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Original Research

Measuring the Willingness to Pay for Improved Air Quality: A Contingent Valuation Survey

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Abstract

This study attempts to estimate how much Polish citizens would be willing to pay for clean air by applying a contingent valuation of six damage components using the payment card question format: mortality, morbidity, visibility loss, material damages, damages to cultural heritage, and ecosystem damages. The system of the valuation questions approach helps to avoid an embedding problem. The analysis of protest voters is conducted. Although mortality and morbidity remain the most valuable damage components, the percentage shares of the total willingness to pay are more evenly distributed between all the damage components compared to literature. Damages to ecosystems and cultural heritage compose almost 30% of the total value, and their omission by the literature seriously underestimates total benefits.

Keywords: air pollution, contingent valuation, willingness to pay, Poland

Introduction

Poland has, alongside Bulgaria, the most polluted air in the EU. Although since the fall of communism in 1989 Poland has experienced a sharp improvement in air quality (primarily due to the introduction of better pollution policies), ambient air pollution remains very high [1].

Currently, the most pressing problem of poor air quality around the world – including Europe and Poland – are solid particles with a diameter of less than 10 µm (PM10) and less than 2.5 µm (PM2.5). In Poland, the source of over 50% emissions of particulate matter are individual households. The second largest source of particulate matter is road transportation [2].

The 2016 EEA report states that the short-term limit value for PM10 (i.e., not more than 35 days per year with a daily average concentration exceeding 50 $\mu g/m^3$) is the limit value that is most often exceeded in Europe [3]. Concentrations above the PM10 annual limit value were monitored in 2014 in reporting stations located mainly in urban areas in Poland and Bulgaria. In 2014 PM2.5 concentrations were higher than the target value in four Member States: Poland, Bulgaria, the Czech Republic, and Italy, occurring in 96% of cases in urban or suburban areas [3].

Ambient air concentrations of benzo[*a*]pyrene (a potent carcinogen found mainly in fine PM) are high across large parts of Europe, mostly as a result of emissions from the domestic combustion of coal and wood. These values above 1.0 ng/m^3 are most predominant in central and eastern Europe. The average concentration measured at Polish stations was 4.8 times as high as the target value [3].

Air pollution is known to cause health problems [4-8]. Spirić et al. (2012) compiled targeted studies on the association between the effects of air pollution and respiratory health endpoints published between January

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2000 and June 2010 [9]. Samek (2016) found that concentrations of PM10 and PM2.5 as well as nitrogen dioxide (NO_2) have considerable impact on human mortality, especially in the cases when cardiovascular or respiratory causes are attributed. Additionally, they affect morbidity. An estimation of human mortality and morbidity due to the increased concentrations of PM10, PM2.5, and NO_2 in 2005-13 was performed for the city of Kraków – one of the most polluted cities in Poland. Total mortality due to exposure to PM10 in 2005 was found to be 41 deaths per 100,000, and dropped to 30 deaths per 100,000 in 2013. Cardiovascular mortality was two times lower than total mortality. However, hospital admissions due to respiratory diseases were more than an order of magnitude higher than respiratory mortality. The calculated total mortality due to PM2.5 was higher than that due to PM10 [10]. Fengying et al. (2014) found a similar association between concentrations of ambient air pollutants and daily mortality numbers in an urban area of Beijing, China [11]. Research by Jedrychowski et al. (2017) found a negative effect of PM and polycyclic aromatic hydrocarbons (PAH) (a component of PM) exposures on birth outcome deficits (on birth weight and length) in Kraków [12]. Edwards et al. (2010) found that prenatal exposure to airborne PAHs adversely affects a child's cognitive development with potential implications for school performance. The findings for Kraków are consistent with findings in a parallel cohort in New York City [13].

According to the World Health Organization [14], which has been used to review the EU's policies on ambient air quality and to address health aspects of these policies, the adverse effects on health of particulate matter (PM) are especially well documented. Pollution from PM creates a substantial burden of disease, reducing life expectancy by almost nine months on average in Europe.

Air pollution is also known to reduce productivity [15-16]. Chang et al. (2016) in a U.S. study found that outdoor air pollution affects the productivity of not only outdoor but also indoor workers. Increases in PM2.5, a pollutant that readily penetrates indoors, leads to significant decreases in productivity, with effects arising at levels below air quality standards. Preliminary calculations suggest the labor savings from nationwide reductions in PM2.5 generated a sizable fraction of total welfare benefits [15].

Air pollution also affects visibility [17] and materials [18-19] (including historical buildings and monuments) [20-21]. Tidblad et al. (2016) showed the results of research on various corroded materials at 10 locations in Kathmandu (Nepal) related to SO_2, NO_2, O_3, HNO_3, and PM concentrations and climatic factors, and compared the results with a general pattern from exposures at different sites in Asia, Africa, and Europe [20]. Air pollution also affects wildlife and reduces both the yield and nutritional quality of farm produce [22]. Rai (2016) reviews harmful effects of PM pollution (as an effective indicator of the overall impact of air pollution) on vegetation, covering an extensive span of 1960 to 2016 [23].

Given the adverse impacts of air pollution, clean air becomes a highly valued commodity, especially in urban areas. People should be willing to "buy" clean air. However, air quality is not a market good but externality and an explicit market for trading clean air does not exist, which is why its market value must be estimated by indirect methods.

Navrud and Pruckner (1997) state five types of using environmental valuation: project evaluation (from a social perspective, usually with the application of cost-benefit analysis, or CBA), regulatory review, natural resource damage assessment, environmental costing, and environmental accounting [24]. Among these, CBA is probably the most frequently used tool requiring environmental valuation [25]. For example, cost-benefit analysis based on contingent valuation for improved air quality conducted for Mexico City indicated that benefits from improved air quality surpass the costs of investing in hybrid buses [26].

