



Economic valuation of noise pollution control policy: does the type of noise matter?

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Abstract

As the average noise level and number of noise sources have increased, governments have taken various measures to make soundscapes sustainable. Wise policy decisions require information about the monetary value of noise-control policies. This study elicited people's willingness to pay (WTP) for noise policies, separating traffic noise from residential noise to compare the value of controlling different types of noise. The contingent valuation method was used for the empirical analysis, with data from South Korea. The results show that the monthly mean WTP of respondents was KRW 3392.3 for residential noise reduction and KRW 3507.1 for transport noise reduction; thus, the WTP for the latter is slightly higher than that for the former. Moreover, about 80% of people are unwilling to pay for a noise policy at all, and that high ratio of people with zero WTP must be taken into consideration in the process of policy formulation and implementation. Respondents' experiential and psychological factors were found to be more important than their demographics in explaining their WTP for a noise policy. Potential policy implications based on the analysis results are provided.

Keywords Contingent valuation method · Economic benefit · Monetary value · Residential noise · Transport noise · Willingness to pay

Introduction

Noise is a global issue that detracts from sustainable development, especially in areas with a dense population and dense transportation networks (Miedema 2007). In most regions surrounding a big city, noise disturbs more people in their daily lives than any other pollutant (Stewart et al. 2011). Noise is defined as an unwanted sound or a combination of sounds that can cause adverse effects, such as sleeping disorders,

cognitive impairment, poor health, and depreciation of real-estate values, all of which can lead to a significant deterioration in quality of life (Seidman and Standing 2010). Therefore, noise reduction can increase the overall productivity and welfare of a society.

As average noise levels and the number of noise sources have increased due to expanding industrialization and urbanization, governments have adopted a variety of noise policies to make soundscapes sustainable (Adams et al. 2006). For example, since Environmental Noise Directive 2002/49/EC was established in 2002, the European Union has been committed to a significant, long-term decrease in noise pollution (European Commission 2002; Wolde 2003). In Australia, the government has implemented a range of traffic-noise management measures, including legislation for vehicle noise limits (Burgess and Macpherson 2016). The government of India has initiated a new monitoring network that collects real-time noise data from its major cities as a part of its noise pollution control policy (Garg and Maji 2016). All those examples indicate that the research and policy interest in developing effective noise-control measures is growing.

Regardless of its details, any noise-control policy requires adequate finances for its development and enforcement. After

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its implementation, many people benefit from noise reduction (Yoo 2007). When using economic efficiency as a criterion for judgment, the decision of whether to implement a noise policy should be evaluated using a cost-benefit analysis. Therefore, to provide unbiased estimates of the costs and benefits of a noise-control policy (and to ensure that the benefits exceed the expected costs), it is essential to gather credible information about the monetary value of noise nuisances (Bristow et al. 2015). An ex-ante evaluation of economic feasibility should elicit people's willingness to pay to reduce noise or enforce a noise policy. Therefore, several studies have assessed the economic value of noise using different research methodologies (Dekkers and van der Straaten 2008; Matos et al. 2013; Navrud 2002; Wang et al. 2017).

It is important to consider whether people assign different values to different types of noise; in other words, do different noise sources have different economic values? Each noise source indeed has its own acoustic spectrum and generation pattern, and each individual has different personal experiences of suffering from noise. For example, some people are particularly sensitive to transport noise, whereas other people are more sensitive to noise from their neighbors. Therefore, even though two noises have the same decibel level, the degree to which they induce annoyance can vary by individual, which implies that people's willingness to pay to reduce different types of noise might also differ. Thus, a value estimation for each type of noise is necessary. In addition, detailed information about each noise source is required before an effective noise-control policy can be made because policy makers should fine-tune policy actions by the type of noise. To obtain that kind of detailed information, previous studies have studied the value of noise relative to other pollutants (Saelensminde 1999), the change in the value of noise reduction according to noise levels (Bjørner 2004; Fosgerau and Bjørner 2006), and the difference in noise value depending on its time and place (Carlsson et al. 2004; Bristow and Wardman 2006). However, no one has yet used a single dataset and methodology to compare the relative values of different noise sources.

For this study, we measured people's willingness to pay (WTP) for noise reduction measures, and we suggest implications of our findings for related policy provisions. Years ago, the public in South Korea demanded improved noise control (Interagency Committees 2010). Therefore, we used the contingent valuation method (CVM), which is a type of representative stated preference (SP) method, for our empirical analysis of South Korean data. The novelty and contributions of this study are as follows. First, we analyzed the monetary value of noise policies in an Asian country in which few similar studies have been conducted. Second, we separated traffic noise from residential noise and elicited the WTP for each of them to compare the values of different types of noise. Third, we used the spike model to account for zero WTP responses and examined the demographic and psychological determinants of

WTP, thereby providing useful insights for detailed policy development.

