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Evaluating the Economic Benefits of Tightening Regulations on the Use of Toluene, a Hazardous Chemical, in South Korea

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Abstract: The South Korean government currently designates toluene as a hazardous chemical, only limiting its use in products that are feared to be harmful. Since no measures to prohibit the use of toluene have been implemented, toluene is frequently detected in amounts that exceed the limit. Accordingly, the Government is considering implementing a plan to tighten the current regulations related to the use of toluene to prevent the occurrence of diseases caused by exposure and addiction to it. Therefore, the most important objective of this research is to evaluate quantitatively the economic benefits arising from the implementation of the plan in South Korea. To achieve the purpose of this paper, contingent valuation, an economic technique for analyzing data collected from a survey of people based on economic theory, is applied. For this purpose, a survey of 1000 people nationwide is conducted, and an analysis model that is well received in the literature is adopted. In other words, the annual willingness to pay (WTP) per household to strengthen the regulations to reduce the human health risks of toluene is evaluated to calculate its economic benefits. All the estimated WTP models secure statistical significance. The average WTP per household per annum is derived as KRW 3394 (USD 3.02). Considering that the country contained 20,573,060 households in 2021, the national economic benefits are calculated as KRW 69.82 billion (USD 62.23 million) every year. It is difficult to estimate accurately the costs incurred by tightening the regulations on toluene use, but they do not seem to exceed the benefits. Because tightening the regulations would be socially desirable, the Government would be justified in making this decision.

Keywords: toluene; hazardous chemical; human health risk; economic benefit; contingent valuation

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1. Introduction

Toluene, which is also referred to as toluol, methylbenzene, and phenylmethane, is a compound obtained by substituting one hydrogen atom of benzene with a methyl group. It is a transparent, colorless liquid with a unique scent and is a volatile substance that easily diffuses into the air. Moreover, it has the properties of catching fire easily and floating in water because it is less dense than water and is insoluble. Toluene, which is an important compound in organic synthesis chemistry, is widely used as a raw material for synthesizing many materials and as a solvent. For example, it is used in the manufacture of aviation fuel, automobile fuel, paints, adhesives, ink, nail polish, stain remover, and other chemicals [1,2]. In particular, the thinner used as a solvent for paint is a mixture of ethyl acetate and the like using toluene as the main component (65%), and its toxicity is due to toluene [3].

Toluene vapor is heavier than air, making it easy for the human body to encounter, inhale, and absorb [4]. In general, toluene is discharged into the air when manufacturing chemicals, automobiles, rubber, and plastic products, and it is discharged from gas stations because it is contained in gasoline. In addition, toluene is also discharged from paints, interior materials using adhesives, and furniture. Because toluene is easily decomposed

in the body and does not remain in the body for a long time, the concentration of toluene generated in a general environment does not affect the human body significantly.

However, exposure to toluene at high concentrations in a short period of time can irritate the skin and eyes. Long-term exposure, in particular, can cause eye tremors or problems with athletic performance and affect the nervous system, for instance producing headaches, dizziness, memory impairment, or hallucinations [5–7]. Therefore, the South Korean government is urging people to be careful not to excessively inhale it when using toluene-based adhesives or paints [8]. Furthermore, toluene is the main cause of new car syndrome or new house syndrome, which causes symptoms such as chronic headache, respiratory and skin diseases, and asthma. In South Korea, atopic dermatitis in children is becoming a social problem, and toluene is known to be the causative agent of this [9].

Toluene causes central nervous system disorders when exposed to the human body and has heart and blood toxicity [10]. However, it was evaluated that there was no carcinogenicity [11]. Short-term toluene exposure in humans causes headache, dizziness, feeling of intoxication, sleepiness, hallucinations, and so on as an acute toxic effect [12–14]. Repeated exposure to toluene results in ophthalmoplegia, retinal impairment, ocular flutter, and so forth [15–22]. Long-term exposure to toluene also leads to central nervous system disorders, including decreased neurological performance, impaired vision, and ataxia, severe muscle paralysis, anesthesia, and death [10]. Thus, European Chemical Bureau [14] suggested that toluene is human-hazardous and the risk of exposure to it should be limited.

Accordingly, the Government currently designates toluene as a harmful substance and only limits its use in products that are feared to cause harm [8]. For example, for detergent and dye products, the presence of toluene must be marked on the product label [23]. For adhesives and pesticides, the amount of toluene detected must be small or non-existent. However, since the toluene use ban has not been executed, the amount of toluene detected is often higher than the accepted levels. Thus, the Government is considering implementing a plan to tighten the current regulations related to the use of toluene to about half the current level to prevent the occurrence of diseases caused by toluene exposure and addiction.

