protection zones following Article IV of the Han River Law. These areas correspond to 191.3 km$^2$ distributed in Gyeonggi_do (78.2%), Gangwon_do (11.0%), and Chungcheongbuk_do (10.8%) [67].

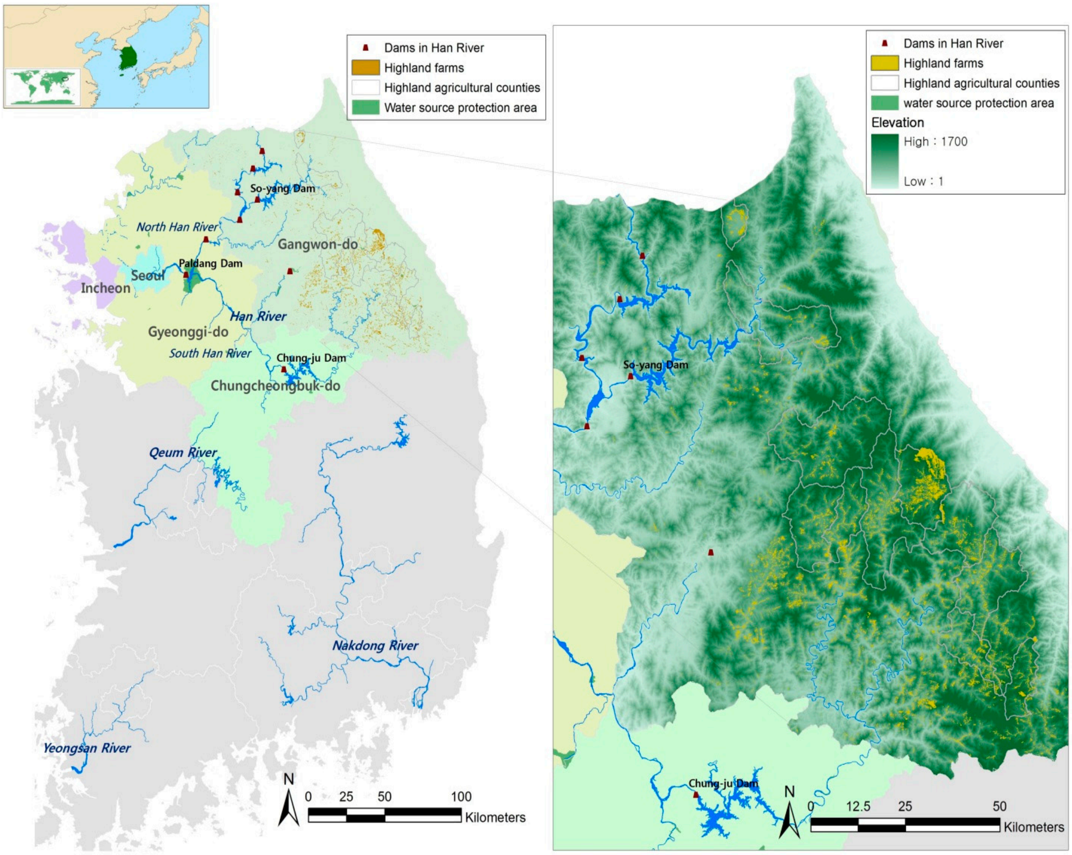


**Figure 1.** The Han River basin in South Korea, study area.

Due to the monsoon climate condition, it is essential to store water in the rainy season in preparation for the dry season. A large number of dams, Chungju, Hoengseong, and Goesanin in the Namhan River basin, and Peace, Hwacheon, Soyanggang, Chuncheon, Uiam, and Cheongpyeong in the Buckhan River basin, were built in the Han River basin during the last four decades for the development of hydroelectric power, flood control, and dealing with an increasing water demand for domestic, industrial and agricultural uses. It has been substantially needed to sustain the rapid economic growth and population expansion of the Seoul metropolitan area downstream of the Han River.

In 2011, the average biochemical oxygen demand (BOD) concentration in the Namhan River basin ranged from 0.47 to 3.48 mg/L. Total phosphorus concentration was also very high and originated from pollutants released from highly concentrated population areas, livestock farming and agricultural activities associated with the production of summer crops such as Chinese cabbage and radish in the highland areas of the basin. In particular, heavy rain events have caused the turbidity of water to worsen, leading to increases in water treatment costs and decreases in the quality of ecosystems [14]. For example, heavy rain events during typhoon Ewiniar in 2006 led to the export of a massive quantity of sediments to Soyang Lake and, in turn, caused long term discharge problems within the basin. For instance, the number of nepthelometric turbidity units (NTU) of water was twenty five times higher in 2006 (328 NTU) than in 2005 (13 NTU) [15].