The rest of this study is organized as follows. The "Research background" section summarizes the existing research on the economic value of noise and probes its limitations and implications for our research. It also reviews noise issues in Korea, the subject of our empirical analysis. In the "Methodology" section, we describe CVM, our main research method, and address several issues with WTP analyses from a modeling perspective. The "Survey design and data collection" section discusses the details of our survey and data generation methods. The results and discussion of our empirical analysis are presented in the "Results and discussion" section, including the economic value of noise policies and related policy implications. Finally, the "Conclusions" section concludes the article with research limitations and directions for future research.

Research background

Economic valuation of noise with stated preference methods

Most previous research on the monetary value of noise used hedonic price methods, SP methods, or methods based on epidemiological data (Dekkers and van der Straaten 2008; Matos et al. 2013; Wang et al. 2017). Among them, SP methods have been the most frequently used because noise levels do not have a market value (Merchan et al. 2014). Because we also use an SP method, we here consider previous studies that have a close relation to our study. From a methodological perspective, studies that use SP methods to analyze the value of noise and related policies can be divided into two groups: choice experiments (CEs) and the CVM.¹

From a topical perspective, previous studies can be divided into studies on transport noise and studies on other types of noise. Transport noise, such as road, railroad, and aircraft noise, has been the most frequently featured topic in previous studies because it is an important environmental public health issue that reduces people's well-being (Clark et al. 2006; Ouis 2001). Table 1 provides a summary of the monetary valuation of transport noise using typical SP techniques and recent studies about transport noise, including Łowicki and Piotrowska (2015) and Bravo-Moncayo et al. (2017).

It is also worth examining studies on the value of noise in Korea, the main focus of our empirical analysis. Kim et al. (2007) evaluated the monetary effect of traffic noise on land prices using the hedonic price method. They found that a 1% increase in traffic noise was associated with a 1.3% decline in

¹ The main differences between CEs and the CVM and the merits of each are well summarized in Wardman and Bristow (2004).

Table 1 Previous studies on the monetary valuation of transport noise using SP techniques

Author and year	Country/source type	Methodology	WTP/key findings
Feitelson et al. (1996)	- Unknown (USA) - Aircraft	- CVM (open ended)	- 1.5–4.1% for home owners and 0.9–3.0% for renters. - Higher monetary values for CVM than hedonic price.
Saelensminde (1999)	- Norway - Urban traffic	- CE - Multinomial logit	- NOK 3550–7100/year for a 50% reduction in the noise level. - Respondents are willing to pay more for the reduction of air pollution than noise.
Bjørner (2004)	- Denmark - Road traffic	- CVM (open ended)	- 2 EUR/year for 1 dB reduction at 55 dB and 10 EUR/year at 75 dB. - The value of noise reduction depends on the level of noise.
Carlsson et al. (2004)	- Sweden - Aircraft	- CE - Mixed logit	- 10–20 SEK per month for decrease in flight movements. - The time of day affects the value of noise reduction.
Wardman and Bristow (2004)	- UK - Traffic	- CE (logit) - CVM (open ended)	- £1.48–3.17 per household for 50% noise improvements. - CVM values are found to be lower than CE values for noise.
Bristow and Wardman (2006)	- UK - Aircraft	- CE - Ordered logit and logit	- 0.37–91.20 €/week. - Large differences depending on the airport and analysis model.
Fosgerau and Bjørner (2006)	- Denmark - Road traffic	- CV data - Joint discrete-continuous models	- Large differences depending on the noise level. - Proposed model reduces standard errors of the expected marginal WTP by 3–10%.
Wardman and Bristow (2008)	- UK, France, Romania - Aircraft	- CE - Priority ranking	- Differs according to the choice format, time of day, and country.
Thanos et al. (2011)	- Greece - Aircraft	- CE - Logit and mixed logit	- €13.12/month for terminating aircraft noise exposure. - €9.53/month for avoiding the onset of aircraft noise.
Chalermpong and Klaiklueng (2012)	- Thailand - Aircraft	- CE - Multinomial logit	- Compensation of 18.87–68.62 baht per month for an increase of one flight. - Attitudes toward noise annoyance influence the valuation of airport noise.
Istamto et al. (2014)	- UK, Finland, Germany, Netherlands, Spain - Road traffic	- CVM (open ended)	- €90–€320 per person per year to avoid an increase in the noise level from 50 to 65 dB. - WTP to avoid noise effects varied substantially by country.

land price. Chang and Kim (2013) offered a valuation of urban rail noise using the hedonic pricing method and found that a unit increase in decibel decreased property values by 0.53%. Yoo (2007) estimated the economic benefits of urban noise reduction in a metropolitan area using the CVM and found that households were willing to pay KRW² 997–1778 to reduce noise down to domestic environmental standards.