A considerable budget is necessary for the Government to implement this tightening. For example, evaluating the harmfulness of toluene, investigating the impact of the tightening on industries that manufacture or utilize toluene, and monitoring whether the tightening works well are costly. If the tightening of the regulation on toluene use is introduced, the number of companies affected reaches about six thousands. Since there are only less than 10 people in the Government who enforce and manage the tightening, a large number of additional personnel are needed to monitor whether the companies comply with the tightened regulation properly. In addition, since the companies are located in industrial complexes throughout the country, local monitoring organizations must be established, or government-related officials must travel around the country every time to implement practical monitoring.

Therefore, additional budgets must be secured to monitor the proper operation of the tightened regulation. For the tightening of the regulation to be justified, the economic benefits arising from it must be greater than the costs incurred. Therefore, the primary purpose of this research is to evaluate quantitatively the economic benefits ensured by the tightening.

To achieve the purpose of this paper, the contingent valuation (CV) approach, one of the economic techniques for collecting data from a survey based on economic theory and analyzing the collected data, was applied. A survey of 1000 people nationwide was conducted, and the models that are well accepted in the literature were adopted. The remainder of this article consists of three sections. The next section reports the methodology utilized in this research, and the third section presents the results and a discussion.

2. Methodology

2.1. Determination of the Evaluation Method

As mentioned earlier, this study applies the CV approach to evaluating the economic benefits of tightening regulations to reduce the risk caused by toluene. The rationale for this can be summarized in the following four ways. First, the concept of economic benefits is based on microeconomics, and CV corresponds to this. In microeconomics, the economic benefits arising from the consumption of a particular good can be computed as the underside of the demand function for that good, which means the willingness to pay (WTP).

The demand function is expressed as the marginal WTP function in other terms. In other words, the economic benefits in this study are evaluated as the WTP. CV is a technique that allows respondents to provide information on the lower area of the demand function through a well-designed survey and enables researchers to analyze the information to obtain the lower area of the demand function. In this way, CV directly induces the WTP.

Second, the application of CV has been highly recommended in several relevant studies in relation to the method of estimating the economic benefits obtained from reducing the risk of hazardous chemicals. For example, Smith et al. [24] argued that CV is an appropriate way to assess the economic benefits of reducing in hazardous waste risks. Carson [25] presented several factors to be observed when applying CV, pointing out that it may be useful in measuring the economic benefits of a good that is not traded on the marketplace. The European Chemicals Agency [26] recommended the application of CV in evaluating the economic benefits arising from preventing human health damage from harmful chemicals. Ávalos et al. [27] proposed the use of CV to appraise the economic benefits of hazardous waste management.

Third, the application of CV is consistent with related previous studies. For example, Corso et al. [28] adopted CV for estimating the economic benefits of mobility risk reduction. von Stackelberg and Hammitt [29] used it to evaluate the economic benefits of decreasing human health risks by reducing exposure to chemicals. Lee et al. [30] applied CV in assessing the economic benefits arising from halving the number of leakage accidents of hazardous chemicals in a case study in South Korea. Liu et al. [31] appraised the economic benefits related to improving the air quality affecting the working environment of factory workers through CV. Huang et al. [32] and Khan and Damalas [33] estimated the WTP for reducing chemical industry accidents risk and reduction of pesticide health risk, respectively, using CV. Table 1 presents a summary of main findings from some previous related studies applying CV.

Fourth, CV is the most frequently applied technique in the related former studies for estimating the economic value of a non-market good [34–40]. Of course, the choice experiment (CE) method is also widely applied, but for the application of the CE method, various attributes related to the good to be evaluated must be well defined, and researchers tend to suffer from statistical estimation complexity. On the other hand, CV is easy to apply, and the statistical estimation of the CV model is not complicated.

Table 1. A Summary of main findings from some previous related studies applying contingent valuation.

Sources	Objects to Be Valued	Countries	Payment Unit	Main Results of Willingness to Pay
Corso et al. [28]	Reduction in mortality risk	United States	Purchase of a car	USD 159 to 362 per year
von Stackelberg and Hammitt [29]	Reduction in developmental health risk	United States	Not available	USD 466 per intelligence quotient point for decreasing exposure to polychlorinated biphenyls
Lee et al. [30]	Reduction in incidence of hazardous chemical spill accidents by half	South Korea	Household	KRW 3830 (USD 3.41) per year

Table 1. *Cont.*

Sources	Objects to Be Valued	Countries	Payment Unit	Main Results of Willingness to Pay
Liu et al. [31]	Improvement in air quality	China	Not available	More than 53% of the total respondents have positive willingness to pay
Huang et al. [32]	Reduction in chemical industry accidents risk	China	Person	USD 9.36, 16.80, and 19.78 per month for reducing the risk 20%, 50%, and 80%, respectively
Khan and Damalas [33]	Reduction in pesticide health risk	Pakistan	Farmer	USD 5.8 per year