**Table 1.** Area, population, and land use in the Han River basin.

| Administrative District | Land Use in the 5 Administrative Districts ($km^2$) | | | | | The Han River Basin | | Water Protection Zone |
|---|---|---|---|---|---|---|---|---|
| | Forest | Rice Paddy | Highland Vegetables | Others | Total | Area ($km^2$) | Population (Thousand) | Area ($km^2$) |
| Seoul | 148<br>(0.6) | 15<br>(0.5) | 13<br>(0.5) | 120<br>(0.6) | 605<br>(1.7) | 605<br>(2.4) | 10,575<br>(51.8) | 0<br>(0.0) |
| Incheon | 410<br>(1.7) | 184<br>(6.5) | 86<br>(3.1) | 140<br>(0.7) | 1029<br>(2.9) | 99<br>(0.4) | 980<br>(4.8) | 0<br>(0.0) |
| Gyeonggi_do | 5518<br>(22.2) | 1375<br>(48.5) | 952<br>(34.6) | 3191<br>(16.6) | 10,167<br>(28.3) | 7886<br>(31.6) | 7476<br>(36.6) | 149.6<br>(78.2) |
| Gangwon_do | 13,721<br>(55.3) | 590<br>(20.8) | 1036<br>(37.6) | 12,095<br>(62.9) | 16,693<br>(46.5) | 12,355<br>(49.4) | 914<br>(4.5) | 21.1<br>(11.0) |
| Chungcheongbuk_do | 5015<br>(20.2) | 669<br>(23.6) | 666<br>(24.2) | 3680<br>(19.1) | 7433<br>(20.7) | 4043<br>(16.2) | 487<br>(2.4) | 20.6<br>(10.8) |
| Total | 24,812<br>(100) | 2833<br>(100) | 2753<br>(100) | 19,226<br>(100) | 35,927<br>(100) | 24,988<br>(100) | 20,432<br>(100) | 191.3<br>(100) |

Note: The numbers in parentheses are the proportions of each contents, respectively.

The highland areas (over 400 m in altitude) of the Han River basin are well developed for highland agriculture during the summer season. Heavy rain events during the summer season further accelerate soil erosion and nutrient runoff in the highland fields where about 50% of the highland fields have more than 15° slope. Since agrochemicals are intensively overused, the fertility of the topsoil is poor. For example, highland Chinese cabbage and radish farmers in Gangwon Province apply 1.4 times more nitrogen (N), 2.4 times more phosphoric acid ($P_2O_5$), and 2.0 times more potassium oxide ($K_2O$) than the regulated standards [10]. This has led to a high level of concentrated turbid water in rivers and lakes of the basin, considerably decreasing water quality and degrading aquatic ecosystem [14,15].

### *3.2. Survey Design and Administration*

In this study, the head of households of the Han River basin was targeted for the contingent valuation survey. The survey includes questions related to the respondents' WTP for the land use policy such as the highland agricultural restriction program, as well as information about their socio-demographic characteristics. We provided the respondents with the information of contingent valuation scenario as a means of taking plausible future alternatives into account [68] on: (1) the importance of highland vegetable farming, which plays a vital role in the supply of domestic summer crops (since summer Chinese cabbage and radishes can only be produced in the highland agriculture fields due to the low temperature during the summer season, it is very critical to satisfy domestic consumers with their fresh produce); (2) the primary cause of soil erosion in the highland dry fields with steep slopes and the consequential turbidity in water; (3) their current and potential damages to the Han River basin; (4) the proposal of the highland agriculture restriction policy as its alternative; and (5) the need for financing mechanisms to support highland farmers for the conversion and the compensation for their income loss.