On the other hand, few studies have estimated the value of noise other than transport noise. Examples include Galilea and Ortuzar (2005), who evaluated the value of noise reduction in residential locations, and Merchan et al. (2014), who analyzed

the economic value of noise pollution in a national park. As societies become more complex and highly developed, however, various types of noise other than transport noise occur, such as noise from construction sites, factories, and demonstrations. Therefore, to take more comprehensive measures, it is necessary to evaluate and compare the relative values of various types of noise rather than focusing on transport noise alone.

Current issues with noise policies in Korea

Korea faces several noise issues, and related studies have recently been published. Notable examples include an analysis of the effect of noise on human health (Lee et al. 2009), an analysis of the relationship between noise levels and noise

² “KRW” refers to the South Korean Won. According to the “Economic Statistics System” by the Bank of Korea (<http://ecos.bok.or.kr>), USD 1 = KRW 1144.09 in July 2016

annoyance (Sung et al. 2017), predictions of noise levels (Ryu et al. 2017), an estimation of the population exposed to noise (Ko et al. 2011; Lee et al. 2014), and issues with neighbor noise in residential buildings (Park et al. 2017).

The first priority in formulating an effective noise policy is to have a clear grasp of the present state of noise. The Korean government established and has operated a nationwide noise-vibration measuring system since 2010 to collect information about current noise for use in developing noise policies. The system consists of 826 measuring instruments, and the measurement frequency of each instrument is once per calendar quarter. Information and statistical data collected by the system are available to the public through the National Noise Information System (<http://www.noiseinfo.or.kr>). Noise standards in Korea differ by the type of land use and time of day; Table 2 summarizes those noise standards and the yearly average noise levels in major metropolitan areas in 2015.

The Korean government has made several efforts to mitigate or resolve those noise problems, spending a budget of approximately KRW 40 billion on noise-related projects in 2015 (Ministry of Environment 2016). Despite those efforts, however, 106,283 civil petitions for noise and vibration were made in Korea in 2015, 18.3% more than in the previous year, representing an 89.0% increase during the past five years and accounting for 50.0% of all environmental petitions in 2015. Table 3 clearly shows the steady increase in the number and percentage of civil petitions for noise problems, reflecting the public's increased expectation of a quiet living environment and the increased public demand for noise-control measures to improve living standards. It also implies the failure of the government's noise policies to date.

Therefore, the Korean government should improve its efforts to decrease current noise levels to meet its own environmental standards. Developing and enforcing different noise-control policies, however, requires information about the social benefits and economic feasibility of each policy option. It is especially necessary to improve the effectiveness of the noise policies implemented so far, which requires an accurate estimation of the financial resources available based on the intentions of the whole population. For that reason, we undertook this study to provide the information needed to complete an economic feasibility analysis for policy-making, suggesting not only the mean household WTP but also the economic value of noise policies.

Moreover, estimating and comparing the economic value of each noise source can contribute to more efficient use of limited government budgets to maximize social well-being. For example, the Korean government is spending a total of KRW 429.8 billion on noise reduction measures in 2016–2020, aiming to raise people's satisfaction level with the noise-vibration environment from 26.8% in 2014 to 40% in 2020 (Joint Ministry of Korean government 2015). Therefore, to effectively use that budget, policy makers and enforcers need information about how people value specific noise reduction measures.

Methodology

We estimate the monetary value of noise policies using the CVM, one of the most commonly used methodologies to

Table 2 Noise standards and noise levels in major metropolitan areas of Korea in 2015. Unit: L_{eq} dB (A)

Area type			Standard	Entire country	Seoul	Busan	Deagu	Incheon	Gwangju	Deajeon	Ulsan
General	Residential (exclusive)	Day	50	53	<i>54</i>	<i>55</i>	53	<i>54</i>	<i>55</i>	53	<i>53</i>
		Night	40	46	<i>48</i>	<i>49</i>	48	<i>49</i>	<i>48</i>	48	<i>45</i>
	Residential (general)	Day	55	53	55	<i>56</i>	54	<i>57</i>	53	53	<i>52</i>
		Night	45	47	<i>48</i>	<i>52</i>	48	<i>50</i>	<i>46</i>	<i>46</i>	<i>45</i>
	Commercial	Day	65	59	61	60	60	59	57	57	61
		Night	55	53	55	53	52	52	49	52	55
Industrial	Day	70	60	–	63	62	60	61	61	63	
	Night	65	55	–	56	54	53	55	55	59	
Near roads	Residential	Day	65	63	<i>69</i>	<i>67</i>	<i>67</i>	<i>66</i>	63	60	62
		Night	55	57	<i>66</i>	<i>62</i>	<i>62</i>	<i>62</i>	<i>57</i>	<i>56</i>	<i>55</i>
	Commercial	Day	70	66	<i>69</i>	70	69	70	68	64	67
		Night	60	61	<i>66</i>	<i>66</i>	<i>64</i>	<i>65</i>	62	60	<i>61</i>
	Industrial	Day	75	67	–	69	68	72	70	65	69
		Night	70	62	–	64	62	66	64	57	64