2.2. Preparation of the Questionnaire

For the purpose of applying CV, a questionnaire to be presented to respondents had to be prepared before conducting a field survey. This task involved three main steps. First, the target to be evaluated must be specifically determined. Basically, CV evaluates a change from one state to another rather than evaluating the consumption of a certain good. Therefore, the researchers should clearly determine the target state as well as the current state. The current regulations related to the use of toluene and the target regulations covered in this study are summarized in Table 2. In short, the evaluation target in this CV study can be said to be a change from the current regulations to the target regulations.

Table 2. Current and target regulations on toluene employed in this study.

Products Including Toluene	Current Regulations	Target Regulations
Chemicals containing toluene	Less than 85.0% content	Less than 42.5% content
Thinner	Less than 85.0% content	Less than 42.5% content
Paint and ink	If included state that this fact should be indicated on the product	Limit the amount of toluene used
General glue	Less than 5000 mg per kg	Less than 2500 mg per kg
Spray glue	Less than 1000 mg per kg	Less than 500 mg per kg
Glue for wigs, eyelashes, and nails	Less than 20 mg per kg	Less than 10 mg per kg

Second, the method of inducing the WTP should be determined. This method is largely composed of open-ended questioning and closed-ended questioning. Open-ended questioning is to ask the WTP directly, which can cause respondents to express a protest bid response or engage in strategic behaviors [41]. Thus, it is not advocated in the literature [42]. However, closed-ended questioning involves asking an interviewee whether she/he agrees to pay a specific amount. Since this questioning is known to induce an incentive-compatible response, it is preferred in the literature. There are various types of closed-ended questioning, but in this study, the one-and-one-half-bounded (1.5B) model presented in the paper of Cooper et al. [43] was applied.

Third, the payment vehicle must be determined. In this study, income tax, a representative national tax in South Korea, was used for this purpose. Four criteria were considered to determine the payment vehicle. The first criterion is that the payment vehicle must be familiar to the respondents. In this regard, income tax, the payment vehicle adopted in this study, is quite familiar to respondents in South Korea. The second criterion is that the payment vehicle should not be too limited to ordinary expenditure. For example, electricity bills or water bills may be ordinary expenditures and can cause respondents to report amounts lower than their true WTPs. The third criterion is that non-specific payment vehicles such as donations and funds should not be used. In particular, donations and funds, not taxes, are quite unfamiliar to South Koreans. The fourth criterion is that the payment vehicle should be explicitly related to the source of funding for the supply of a good to be evaluated. For tightening of the regulation on toluene, the injection of national taxes was inevitable, and income tax must be an

important part of national taxes. Since income tax met all four of these criteria, this study adopted income tax as the payment vehicle.

In addition, the payment period, the number of payments, and the payment unit concerning the payment vehicle should be decided. The payment period was set as the next 10 years, the number of payments as once a year, and the payment unit as income tax per household, not personal income tax. Let X be a specific bid amount provided to the interviewees. Therefore, the question "Does your household intend to pay an additional amount of X Korean won per year for the next 10 years for reducing the incidence of toluene exposure (e.g., atopic dermatitis) by tightening current regulations on toluene by 50%?" was presented to the interviewees. The main part of the survey questionnaire adopted in this study is given in Appendix A.

2.3. Execution of the CV Survey

Four major matters related to the execution of the CV survey had to be determined. First, the sample size must be properly determined. In this study, it was decided to collect 1000 observations because the Korea Development Institute [44] provided guidelines related to CV surveys conducted in the country and recommended that the number of observations should be 1000. In addition, Arrow et al. [45] suggested the use of 1000 observations, and this was supported by Sajise et al. [42] and Mariel et al. [46].

Second, the subject of the interview in the survey should be selected from among researchers and experienced interviewers belonging to a professional polling firm. In this regard, this study adopted the latter for the following reasons. The authors have limitations in their ability to perform scientific sampling across the country. In addition, there is a time limit, which will make it difficult for only a few researchers to conduct surveys around the country. The interview skills of researchers are also far inferior to those of the trained interviewers belonging to the firm. Consequently, a sufficient budget was secured by the authors. A survey company with substantial experience in CV surveys was given the responsibility for the sampling and survey.