We held focus group discussions, which included 50 random residents over 19 years old recruited from the Han River basin (five administrative districts) to obtain information on their perceptions and preferences for water use and its quality. Based on this preliminary analysis using data gathered from the focus group meetings, four bid levels of payments in the double-bounded dichotomous choice format were set up as follows: Type A, KRW 2,000 (higher KRW 4,000 or lower KRW 1,000); Type B, KRW 4,000 (higher KRW 8,000 or lower KRW 2,000); Type C, KRW 6,000 (higher KRW 12,000 or lower KRW 3,000); and Type D, KRW 8,000 (higher KRW 16,000 or lower KRW 4,000). The first bid level of each type is proposed to the respondents. When the answer is positive, a doubled value for the bid is asked, and, when the answer is negative, a half value for the bid is asked. In terms of recognizing inconsistent responses, an open-ended question deriving the maximum WTP amount was asked at the last stage of the questionnaire. The first and second bids and ratio of acceptances for each bid are represented in Table 2.

**Table 2.** The first and second bids proposed, and proportion of acceptance in the double-bounded contingent valuation survey.

| "No" Bid Follow-Up (KRW) | Acceptance Ratio | First Bid (KRW) | Acceptance Ratio | "Yes" Bid Follow-Up (KRW) | Acceptance Ratio |
|---|---|---|---|---|---|
| 1,000 | 0.03 (0.04) | 2,000 | 0.52 (0.58) | 4,000 | 0.47 (0.34) |
| 2,000 | 0.01 (0.00) | 4,000 | 0.38 (0.38) | 8,000 | 0.57 (0.20) |
| 3,000 | 0.00 (0.00) | 6,000 | 0.36 (0.35) | 12,000 | 0.54 (0.09) |
| 4,000 | 0.00 (0.00) | 8,000 | 0.34 (0.18) | 16,000 | 0.72 (0.13) |

Notes: Respondents are asked for a yes-no answer to the WTP question with the first bids assigned randomly. If positive, a new question with a higher bid is asked ("yes" bid follow-up). If negative, a new question with a lower bid is asked ("no" bid follow-up). Acceptance ratio is the proportion of "yes" responses to each bid. The values in parentheses are the percentage after correcting inconsistent responses with open-ended WTPs.

Internet survey methods were employed instead of face-to-face interviews due to time and budget constraints. Sheehan (2001) [69] highlighted that many studies have touted the promise of e-mail surveys for research. With rapidly growing access rate to the Internet around the world in general and in South Korea in particular, researchers obtain many important advantages from online surveys by email or on the web, including cost efficiency and effective survey administration with respect to time and resource management [70–74]. By precise tracking of e-mailed surveys, the researcher can know the number of undeliverable e-mail as well as what time the e-mail survey was opened, replied to and deleted. This can improve sampling procedures [75]. People are apt to give longer open-ended responses to e-mail, which tend to be more candid, than other types of surveys. This can also increase response quality [75,76] by avoiding the problem of social desirability and interviewer biases, both well-known problems of face-to-face interview surveys [77].

For the sampling approach, we used a quota sample technique, as an important kind of non-probability samples. We set quotas on key variables, which shape who is chosen for the sample, so-called quota controls such as age, gender, and regional population. It could not only balance the bias inherent in using public hearings to gauge wider public sentiment, but also provide the additional information on respondents at a substantially lower cost and in much less time than a probability sample could [78,79]. The sample size of 2015 households with ±5% sampling error was accepted based on the 2011 demographics of the five administrative districts of the Han River basin. The CVM questionnaires were evenly and randomly distributed to each administrative district in order to prevent the survey from being substantially conducted in populous downstream areas and one bid level from being concentrated in one district.

The information on socio-demographic characteristics of households crucial for the valuation is widely used by planners and policymakers for programmatic purposes, in particular for the planning of community institutions, and for determining the community needs and requirements. In addition, changes in household characteristics have an impact on the decision-making regarding allocations and the distribution of goods and services [80,81].

## 4. Results and Discussion

### 4.1. Plofile of Surveyed Households

For the households surveyed in this study, the number of male (53.6%) was slightly larger than that of female (46.4%). In the contingent valuation survey, the responses of household head or their spouse are very important because they directly make it possible for the researcher to achieve a better idea about the variables that affect their true WTP and explain differences in consumption behavior regarding goods and services [82].

The response rate for the respondents who did not have children or did not reside together with their children (52.9%) was slightly higher than that of respondents who had children residing together (47.1%). The number of household members is negatively correlated with the WTP of the household for the highland restriction policy. This is because household budgets are tighter for larger families than for smaller families with the same income [83].

The number of surveyed households of upstream areas (40.1%) was almost the same as that of downstream areas (39.9%). Due to repeated water quality deterioration, downstream residents may be more likely to accept the highland agricultural restriction policy on water quality improvement, while upstream residents may be more likely to reject the policy because of the concern about a potential income loss from constraints of economic activities.