Source: Ministry of Environment (2016)

Notes: The figures in italics exceed the relevant standards and confirm the seriousness of noise problems in Korea, especially in residential areas

Table 3 The number of civil petitions for noise and vibration in Korea

Year	Number of noise petitions	Share of all environmental petitions (%)	Year	Number of noise petitions	Share of all environmental petitions (%)
2006	32,800	24.3	2011	56,244	33.4
2007	38,159	26.7	2012	59,148	34.3
2008	44,784	30.2	2013	74,008	39.6
2009	42,400	29.3	2014	89,827	45.9
2010	53,718	35.4	2015	106,283	50.0

Source: Ministry of Environment (2016)

analyze preferences and the WTP for non-market environmental goods (Carson et al. 2001; MacMillan et al. 2006). The CVM has been used to measure the value of non-market goods in various fields of study, such as the environment (Loomis et al. 1993), weather (Rollins and Shaykewich 2003), and energy policy (Huh et al. 2015). The theoretical formulation of the CVM corresponds to two individual approaches: the difference in indirect utility functions (Hanemann 1984) and the difference in cost functions (Cameron and James 1987; Cameron 1988). McConnell (1990) showed that the two approaches produce the same results, so the choice between them is a matter of style. We use the indirect utility function of Hanemann (1984).

Among the elements of the CVM, the choice of an elicitation format is known to affect the mean or median WTP estimates. Dichotomous choice (DC) formats are often used for their convenience in survey design (Arrow et al. 1993), and they are also incentive compatible and facilitate respondents' valuation task (Bateman et al. 2002). DC formats are classified as single-bounded, double-bounded, or one and one half-bounded according to the number of inquiries. For our analysis, we used a double-bounded dichotomous choice (DBDC). In a DBDC setting, a respondent is presented with a closed-ended question twice. If the respondent responds "yes" to the first bid (t_i), indicating that he or she is willing to pay a stated amount, then the second bid (t_i^U) is somewhat greater than the first. If, on the other hand, the first response is "no" (he or she is not willing to pay the stated amount), the second bid (t_i^L) is somewhat smaller.

It should be kept in mind that some households might have no intention of paying any amount for a noise policy, which means they have a zero WTP. In that case, the sample represents two separate groups: one that has a WTP of zero, and one that has a positive WTP for the change being offered (Bateman et al. 2002). It is necessary to specify the probability distribution between the groups to obtain a mean WTP; if the possibility of zero WTP is not considered, the mean WTP is likely to be overestimated. One way to resolve that problem is to use the spike model (Kjiström 1997). Unlike the difference in indirect utility functions model, the spike model considers

the interaction of two distributions: a spike that represents the probability of having zero WTP and a logistic distribution that admits only positive probabilities to positive values.

A respondent's WTP is represented as a function of explanatory variables, such as individual characteristics (Willig 1976). If a linear WTP function is assumed, the WTP of an individual respondent i is represented by Eq. (1).

$$Y_i = a - bt_i + x_i'\beta + u_i \tag{1}$$

In Eq. (1), Y_i represents respondent i 's WTP, x_i' is the vector of explanatory variables, t_i is the bid amount, a, b , and β are the parameters to be estimated, and u_i is the error term. Facing a bid amount of t_i , each respondent answers *yes* or *no*, and thus the data show whether respondent i 's valuation is larger or smaller than t_i . In this case, the indicator variable y_i is used to express *yes* ($Y_i > t_i, y_i = 1$) and *no* ($Y_i < t_i, y_i = 0$) responses in mathematical form (Eqs. (2) and (3)).

$$\Pr(y_i = 1|x_i) = \Pr(Y_i \geq t_i) = 1 - G_Y(t_i) \tag{2}$$

$$\Pr(y_i = 0|x_i) = \Pr(Y_i < t_i) = G_Y(t_i) \tag{3}$$

Here, $G_Y(t_i)$ represents the cumulative density function of respondents' WTP. In the DBDC format, the respondent samples can be divided into four groups according to their responses. However, because the spike model we used further divides respondents' responses into zero and positive WTP, each response belongs to one of five groups. Therefore, the binary indicator value, which indicates which group contains respondent i , can be defined using Eq. (4).

$$\begin{aligned} I_i^{YY} &= 1 \text{ if } WTP \geq t_i^U \text{ (0 otherwise)} \\ I_i^{YN} &= 1 \text{ if } t_i \leq WTP < t_i^U \text{ (0 otherwise)} \\ I_i^{NY} &= 1 \text{ if } t_i^L \leq WTP < t_i \text{ (0 otherwise)} \\ I_i^{NNY} &= 1 \text{ if } 0 < WTP < t_i^L \text{ (0 otherwise)} \\ I_i^{NNN} &= 1 \text{ if } WTP \leq 0 \text{ (0 otherwise)} \end{aligned} \tag{4}$$

Here, t_i indicates the initial bid presented to the respondent in the DBDC format, and t_i^U and t_i^L stand for the second bids.