Third, the unit of the survey should be chosen. First, one must decide between individuals and households. If the respondent is determined as an individual, difficulties arise when selecting the scope of the individuals; for example, whether elementary, middle, and high school students and the elderly, aged 65 and older, are included in the survey should be determined. However, when households are established as the unit of the survey, these difficulties do not arise. Therefore, in this study, the unit of the survey was determined as households. Next, the subject who will respond to the survey as the representative of the household should be identified. In this study, in compliance with the recommendations of the Korea Development Institute [44], the subjects were set as household heads or spouses of household heads aged 20 to 65.

Fourth, an appropriate survey method should be adopted. Among various survey methods, this study selected the method of receiving responses to the questionnaire through person-to-person individual interviews during which the interviewer visited the households. This method requires a significant amount of time and costs; however, it makes it easier for interviewers to explain fully why the survey was designed and implemented with respondents rather than using mail, phone calls, or the Internet. For this reason, Arrow et al. [45] and the Korea Development Institute [44] supported the survey method selected in this study.

2.4. Analysis of the CV Data

Applying the aforementioned 1.5B model results in one or two discrete choice responses for each respondent. The respondent's WTP was denoted as S. In the 1.5B discrete choice question, two predetermined bids, T^L and T^H ($T^L < T^H$), were assigned to each interviewee. About 50% of the interviewees were presented with T^H first. If an interviewee answers "yes" to the payment of T^H, $T^H < S$ was obtained. If an interviewee answers "no" to the payment of T^H, T^L was additionally presented. If "yes" was the

response, $T^L < S < T^H$ was obtained, and if "no" was the response, $S < T^L$ was observed. Respondents with $S < T^L$ were further divided into $S = 0$ and $0 < S < T^L$ through an additional question.

Eventually, each respondent provided one of four responses: "yes", "no-yes", "no-no-yes", and "no-no-no". Four indicator variables concerning the responses may be defined as I^Y, I^{NY}, I^{NNY}, and I^{NNN}. These responses or indicator variables correspond to $T^H < S$, $T^L < S < T^H$, $0 < \mathrm{S} < T^L$, and $S = 0$, respectively. At this time, $S < 0$, negative WTP, was not considered because negative WTP means that compensation is required, but this cannot happen and is not reasonable.

The other half of the respondents were presented with T^L first. As in the previous case, in which half of the respondents were provided with T^H first, each respondent's answer will be one of the following four: $T^H < S$, $T^L < S < T^H$, $0 < \mathrm{S} < T^L$, and $S = 0$. The indicator variables corresponding to each are defined as J^{YY}, J^{YN}, J^{NY}, and J^{NN}, respectively. The modeling of the responses should reflect the fact that the last response is point data with a value of zero and the other three are interval data. One of the models suitable for dealing with positive interval data as well as zero observations at the same time is the spike model given in Kriström [47]. A modified version of the model to suit the 1.5B CV data was applied in this study [48].

Let T_k and $F_S(\cdot)$ be the bid offered to respondent k ($k = 1, \ldots, K$) and the distribution function S, respectively. The $F_S(\cdot)$ adopted in this paper is defined as:

$$F_S(T; m_0, m_1) = \begin{cases} [1 + \exp(m_0 - m_1 T)]^{-1} & if\ T > 0 \\ [1 + \exp(m_0)]^{-1} & if\ T = 0 \\ 0 & if\ T < 0 \end{cases} \quad (1)$$

where m_0 and m_1 are the parameters of $F_S(\cdot)$ to be estimated.

The log-likelihood function covered in this study is as follows:

$$\begin{aligned} \ln L = \sum_{k=1}^{K} \{ & (I_k^Y + J_k^{YY}) \ln [1 - F_S(T_k^H; m_0, m_1)] + (I_k^{NY} + J_k^{YN}) \ln [F_S(T_k^H; m_0, m_1) \\ & - F_S(T_k^L; m_0, m_1)] + (I_k^{NNY} + J_k^{NY}) \ln [F_S(T_k^L; m_0, m_1) \\ & - F_S(0; m_0, m_1)] + (I_k^{NNN} + J_k^{NN}) \ln F_S(0; m_0, m_1) \} \end{aligned} \quad (2)$$

where ln denotes natural logarithm, and the indicator variables, I^Y, I^{NY}, I^{NNY}, I^{NNN}, J^{YY}, J^{YN}, J^{NY}, and J^{NN}, were defined in the preceding paragraphs.

3. Results and Discussion

3.1. Data and Results

The numbers of responses obtained in this study are summarized in Table 3. A preliminary survey of the focus group enabled the authors to determine a total of seven sets of bid amounts. The 1000 respondents were allocated to one of seven groups. Each group consisted of an equal number of observations. Each set was presented to each group. The upper and lower parts of the table refer to the case in which a higher and lower bid were offered first, respectively. The "no-no-no" and "no-no" responses mean $S = 0$, corresponding to 595 (=288 + 307) of the total.