The average number of years respondents had stayed in their current residence was about 23 years. The respondents who lived longer in the Han River basin may give more reliable answers to WTP questions because they directly or indirectly observed more water quality problems [15]: 96.6% of the respondents agreed that the turbid water inflow prevention measure is needed for water quality improvement; 95.7% also agreed that the individuals have to take responsibility for conserving and managing water quality.

The average annual income of respondents was in the range of 35.0 to 40.0 million KRW and those who earned from 30.0 to 39.9 million KRW per year (20.9%) were the largest proportion. Income variable tends to have positive direction in payment for social benefit improvement because respondents with higher levels of income may be more likely to desire clean and safe drinking water [84]. Table 3 presents profile of households surveyed in this study method.

**Table 3.** Profile of households surveyed in the double-bounded contingent valuation method.

| Questions | Examples | Proportion (%) |
|---|---|---|
| Annual total household income | 1. Less than 2.0<br>2. 2.0 to less than 3.0<br>3. 3.0 to less than 4.0<br>4. 4.0 to less than 5.0<br>5. 5.0 to less than 6.0<br>6. More than 6.0 | 14.1<br>17.3<br>20.9<br>16.0<br>11.5<br>20.2 |
| Gender | 1. Male<br>2. Female | 53.6<br>46.4 |
| Household size | 1. No children<br>2. Residing with children | 52.9<br>47.1 |
| Current residence (downstream: 1, 2; midstream: 3; upstream: 4, 5) | 1. Seoul<br>2. Incheon<br>3. Gyeonggi_do<br>4. Gangwon_do<br>5. Chuncheongbuk_do | 19.9<br>20.0<br>20.0<br>20.1<br>20.0 |
| Number of years respondent has resided in the current residence (year) | | 22.5 |
| Individual importance of water quality conservation and management | 1. Important<br>2. Unimportant | 95.7<br>4.3 |
| Need for the turbid water inflow prevention measure to the Han River basin | 1. Necessary<br>2. Unnecessary | 96.6<br>3.4 |

*4.2. Correcting the Potential Preference Anomalies and Willingness to Pay*

Around 54.0% of the respondents accepted the highland agricultural restriction program for water quality improvement of the Han River basin. In addition, we detected that about 21.4% of the respondents who are in favor of the highland restriction policy gave lower WTP values in the open-ended questions than the accepted bid in the follow-up questions (inconsistency between the open-ended WTP value and the chosen closed-end bid in intervals). Figure 2 shows that although the bid level in the "yes" bid follow-up question increases, the proportion of "yes-yes" responses of the 54% respondents accepting the policy increases, violating the basic consumer theory. Regardless of a rise or fall in the bid level, the proportion of "yes-yes" responses of the respondents who made contradictory answers across the closed-ended and the open-ended questions was very high, showing 100% probability for bid choice. This might come from some factors including the yea-saying bias. As mentioned earlier, the presence of yea-saying bias in the CVM may be motivated by the warm glow effect, which results from the private contribution (moral satisfaction, social pressure, guilt, and sympathy) to the environmental goods [26]. On the other hand, as the bid levels increase, the proportion of "yes-yes" responses of the respondents who gave consistent answers to the closed-ended and the open-ended questions decreases.