In this study, t_i^U and t_i^L are twice and half of t_i . The log likelihood function of the above model for n samples is expressed as Eq. (5).

$$\ln L = \sum_{i=1}^n I_i^{YY} \ln[1 - G_Y(t_i^U)] + I_i^{YN} \ln[G_Y(t_i^U) - G_Y(t_i)] + I_i^{NY} \ln[G_Y(t_i) - G_Y(t_i^L)] + I_i^{NNY} \ln[G_Y(t_i^L) - G_Y(0)] + I_i^{NNN} \ln[G_Y(0)] \quad (5)$$

If a logistic distribution is assumed as a cumulative distribution function of respondents' WTP, it can be expressed using Eq. (6).

$$G_Y(t_i) = \begin{cases} 0 & \text{if } t_i < 0 \\ [1 + \exp(\alpha + \beta X_i)]^{-1} & \text{if } t_i = 0 \\ [1 + \exp(\alpha - \beta_p t_i + \beta X_i)]^{-1} & \text{if } t_i > 0 \end{cases} \quad (6)$$

The parameters are estimated by maximizing the log likelihood of Eq. (5). The ratio of zero WTP responses (the spike) is expressed as $[1 + \exp(\alpha + \beta X_i)]^{-1}$. The mean WTP of the sample, the main objective of our analysis, is then calculated using Eq. (7).

$$\text{mean WTP} = \ln[1 + \exp(\alpha + \beta X_{\text{mean}})]/b \quad (7)$$

Survey design and data collection

A survey for SP data collection was conducted in eight major metropolitan areas in South Korea from July 7 to August 4, 2016. The 1002 respondents, aged 20 to 65, were all householders or their spouses with the right to decide whether to pay for noise reduction. The actual fieldwork was done by a polling firm (Gallup Korea) and adopted the one-on-one face-to-face interview format with a well-trained interviewer. Purposive quota sampling based on respondents' residence and ages was used to capture a representative sample of the Korean population.

The survey contained three parts, and it was designed to elicit the desired information using guidance from Bateman et al. (2002) and Whitehead (2006). Part I asked for respondents' overall perceptions and attitudes toward noise and noise policy. It included several questions, such as the perceived intensity and frequency of noise in daily life, interest in environmental noise issues, perceived level of annoyance caused by noise, and level of satisfaction with soundproofing. The answers to those questions were used to examine the effects of those factors on respondents' WTP for noise and related policies. Part I was also designed to call the respondents' attention to the survey before the main CV questionnaire.

Part II was the main valuation section containing the key questions about WTP for noise policies. It began with information to help respondents complete the valuation task, such as the definition, types, and effects of noise; possible damage from noise; and the intent, purpose, and expected impact of each noise policy. If a respondent needed an additional explanation or further clarification, the interviewer provided it. As explained in the "Research background" section, we compared the relative value of two different types of noise—residential and transport noise. Therefore, we set respondents two CV tasks. We defined residential noise to include neighbor noise and construction noise, and we defined transport noise to include road traffic noise, aircraft noise, and railway noise. Respondents were told that enforcing a noise policy could incur additional government expenses that would be covered by an increase in income tax, which is a common payment vehicle used in CVM studies (Morrison et al. 2000; Kuhfuss et al. 2016; Lewis et al. 2017).

When applying the CVM, especially in DC formats, the initial bid amounts are very important in obtaining a good estimate of the mean WTP (Herriges and Shogren 1996; McLeod and Bergland 1999). Therefore, we conducted a pre-test to examine the distribution of WTP values.³ The pre-test indicated that the WTP for a policy to reduce transport noise was larger than that for a policy to reduce residential noise. We reflected that result in the initial bids for each type of noise. Table 4 shows the initial bid amounts used and the number of respondents facing each bid amount in our CV survey. The initial bids were said to take the form of annual income tax payments for the next five years.⁴ Finally, the following key WTP question was asked to the respondent as the valuation task: "To implement [residential/transport] noise reduction measures at your home or workplace, is your household willing to pay [KRW _____] of additional income tax per year for the next five years?"

Part III of the survey investigated the socioeconomic and demographic characteristics of the respondents. By examining various characteristics (gender, education status, income, and occupation), it is possible to analyze their effects on the WTP for each noise policy. Table 5 represents the basic descriptions of the survey respondents.