Two models can be constructed depending on whether covariates are included. Table 4 reports information on the seven covariates employed here. The results from estimating these two 1.5B models are presented in Table 5. The Wald-statistics imply that both models held statistical significance. Combining the mean formula and Equation (1), the average WTP was $(1/m_1)[1 + \exp(m_0)]$. Looking at the estimation results of the model excluding covariates, both the two coefficients and the average WTP secured statistical significance. The spike also possessed statistical significance. The value was 0.5954, which was not very different from the sample ratio of 0.595.

Table 3. Number of responses obtained in this study.

Bids [1]		Number of Responses				
First	**Second**	**"Yes"**	**"No-Yes"**	**"No-No-Yes"**	**"No-No-No"**	**Totals**
3000	1000	23	11	5	32	71
4000	2000	23	12	2	35	72
6000	3000	19	8	3	42	72
8000	4000	11	6	11	43	71
10,000	6000	11	7	8	45	71
12,000	8000	10	6	14	41	71
15,000	10,000	6	4	12	50	72
	Totals	103	54	55	288	500
First	Second	"yes-yes"	"yes-no"	"no-yes"	"no-no"	Totals
1000	3000	18	14	3	37	72
2000	4000	8	15	4	45	72
3000	6000	10	11	9	41	71
4000	8000	7	10	5	49	71
6000	10,000	11	9	8	43	71
8000	12,000	5	6	19	41	71
10,000	15,000	7	7	7	51	72
	Totals	66	72	55	307	500

[1] They are given in Korean won (USD 1.0 = KRW 1122).

Table 4. Description of the variables employed in this study.

Variables	Definitions	Mean	Standard Deviation
Education	Education level of the interviewee in years	14.14	2.25
Income	Dummy for the interviewee's monthly income being higher than KRW 2.61 million (USD 2.33 thousand) (0 = no; 1 = yes)	0.49	0.5
Gender	Gender of the interviewee (0 = male; 1 = female)	0.50	0.50
Metro	Dummy for the interviewee dwelling in the Seoul Metropolitan area (0 = no; 1 = yes)	0.53	0.50
Knowledge	Dummy for the interviewee recognizing toluene before being confronted with the questionnaire (0 = no; 1 = yes)	0.94	0.24
Experience	Dummy of the interviewee having experienced illness from toluene exposure (0 = no; 1 = yes)	0.03	0.17

For the purpose of explicitly dealing with the uncertainty associated with the average WTP estimation, a confidence interval (CI) can be computed. Therefore, Table 5 also provides 95% CIs for the average WTP derived through the application of the method presented in Krinsky and Robb [49]. The estimation results of the model with covariates were not distinguishable from those of the model with no covariates. The R^2 is most widely used in relation to the goodness-of-fit of an estimated equation. Unfortunately, it cannot be defined for the covariate-free model. On the other hand, McFadden's pseudo-R^2, suggested by Herriges [50], is defined for a model including covariates. It was calculated to be 0.06.

The coefficient estimates for the six variables, except for Knowledge and Experience variables, held statistical significance at the 10% level. The coefficient estimate for a covariate itself does not mean much, but its sign has an important meaning. If the sign is positive, the size of the variable is positively associated with the likelihood of responding "yes" to the presented bid amount. For example, the coefficient for the Income term had a positive sign, which means that the higher the income, the greater the likelihood of accepting the payment of the suggested bid amount. In addition, the estimated coefficient for the Gender term was positive, which suggests that women tend to be more likely to say "yes" to the presented bid amount than men. Respondents with higher education and

living in the Seoul Metropolitan area were more likely to respond "yes" to the given bid than others.

Table 5. Estimation results of the one-and-one-half-bounded models.

Variables [1]	Model without Covariates [2]	Model with Covariates [2]
Constant	−0.3864 (−6.02) *	−3.0080 (−5.65) *
Bid amount [3]	−0.1527 (−16.71) *	−0.1678 (−16.96) *
Education		0.0850 (2.60) *
Income		0.2875 (1.70) *
Gender		0.4328 (2.65) *
Metro		1.2902 (9.27) *
Knowledge		0.3568 (1.21)
Experience		−0.0340 (−0.09)
Spike	0.5954 (38.53) *	0.6057 (36.80) *
Mean willingness to pay per	KRW 3394 (USD 3.02)	KRW 2988 (USD 2.66)
household per year	14.73 *	14.57 *
t-values	KRW 2994 to 3891	KRW 2630 to 3424
95% confidence interval [4]	(USD 2.67 to 3.47)	(USD 2.34 to 3.05)
Wald statistics (*p*-values) [5]	217.10 (0.000)	212.21 (0.000)
Log-likelihood	−1117.04	−1050.34
Sample size	1000	1000
McFadden's pseudo-R^2		0.060

[1] They are described in Table 4. [2] The values are the coefficient estimates and the *t*-values corresponding to them are showing in the parentheses. [3] The unit is 1000 Korean won (USD 1.0 = KRW 1122). [4] They were obtained by adopting the technique given in Krinsky and Robb [49]. [5] The null hypothesis is that the model is mis-specified. * implies that the estimate holds statistical significance at the 10% level.