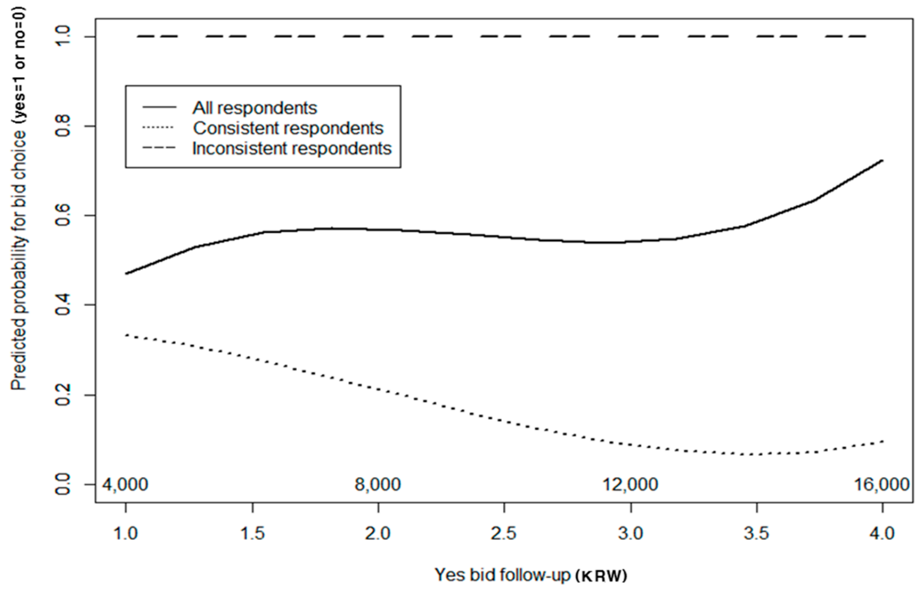


**Figure 2.** Choice probability of the consistent and inconsistent responses to the "yes" bid follow-up question.

Table 4 presents the results of the random-effects interval-data regression models. The naïve model is defined as the base random-effects interval-data model, which is unconcerned about possible preference anomalies. The shift effect is introduced as a dummy variable ($D_j$), defined as the shift effect model. The results indicate the negative sign of this variable ($\delta = -1273.20$), which is occasionally mentioned as the nay-saying effect (a downward shift in WTP). While this is contrary to the yea-saying effect founded by Chien et al. (2005) [26], it is consistent with Gelo and Koch (2015) [22], Alberini et al. (1997) [23], and Whitehead (2002) [25] ($\delta < 0$).

In the anchoring effect model, $B_1D_j$ is introduced to grab potential anchoring bias, i.e., respondents' answers to the second payment questions may be affected by the first bids. The results show that the coefficient of the anchoring variable $(B_1D_j)$ is negative $(\gamma = -0.04)$ and statistically significant $(p < 0.01)$. This violates the assumption that if the second response is anchored to the first bid amount the coefficient of $B_1D_j$ will be positive and its value lies in between zero and one $(0 < \gamma < 1)$. As stated by Whitehead (2002) [25], the negative anchoring effect might be attributed to model misspecification because the starting bid amount is interacted with the shift dummy variable.

While our result is in line with Gelo and Koch (2015) [22], and Whitehead (2002) [25], it is opposed to Chien et al. (2005) [26] and Flachaire and Hollard (2006) [28].

To confirm that the anchoring bias may be incorrectly capturing other effects, we consider the concurrent existence of both shift and anchoring effects, defined as the shift–anchor model. The results of this model indicate that the shift effect is negative and statistically significant, which is identical with the single shift effect model. The anchoring effect is positive and statistically significant, which is corresponding to the assumption of the standard anchoring effect model showing presence of anchoring bias.

Finally, the shift–anchor–inconsistency model, considering the combination of anchoring, shift, and inconsistent response effects, shows that the results of shift and anchoring effects accord with the assumption of the standard shift and anchoring effect models. The inconsistent response effect is positive ($U = 0.06$) (a upward shift in WTP) implying the yea-saying effect is statistically significant. Some previous studies [22,85,86] classified the inconsistent response into a "no" response to the second bid for controlling the yea-saying behavior. However, we directly consider the inconsistent responses in the shift–anchor–inconsistency effect interval-data model, which could be the main difference.

**Table 4.** Parameter estimates of the random-effects interval-data regression models.

| Model | Naïve | Shift | Anchor | Shift-Anchor | Shift-Anchor-Inconsistency [1] |
|---|---|---|---|---|---|
| **Variable** | **β (std.err)** | **β (std.err)** | **β (std.err)** | **β (std.err)** | **β (std.err)** |
| α | 4,977.94 *** (34.76) | 5,038.13 *** (54.09) | 5,117.47 *** (53.04) | 5,008.51 *** (149.31) | 5,025.02 *** (30.40) |
| δ | | −1,273.20 *** (43.89) | | −2,012.2 *** (214.75) | −2,127.36 *** (71.76) |
| γ | | | −0.04 *** (0.01) | 0.50 *** (0.05) | 0.42 *** (0.02) |
| U | | | | | 0.06 *** (0.01) |
| ρ | 0.99 *** | 0.99 *** | 0.99 *** | 0.99 *** | 0.99 *** |
| Log likelihood | −1,750.71 | −1,656.01 | −1,744.76 | −1,469.50 | −1,424.87 |
| Observations | 1,091 | 1,091 | 1,091 | 1,091 | 1,091 |
| Mean WTP | 4,913.23 | 3,715.98 | 5,050.90 | 2,957.82 | 2,860.46 |