³ As a pre-test, we conducted an online survey of 400 respondents aged 20 to 65 in the same eight metropolitan areas. Data from 13 respondents were excluded because they did not provide complete responses to all questions. In the pre-test, we asked for respondents' WTP through open-ended questions. According to Kanninen (1993), the initial bid amount in DC formats should be between 12 and 88% of the pre-test results. In our consideration of the WTP value from the pre-test, we removed the top and bottom 15% of the data to remove outliers.

⁴ Bond et al. (2002) and Adersson et al. (2013) discussed the relationship between payment periods and the sensitivity of WTP. We choose five years as the payment period because shorter and longer payment periods could be more sensitive on respondents' WTP.

Table 4 Initial bid amounts and number of samples in the CV survey

Initial bid (KRW) Residential noise	Initial bid (KRW) Transport noise	Number of respondents	Ratio (%)
3000	5000	129	12.9
6000	8000	128	12.8
10,000	12,000	130	13.0
14,000	18,000	121	12.1
20,000	25,000	125	12.5
26,000	32,000	123	12.3
33,000	40,000	124	12.4
40,000	50,000	122	12.2
Total		1002	100

Results and discussion

WTP estimates for noise-control policy

To analyze the public’s WTP for noise-control policies, we divided the 1002 respondents into eight groups and presented each group with one of eight sets of initial bids. Table 6 shows the distribution of responses by the different initial bid amounts. Regardless of the noise type, as the initial bid increased, the number of respondents whose responses were yes-yes decreased, and the number of respondents whose responses were no-no-(no) increased. For example, for residential noise reduction, the number of respondents answering yes-yes was 22 when the initial bid was KRW 3000, 5 when the initial bid was KRW 6000, and 2 when the initial bid was KRW 10,000. That trend also occurred for transport noise.

We used two models in the analysis. Model 1 simply estimated the mean WTP without considering respondents’ personal characteristics, and model 2 included respondents’ characteristics to identify the determinants of their WTP. The

estimation results for model 1 (the spike model presented in Eqs. (5) through (7)) are shown in Table 7. The minus sign for the bids variable in both types of noise indicates the decreasing preference for an increase in bid amount, again confirming the lower ratio of “yes” responses with a larger bid. The estimated monthly mean WTP of Korean citizens was KRW 3392.3 for residential noise and KRW 3507.1 for transport noise. In Korea, therefore, we found a significant statistical difference (at the 1% level) between the economic values of the two types of noise policy, although the monetary size of the difference is comparatively small. The spike estimate was statistically significant and similar to the ratio of respondents with no-no-no responses, which confirms the validity of our model. Therefore, policymakers should take people with zero WTP into consideration when interpreting our results and making new noise policies.

The expected consequences of the described noise-control policies and the individual WTP can differ depending on respondents’ characteristics. Therefore, model 2 decomposes the constant term (*a* in Eq. (1)) into the effects of sociodemographic

Table 5 Descriptive statistics of the respondents

		No. of respondents	Ratio (%)
Total		1002	100
Gender	Male	528	52.7
	Female	474	47.3
Age	20–29	183	18.3
	30–39	209	20.9
	40–49	247	24.7
	50–59	246	24.6
	60–64	117	11.7
	Monthly household income	Under KRW 3 million	280
	KRW 3–4 million	272	27.1
	KRW 4–5 million	213	21.3
	Over KRW 5 million	237	23.7

Table 6 Results of WTP responses for noise-control policy

Initial bid (KRW)	WTP for residential noise reduction					Total
	Yes-yes	Yes-no	No-yes	No-no-yes	No-no-no	
3000	22	20	11	3	73	129
6000	5	23	18	1	81	128
10,000	2	9	18	2	99	130
14,000	3	8	8	2	100	121
20,000	3	11	8	2	101	125
26,000	0	8	4	2	109	123
33,000	3	1	7	1	112	124
40,000	1	1	4	2	114	122
Total	39 (3.9%)	81 (8.1%)	78 (7.8%)	15 (1.5%)	789 (78.7%)	1002 (100%)
Initial bid (KRW)	WTP for transport noise reduction					Total
	Yes-yes	Yes-no	No-yes	No-no-yes	No-no-no	
5000	13	16	20	3	77	129
8000	4	17	19	3	85	128
12,000	1	8	22	2	97	130
18,000	4	11	8	0	102	125
25,000	1	6	8	3	103	121
32,000	1	2	7	2	112	124
40,000	0	4	6	2	111	123
50,000	1	2	4	2	113	122
Total	25 (2.5%)	66 (6.6%)	94 (9.4%)	17 (1.7%)	800 (79.8%)	1002 (100%)

variables: respondents' key demographic characteristics, experience with noise damage, and interest in environmental noise. Table 8 summarizes the definitions and descriptive statistics of the covariates. Among them, the level of interest in environmental noise was measured using a 5-point Likert scale, with higher points indicating more interest.