Choosing which of the two models to use is an issue. The model with covariates has a problem that the estimation results of the average WTP vary depending on which set of covariates is to be determined. On the other hand, the model without covariates is free from this problem because it does not include any covariates. Consequently, the subsequent analysis was based on a model with no covariates.

Considering the negative effect of toluene on human health, it was judged that the annual mean WTP of KRW 3394 per household obtained in this study was not large. This was because 59.5 percent of all respondents said they were not willing to pay a penny. Although the average WTP value for the respondents with positive WTP values was not low, the large proportion of zero WTP observations significantly lowered the average WTP estimate for the whole. There were three reasons for reporting zero WTP. First, some respondents thought that regulating the use of toluene did not create much value for their households. Second, some respondents said they could not afford to make additional payments for economic reasons. Third, some respondents believed that the regulations on toluene use could pose a threat to the livelihood of their households because they had occupations related to the use of toluene.

3.2. Discussion of the Results

The discussion of the results will consist of three major parts. First, the 1.5B model can suffer from the response effect [51]. To deal with this problem, it is necessary to compare the results from the 1.5B model with those from the single-bounded (SB) model. The SB model employed not the response to the second bid but the response to the first bid. Table 6 contains the results of the SB model. The average WTP obtained from the SB model was greater than that obtained from the 1.5B model. Regarding the 95% confidence intervals, they overlapped with each other. Using the overlap test, the null hypothesis that the two estimation results were the same cannot be rejected. In other words, the estimation results of the two models did not differ significantly; thus, the response effect was not a problem in the 1.5B model used in this study.

Table 6. Estimation results of the single-bounded models.

Variables [1]	Model without Covariates [2]	Model with Covariates [2]
Constant	−0.3911 (−6.09) *	−3.0166 (−5.61) *
Bid amount [3]	−0.1300 (−13.66) *	−0.1440 (13.83) *
Education		0.0827 (2.50) *
Income		0.3342 (1.92) *
Gender		0.4661 (2.78) *
Metro		1.2672 (9.03) *
Knowledge		0.3668 (1.23)
Experience		−0.1750 (−0.46)
Spike	0.5965 (38.59) *	0.6078 (36.96) *
Mean willingness to pay per household per year	KRW 3973 (USD 3.54)	KRW 3458 (USD 3.08)
	12.63 *	12.58 *
t-values	KRW 3424 to 4685	KRW 2976 to 4076
95% confidence interval [4]	(USD 3.05 to 4.18)	(USD 2.65 to 3.63)
Wald statistics (*p*-values) [5]	159.45 (0.000)	158.20 (0.000)
Log-likelihood	−926.49	−862.76
Sample size	1000	1000
McFadden's pseudo-R^2		0.069

[1] They are described in Table 4. [2] The values are the coefficient estimates and the *t*-values corresponding to them are showing in the parentheses. [3] The unit is 1000 Korean won (USD 1.0 = KRW 1122). [4] They were obtained by adopting the technique given in Krinsky and Robb [49]. [5] The null hypothesis is that the model is mis-specified. * implies that the estimate holds statistical significance at the 10% level.

Second, the average WTP per household obtained earlier needs to be extended to the population. The important aspect to examine at this time is the representativeness of the sample. For the sake of avoiding any problems in this regard, the authors of this study did not conduct the sampling and survey arbitrarily. Instead, a company with extensive CV survey experience was commissioned to carry out the sampling and survey. Therefore, for the data used in this study, it can be seen that the issue related to the representation of the sample has been addressed.

As previously discussed, the household WTP was derived as KRW 3394 (USD 3.02) per year. There were 20,573,060 households in the country in 2021. As shown in Table 7, the economic benefits for the entire nation were 69.82 billion won (USD 62.23 million) every year. It did not fall within the scope of this research to estimate accurately the costs incurred by tightening the regulation on toluene use. Moreover, this estimation did not seem easy. Nevertheless, the costs did not appear to be greater than the benefits. Therefore, it is judged that the tightening of the regulation can be socially justified.

Table 7. Extension of the sample figure to the population one.