Note: α is the intercept; δ, γ, and $\eta$ are the shfit, anchroring, and inconsistency paraemters, respectively; and ρ is the coefficient of the proportion of the total variance contributed by panel-level variance components (sigma_e and sigma_u). *** $p < 0.01$; [1] We also estimated the random-effects interval-data regression models with socio-economic variables such as income, gender, household size, etc., and examined the goodness of fit compared to the shift–anchor–inconsistency model. This result shows that the shift–anchor–inconsistency is statistically better than the other model. Thus, we used the shift–anchor–inconsistency model without socio-demographic variables in order to estimate the mean WTP per household.

For evaluation of model fit between the models, we performed the log-likelihood test. In comparison with the two models which have high log likelihoods, shift–anchor–inconsistency versus shift–anchor, the results show that the shift–anchor–inconsistency model, which considers shift, anchoring, and inconsistent response effects all together, results in a statistically significant improvement in model fit.

Another focus of this study lies on the elicitation of the respondents' WTP for the highland agriculture restriction policy in the Han River basin. The mean WTP values in Table 4 were adjusted to constant 2013 Korean currency (KRW) by applying a Consumer Price Index (CPI) provided by Statistics Korea [87] to take into account inflationary effects. On the basis of the shift–anchor–inconsistency model, the monthly average WTP per household was estimated at KRW 2,861. This WTP value sharply declined by 41.8% (around KRW 2,053) compared to that of the naïve model (around KRW 4,913), which does not consider any preference anomaly. As each of the potential preference anomalies is, in turn, corrected, the log likelihoods increased and the WTP values decreased. This result indicates that correcting shift, anchoring, and inconsistent response effects simultaneously contribute to increasing the goodness of fit of the model, consequently deriving much better or more reliable WTP estimates. We do not take the single anchor model into consideration since this model violates the assumption about the range of $\gamma$ parameter $(0 < \gamma < 1)$.

## 5. Benefit Calculations

Final focus of this study is the calculation of the benefits generated by water quality improvement due to the implementation of the highland agriculture restriction policy in the Han River basin. Before the benefit calculation, we need to define who these benefits from the policy belong to, or who the beneficiaries are. In South Korea, the Han River basin is a primary source of drinking water supply as well as providing many tangible and intangible benefits to its mid- and downstream areas. Based on the benefits provided by the Han River, the mid- and downstream areas have been economically developed (urban or metropolitan areas) while the upstream areas have not (rural areas) [17]. Although the water use charge has been, since 1999, implemented for supporting communities and their people in the upstream areas and water quality improvement programs in the basin, some problems pertaining to the distribution of the benefits still remain along with frequent turbid water discharge problems.

The implementation of the highland agriculture restriction policy aiming at water quality improvement patently restricts economic activities of the upstream residents including farmers. Instead, the mid- and downstream residents are entirely benefited by the policy for the improvement of water conditions. Based on this circumstance, we calculate the total benefit generated by the highland agriculture restriction policy and compare the benefits to the costs associated with land use policies to protect and improve water quality in the basin.

The result of calculated benefits to the mid- and downstream areas obtained from the land use restriction policy in the upstream areas is shown in Table 5. Based on the population provided by Statistic Korea in 2013 [87], approximately 8.7 million households live in the mid- and downstream areas and the total benefits are calculated to be around KRW 297.73 billion per year. The downstream residents had the highest benefits at around KRW 156.20 billion per year and the midstream residents' benefits were around KRW 141.53 billion per year (see Table 5).

**Table 5.** Total benefit of the mid- and downstream areas estimated from the land use restriction policy in the upstream areas.

| Administrative Province | Location | Household | Mean WTP (KRW/Month) | Total Benefit (Billion KRW/Year) |
|---|---|---|---|---|
| Seoul | Downstream | 3,567,727 | 2,860.46 | 122.46 |
| Incheon | | 982,811 | | 33.74 |
| Gyeonggi_do | Midstream | 4,123,072 | | 141.53 |
| Total | | 8,673,610 | | 297.73 |

Note: The number of households and the annual average income per household are obtained from the Statistics Korea in 2013.