Table 9 shows the parameter estimates for those explanatory variables. Several implications can be drawn from the reported signs of the coefficients that are statistically significant. The coefficients of most of the variables have the same sign for both residential and transport noise. The sign of the bids coefficient is negative, which is expected from and coincides with

the CV rationale. Also, regardless of the noise type, respondents with a high household income, past experience with noise damage, or interest in environmental noise have a higher WTP than others. The positive relationship between income and WTP is commonly seen in studies of non-market goods valuation, including previous research on noise valuation (Bjørner 2004; Li et al. 2009; Istamto et al. 2014). In addition, the fact that a respondent's experiential and psychological factors, such as experience with noise damage and interest in environmental noise, influence their WTP implies that the government needs to make efforts to engage people personally in noise reduction issues. On the other hand, respondents' gender

Table 7 Estimation results for model 1

Variables	Parameter estimates	
	Residential noise (model 1)	Transport noise (model 1)
Constant	- 1.312**	- 1.374**
Bids	- 0.00007**	- 0.00006**
Spike	0.7878**	0.7980**
Number of observations	1002	
Log likelihood	- 853.07	- 822.93
Mean WTP (KRW/year)	3392.3**	3507.1**

**Significant at 1% level

Table 8 Explanatory variables and descriptive statistics in model 2

Variables	Definitions	Mean	Standard deviation
Age	Age of the respondent (years)	44.24	12.56
Gender	Male = 1, female = 0	0.53	0.50
Income	Average monthly household income (10 thousand KRW)	393.03	192.67
E_noise	Experience with noise damage (yes = 1, no = 0)	0.39	0.49
I_noise	Interest in environmental noise (5-point Likert scale)	3.47	0.81
N_infant	Number of infants in the house	0.15	0.45

and the number of infants in their household had no influence on WTP. The latter result differs from previous evidence in Europe, where the presence of children positively influenced the WTP for noise reduction (Bjørner 2004; Pommerehne 1988; Soguel 1994; Wardman and Bristow 2004). Thus, consumer valuation of noise reduction apparently differs with context, such as the cultural, residential, and behavioral characteristics of a society. Age had no significant influence on WTP for a residential noise policy, but younger people reported a higher WTP for a transport noise policy than older people. Previous research produced different results on the effects of age on the WTP for noise reduction (Bjørner 2004; Li et al. 2009). In South Korea, however, it appears that younger age correlates with a higher WTP only in the case of transport noise, possibly because of the residential preferences of different age groups in Korea. Younger Korean generations place the highest importance on transportation convenience in their residential choices (Kim and Noh 2011). Therefore, younger respondents often choose residential areas with dense transportation networks, which might increase their sensitivity to transport noise. Residential noise, on the other hand, is essentially the same everywhere, which could explain the lack of a significant

relationship between age and WTP for residential noise reductions. Putting the estimation results of model 1 and model 2 together, we conclude that in the Korean context, individuals' experiences with and interest in noise issues have important effects on their WTP, with a statistically significant but small difference between the economic values of noise reduction policies for different types of noise.

Although small, the differences between the mean WTP for two types of noise policies were confirmed in this study, which is consistent with existing acoustic evidence that the perceived annoyance and loudness of a noise differ with the noise source, even when the decibel levels are the same. For example, Miedema and Vos (1998) found that perceived annoyance differed by noise source despite the same loudness of transport noises. Aasvang and Engdahl (2004) found a correspondence between subjective responses to noise and personal attitudes toward the noise source. The International Organization for Standardization also encourages researchers to calibrate average noise levels by noise source. Differences in monetary value and perceived annoyance by noise source should be considered when prioritizing noise policies and when estimating compensation for noise damage.

Table 9 Estimation results from model 2 (including covariates)

Variables	Parameter estimates	
	Residential noise (model 2)	Transport noise (model 2)
Constant	− 3.095***	− 2.947***
Age	− 0.007	− 0.014*
Male	0.039	0.118
Income	0.001**	0.001**
E_noise	0.569***	0.606***
I_noise	0.373***	0.370***
N_infant	0.025	− 0.013
Bids	− 0.00007**	− 0.00007**
Spike	0.7965**	0.8088**
Number of observations	1002	
Log likelihood	− 833.85	− 801.82
Mean WTP (KRW/year)	3159.5**	3211.8**

*Significant at 5% level, **significant at 1% level

The economic benefits of noise-control policies: expanding WTP to the population value