Yearly Mean Willingness to Pay (WTP) Obatined in this Study (A)	Total Number of Households in 2021 (B)	Total WTP (A × B)
KRW 3394 (USD 3.02)	20,573,060	KRW 69.82 billion (USD 62.23 million)

Third, useful implications can be derived by comparing the findings from this study with those from studies applying other methods. In this study, CV was applied to estimating the economic benefits ensuing from tightening the toluene use regulations, but other methods can be considered. For example, a cost-of-illness (COI) approach may be applied. In other words, the COI can be defined as all the expenses incurred to receive treatment for diseases caused by toluene. These will include hospital medical expenses, transportation costs, and time costs incurred inside and outside of the hospital. Since the representative disease caused by toluene is known to be asthma, the cost of targeting the disease can be considered.

Toluene can cause asthma; however, the cause of asthma is not necessarily toluene as this is only one of the many factors that causes asthma. Accurately identifying the effects of toluene alone is a difficult task. In addition, the time cost, normally calculated as working

wages, can vary widely from person to person: some people may have a high-income, while others may be unemployed. Time costs are based on the assumption that wages can be reduced by the time that it takes to receive treatment, but, in reality, income may not decrease. Therefore, estimating the benefits of regulating the use of toluene by applying a COI approach would not be an easy task.

In addition, asthma, one of the diseases that can be caused by toluene exposure, can lead to death if it is serious. Thus, it may be necessary to take into consideration deaths from toluene exposure when evaluating the benefits of regulations on toluene use. At this time, the commonly used method is to assess the value of statistical life (VSL). The VSL multiplied by the disease incidence and mortality estimates the death-related benefits. Further in-depth research is needed to establish the incidence and mortality of diseases.

As examined so far, it is difficult to compare the results obtained by applying different methods directly with the results of this study. Therefore, this paper did not perform a separate comparative analysis. Nevertheless, if a comparison is undertaken in the future, useful implications can be derived. It is expected that follow-up studies can be conducted. Furthermore, it is difficult to find similar research cases in the literature that can be directly compared with this study, but, if found, a comparison of their results will provide interesting implications.

As examined so far, it is difficult to compare the results obtained by applying different methods directly with the results of this study. Therefore, this paper did not perform a separate comparative analysis. In addition, the main results from the previous related studies presented in Table 1 and the results from this study had considerable differentiation in two aspects. First, the targets under evaluation were different. Second, the country to which CV was applied, the payment vehicle, and the payment period were also different. In short, there are no former studies applying CV to tightening toluene use regulations in the literature, and the structure of the study was significantly different from that of former studies. Therefore, the authors refrained from directly comparing the results from previous related studies with those from this study. If more related studies are conducted in the future, the comparison will be possible and fruitful.

4. Conclusions

The South Korean government has designated toluene as a hazardous chemical and only limited its use for products that are feared to be harmful. Since no measures to prohibit the use of toluene have been implemented, amounts of toluene exceeding the limit are frequently detected. Accordingly, there is a growing concern about the occurrence of human diseases caused by the exposure to toluene or addiction to that. In order to prevent the occurrence of such human diseases, measures to tighten the current regulations related to its use to prevent may be considered.

Quantitatively investigating the economic benefits arising from the implementation of the plan was the crucial objective of this research. As explained in Section 2.1, from a microeconomic point of view, the economic benefits of consuming a particular good are defined as the lower area of the demand function for that good, and the area becomes the WTP for consuming that good [52]. CV is a technique for directly obtaining WTP by analyzing responses obtained by asking questions about preferences [42]. Thus, for the sake of obtaining the economic benefits, CV, an economic technique for analyzing data collected from a survey based on economic theory, was applied. A nationwide survey of 1000 people was conducted, and a model that is well accepted in the literature was adopted. In other words, the annual WTP per household to strengthen the regulations to reduce the human health risks of toluene was evaluated to calculate its economic benefits.

All the estimated WTP models held statistical significance. The average WTP per household was derived as KRW 3394 (USD 3.02). The national economic benefits were calculated as KRW 69.82 billion (USD 62.23 million) per year. This figure is the most

important finding from this study. It is difficult to calculate accurately the costs incurred by tightening the regulations on toluene use, but they did not seem to exceed the benefits. Because the tightening of the regulation would be socially desirable, it would be justified for the Government to implement the tightening.