We made a comparison of these total benefits with the costs associated with land use policies to protect and improve water quality supported by the water use charge. The water use charge is mainly used for community support programs in upstream areas of the basin, upstream farmland purchase and riparian zone management, construction and operation of waste treatment facilities, etc. We considered the costs of the upstream farmland purchase and riparian zone management as a comparison item with the total benefits. In 2013, the costs were around KRW 129.44 billion and accounted for 29.8% of the total charge, the second largest proportion after the construction and operation of waste treatment facilities. Table 6 shows the results of benefit–cost comparison. The net benefit is around KRW 168.29 billion (see Table 6).

**Table 6.** Comparison result of the benefits and costs from the highland agriculture restriction policy in the Han River basin.

| Administrative Province | Total Benefit (A) (Billion KRW/Year) | Total Cost (B) (Billion KRW/Year) | Net Benefit (A − B) |
|---|---|---|---|
| Mid- and downstream areas | 297.73 | 129.44 | 168.29 |

The costs related to the upstream farmland purchase and riparian zone management in 2013 increased double compared to that in 2012 [88]. This indicates that, to prevent the high soil erosion from highland agricultural fields, as a prime pollutant, from inflowing to the basin, the investment cost of purchasing upstream farmland has gradually increased. However, many of the upstream lands purchased (non-farming areas) are not relevant to the highland agriculture. Since the highland farmers who actually earn their income from such summer crop production have deep concern for their heavy income loss, most of them do not want to give up farming in the highlands.

To improve the negotiation for practical purchase of the high mountainous agricultural fields, valid compensation for the highland farmers' income loss should be a high priority. To realize this, there is a need to increase the unit cost of the highland purchase, which means more costs should be invested in the highland purchase programs.

Operational problems of the water use charge along with frequent turbid water discharge problems in the basin exist. Wasteful and inefficient fund use for water quality control, e.g., overinvestment in waste treatment facilities and temporary expedients for supporting upstream communities, has been criticized by all local communities in the Han River basin [14,89]. If these inefficiently used costs could be invested in other items such as the highland agriculture field purchase and riparian zone management, problems in terms of financing would be to some extent resolved.

## 6. Conclusions and Policy Implication

This study aims at: (1) examining potential preference anomalies such as shift, anchoring, and inconsistent response effects when the double-bounded dichotomous choice question format is used in the contingent valuation survey; (2) eliciting WTP of the respondent for the highland agriculture restriction policy on water quality improvement in the Han River basin, South Korea; and (3) comparing the total benefits from the policy to the total cost of land use restriction policies to improve water quality. Before implementing the land use policy, it is necessary to examine the preferences of residents for the policy. This result could be used to value the outcome (i.e., change in utility/welfare of individual water users through water quality improvement). However, the use of water as an environmental (or non-market) good frequently accompanies non-priced side effects (i.e., environmental externalities). Therefore, the contingent valuation method could be used in order to elicit the preferences (WTP) and carry out economic valuation for the water policy making. When respondents are, however, faced with new or unfamiliar environmental goods or services, they are likely to experience uncertainty [90] such as systematic WTP response bias [32,85], which is caused by a lack of experience with market for non-traded goods [22]. Thus, preference anomalies of respondents may exist and bring about incorrect assessment of the water policy.

In this study, these potential preference anomalies are tested by the random-effects interval-data regression models. The empirical results indicated that significantly anomalous preferences are presented in our survey data. As the shift, anchoring, and inconsistent response effects were corrected in order, the statistical precision of parameter estimates was also improved. After correcting the potential preference anomalies, estimated welfare gains are on average KRW 2,861 per month per household. Based on the WTP estimate, the total benefits from the highland agriculture restriction policy are around KRW 297.73 billion and the total costs are around KRW 129.44 billion. The net benefit is, thus, around KRW 168.29 billion.

In order to make practical land use restriction policies, the valid compensation for the highland farmers' income loss is necessary and this could be realized through increase in the unit cost of the highland purchase. In terms of financing arrangement, wasted or inefficiently used costs (e.g., overinvestment in waste treatment facilities, and temporary upstream community support) should be spread across other cost items, in particular over the purchase program of the high mountainous agriculture fields. The results of our analysis provide South Korean legislators and land use policy makers with useful information for the approval and operationalization of the policy.

As stated by the Millennium Ecosystem Assessment [91], water bodies provide various ecosystem services such as food provision, biodiversity, recreation, tourism, amenities, drinking water, etc. to society. In this study, we consider only one service, water quality improvement generated by land use restriction policy. The total benefits estimated from our analysis are also associated with the water quality improvement due to the implementation of the policy.

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