Once the representativeness of the sample frame and a high survey response rate are secured, mean WTP can be expanded to the aggregated benefits of a policy (Arrow et al. 1993). The CV survey in our analysis satisfies those conditions. Using the mean WTP estimates presented in the “WTP estimates for noise-control policy” section, we can calculate the expanded population value, which is the annual aggregate economic benefit of the two individual noise-control policies considered in the CV. To do that, we multiply the responding households’ annual mean WTP by the total number of Korean households. According to the Korean Statistical Information Service of the Korea National Statistical Office, the total number of households nationwide was 19.84 million in 2016, so the annual total economic benefit from implementing noise policies for residential and transport noise would be approximately KRW 67.30 billion and KRW 69.57 billion, respectively. Each of those amounts is well beyond the total budget (KRW 41.98 billion) and actual expenditures (KRW 38.86 billion) of the Korean government for noise and vibration in 2015 (Ministry of Environment 2016). In other words, the Korean people apparently assign a very large value to the benefits that could accrue from implementing both noise policies. Therefore, the Korean government should increase its budget for noise-control measurement and pursue more active noise-related policies.

It is possible to assess the public acceptance of noise policies using the elicited mean WTP. The median monthly income of a family of four in South Korea was KRW 4.47 million in 2017, which means a middle-class Korean family’s income averages KRW 2.23–6.71 million a month. Comparing those figures with the estimated mean WTP, the additional income tax needed to implement residential and transport noise policies is 0.05–0.15% and 0.05–0.16%, respectively, of the monthly income of a middle-class Korean family. Those figures can be used as a baseline for budgeting future noise-control policies.

Putting all of our discussion together, the level of social benefits calculated from the mean WTP suggests that the feasibility and public acceptance of noise policies are likely to be high in South Korea. As presented in Table 6, however, the ratio of respondents with zero WTP is also very high, so setting noise policies requires a judicious approach.

It is worth mentioning that the results of this study have inherent limitations if they are to be applied to an overall cost-benefit analysis of the two noise policies: noise policies carry various indirect social benefits, and the only benefits calculated in this study are those to consumers. The same argument applies to the calculation of the costs of noise policies. Nonetheless, the results of our analysis provide important information for those determining future noise-control policies.

Conclusions

Assuming that people assign different values to noise from different sources, we estimated the economic value of residential and transport noise-control policies based on householders’ WTP. We used the CVM to elicit the mean WTP of respondents and adopted the spike model to account for those with zero WTP. We then tested the appropriateness of our hypotheses and model using empirical data from South Korea.

The estimated monthly mean WTP of Korean people for a noise policy is KRW 3392.3 for residential noise and KRW 3507.1 for transport noise; the WTP for transport noise reduction is slightly higher than that for residential noise. In other words, although the difference between the two noise policies is statistically significant, the absolute monetary value is small. Moreover, almost 80% of respondents were unwilling to pay anything for a noise-control policy, which highlights the need to consider them during policy formulation and implementation. The key variables affecting the WTP were household income, experience with noise damage, and interest in environmental noise. Thus, respondents’ experiential and psychological factors were more important than their demographic factors in explaining their WTP for a noise policy.

The analysis results of this study have practical implications for future noise-control policies in South Korea, especially for the government’s budget plans. As mentioned in the “Results and discussion” section, the Korean government allocated and executed a total of KRW 40 billion for noise and vibration control in 2015, but the effects of those policies were not very satisfactory. Therefore, the government plans to spend KRW 429.8 billion on noise and vibration reduction projects from 2016 to 2020, KRW 85.96 billion/year on average (Joint Ministry of Korean government 2015). Because the annual benefits of noise reduction calculated in this study are approximately 136.87 billion (KRW 67.30 billion + KRW 69.57 billion), the government’s plan to expand the relevant budget can be justified from a cost-benefit perspective. One major problem is that most of the current budget is used to reduce transport noise. Of the KRW 429.8 billion budget, more than KRW 400 billion will be spent to reduce transport noise, such as the expansion of low-noise vehicles and the management of railway noise. On the other hand, only about KRW 12 billion will be spent on residential noise control. The benefits of controlling residential noise and transport noise calculated in this study were very similar. Therefore, from a purely economic benefit standpoint, the Korean government needs to increase its budget for preventing and managing residential noise.

Some limitations of this study deserve mention. First, certain inherent limitations of our research methodology should be pointed out. The SP data do not necessarily coincide with consumer behaviors in real-life situations because they are hypothetical (Whitehead et al. 2008). In addition, because

the empirical data were obtained from a single source, generalization of our results to other regions or contexts should be done with caution. Second, we considered only two types of noise for parsimony of input. However, both residential and transport noise include various noise sources: for example, transport noise can be subdivided into aircraft, railway, and road traffic noise. It is necessary to estimate the individual values of all the types of subdivided noises when inferring detailed policy implications. Third, the economic viability of a noise policy should be assessed using an elaborate cost-benefit analysis, and this study focuses only on the public's WTP for a noise policy. A complete cost-benefit analysis would require not only a clear understanding of the policy but also interdisciplinary research into several fields of study, including acoustics, economics, law, and public policy.

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