This research can be supplemented through additional future studies in three points. First, this research focused on toluene among various hazardous chemicals, but it needs to be extended to other chemicals. Since various chemicals are used in South Korea, the results obtained through the estimation of economic benefits ensuing from tightening the regulation on the use of each chemical can be used to prioritize the tightening. Through the cost–benefit analysis of the tightening for each chemical, it is possible to consider enforcing the tightening sequentially in the order of economic feasibility from large to small. Second, this study targets only South Korea, but the framework employed in this research can also be applied to other countries. If a cross-country comparison of the application results were performed, various implications can be derived. Third, for a more rigorous cost–benefit analysis, it is necessary to more accurately estimate the costs caused by tightening the regulation. In this study, the cost–benefit analysis results were presented above at the qualitative level, but accurate cost estimation is essential to derive the quantitative cost–benefit analysis results.

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Institutional Review Board Statement: All subjects gave their informed consent for inclusion before they participated in the study. The study was conducted in accordance with the Declaration of Helsinki, and the survey was approved by Institutional Review Board at Seoul National University of Science & Technology for exemption from deliberation.

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Appendix A. Survey Questionnaire

Part 1. Background information

Toluene is easily decomposed in the human body, so it does not remain in the body for a long time. Thus the concentration of toluene in a general environment does not affect the human body. However, high concentrations of exposure in a short period of time can irritate the skin and eyes. In addition, long-term exposure to it can cause eye tremors, motor problems, and affect the nervous system, such as headaches, dizziness, memory impairment, or hallucinations. It is the main cause of new car or home syndrome, which causes symptoms such as chronic headache, respiratory and skin diseases, and asthma. For example, when toluene in the air at home increased by 1 ppb (0.0000001%), the incidence of atopic dermatitis increased by 12.73%. Atopy treatment can take at least six months, and it can take longer for adults. During the treatment period, working hours and income may be affected by hospital visits.

Toluene is currently designated as a hazardous substance only, and usage is limited to some hazardous products. However, the detection amount of toluene is often detected higher than the limit. Therefore, the Government wants to introduce regulations on toluene to prevent diseases caused by exposure and addiction. Tightening the regulation

to restrict the overall use of toluene can reduce the incidence of related diseases (such as atopic dermatitis).

In this survey, we would like to know the value of your household's willingness to pay for tightening the regulations on toluene use. Please answer the following questions carefully after considering that your household has a limited income and that the income must be used for several purposes (food, clothing, housing, etc.).

Q1. Have you ever heard of toluene before you received this questionnaire?

1. Yes
2. No

Q2. Have you ever experienced illness caused by exposure to toluene?

1. Yes
2. No

Part 2. Questions about willingness to pay for tightening the regulation to restrict the overall use of toluene

The additional cost of tightening the regulation to restrict the overall use of toluene is between (lower bid amount) and (upper bid amount) per year.

Type A.

Q1. Would your household be willing to pay additional income tax of 1000 Korean won (lower bid amount) annually for the next ten years for tightening the regulation to restrict the overall use of toluene, supposing that the reduction of human health risks is certain to succeed?

1. Yes—go to Type A. Q2.
2. No—go to Q3.

Q2. Then, would your household be willing to pay additional income tax of 3000 Korean won (upper bid amount) annually for the next ten years for tightening the regulation to restrict the overall use of toluene, supposing that the reduction of human health risks is certain to succeed?

1. Yes—go to Part 3.
2. No—go to Part3.

Type B.

Q1. Would your household be willing to pay additional income tax of 3000 Korean won (upper bid amount) annually for the next ten years for tightening the regulation to restrict the overall use of toluene, supposing that the reduction of human health risks is certain to succeed?

1. Yes—go to Part 3.
2. No—go to Type B. Q2.

Q2. Then, would your household be willing to pay additional income tax of 1000 Korean won (lower bid amount) annually for the next ten years for tightening the regulation to restrict the overall use of toluene, supposing that the reduction of human health risks is certain to succeed?

1. Yes—go to Part 3.
2. No—go to Q3.

Q3. Then, wouldn't your household be willing to pay anything for tightening the regulation to restrict the overall use of toluene?

1. Yes, my household is willing to pay something
2. No, my household is not willing to pay anything

Part 3. Questions about socio-economic characteristics

Q1. What is your gender?

1. Female
2. Male

Q2. Please check your education level in years with V.

Education level	Uneducated	Elementary school	Middle school	High school	University	Graduate school
Education level in years	0	1 2 3 4 5 6	7 8 9	10 11 12	13 14 15 16	17 18 19 20

Q3. Please fill out your household's average monthly income before tax deduction in last year.

KRW_____per month

Q4. Please check your residence with V.

1	2	3	4
Seoul	Busan	Daegu	Incheon
5	6	7	8
Gwangju	Daejeon	Ulsan	Gyeonggi
9	10	11	12
Gangwon	Chungbuk	Chungnam	Jeonbuk
13	14	15	16
Jeonnam	Gyeongbuk	Gyeongnam	Sejong

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