Cost-benefit analysis requires valuation of both benefits and costs in the same units. If the analyses involved just market goods, this would not be too challenging a task. However, most important environmental policy issues involve non-market benefits and market costs: that is, the costs are often fairly obvious and more easily quantified, but the benefits, i.e., of improved air, are far more difficult to estimate.

This paper tries to estimate how much Polish citizens would be willing to pay for clean air. The contingent valuation of six damage components using the payment card question format is applied. Each person was asked to consider individually the impact on mortality, morbidity, visibility loss, material damage, damage to cultural heritage (historical buildings and monuments), and ecosystem damage. The system of valuation questions for all damage components approach helps to avoid the embedding problem. An analysis of protest voters is conducted. As a result, a household's average monthly willingness to pay (WTP) for each damage component and for the overall reduction in air pollution is estimated. The monetary indicators calculated based on the survey research can be used in decisive processes in health care and environmental protection sectors.

Material and Methods

Methods for Valuing Environmental Costs and Benefits

Valuing environmental costs and benefits is difficult, even though they can be easily identified. Moreover, different methods give different numbers since the methodology used for calculating these costs and benefits varies from one study to another. They also differ in the types of benefits they are able to measure [27]. Methods for measuring environmental costs and benefits can be generally classified as indirect and direct (or survey methods) [28]. Indirect methods are market price methods and reveal preferences, while direct methods are stated preference methods [28-27]. Market price methods, also called physical linkage methods, usually are related to the damage function approach, and in the case of biological relationships to the dose-response approach. The damage function approach assesses the estimated effects with the application of market prices, which, along with their simplicity, are why they have a lot of supporters among economists. However, currently the imperfections of that group of methods are widely recognized [28]. All these approaches are based on assessments of the financial costs to society. The value of these costs tend to be less than the monetary value of utility losses to society for a variety of reasons [28-29].

Behavioral linkage methods are all based on some form of behavioral linkage between a change in an environmental amenity and its effects. The methods of revealed preferences take advantage of information from the so-called replacement market, that is the market of a good the consumption of which is somehow connected with the consumption of the non-market good being the subject of the price estimation. The most commonly used method is the hedonic pricing method (HPM). The basic assumption of HPM is that the price of a marketed good is a function of its different characteristics. Usually the market good used is residential property. HPM could also effectively value environmental externalities [28-29]. The fundamental assumption is that in purchasing a house, the homebuyer is paying not only for the dwelling unit but also for its surrounding environmental qualities. There are many aspects that contribute to environmental attributes, for instance air quality [30]. The author made an attempt to value air quality in Poland with the use of HPM [31-33]. However, the limitation in applicability of this method is the requirement of developed and effective residential property market. HPM research was conducted for the biggest cities in Poland: Warsaw, Kraków, and Wrocław. The air quality attributes tested were NO_2 and PM10 concentrations. Most structural and location attributes were statistically significant with expected signs of influence on prices; nevertheless, analyzed air quality attributes occurred to be statistically insignificant. This indicates an insufficient degree of efficiency of the real estate market in Poland in order to valuate environmental attributes.

The methods of stated preferences consist of an attempt to simulate the market of non-market goods, which is most frequently done by means of survey research. The most widely used is the contingent valuation method.

Contingent Valuation Method

With the application of the contingent valuation method (CVM), respondents are directly requested to determine the amount of money they are willing to pay (WTP) for a change in the quality or/availability of a non-market good or, alternatively, the amount of money they are willing to accept as compensation (WTA) for introducing certain changes in environmental quality. The basic idea of CVM is that a realistic but hypothetical market for "buying" quality or availability of a non-market natural resource can be credibly communicated to an individual. Then the respondent is told to use the market to express his valuation of the resource. Key features of the market include a description of the change in environmental quality being valued and means of payment (often called payment vehicle). The method is based on the assumption that people's intended behavior in a hypothetical market reflects preferences for non-market assets [27].

CVM is widely used to valuate environmental goods and externalities [34-35]. Although the method has some limitations (as do each of presented methods), it is regarded as the most flexible method in principle and could be designed to valuate any environmental good, service, or externality. The method also appears to be the only way to measure monetary values of the whole non-use class benefits of a good, and also the existence value and option value [27].

The hypothetical nature of contingent valuation, however, makes it controversial and subject to potential inaccuracy and imprecision [36-37]. Hausman (2012) states three problems: 1) hypothetical response bias that leads contingent valuation to overstatements of value, 2) large differences between willingness to pay and willingness to accept, and 3) the embedding problem, which encompasses scope problems [36]. Therefore, the survey must be designed carefully. The method first came into use in the early 1960s in the USA. The first CV study on air pollution control was by Ridker in 1967 [38-39]. Although the primary purpose of Ridker's work was to valuate household soiling and material damages using HPM, it was his recognition that people might value air pollution because of its "psychic costs," which led him to include a couple of WTP questions in two different surveys he conducted in Philadelphia and Syracuse. He asked how much people would be willing to pay to avoid "dirt and soot" from air pollution [27]. Since the early 1970s the CV method has been used to valuate the benefits of a wide variety of environmental goods [27]. The breakthrough findings on the use of CVM occurred after the publication of the work of a special commission appointed by the U.S. government to give feedback on the valuation of the damage caused to ecosystems of Alaska by the Exxon Valdez tanker spill in 1989 — one of the country's most serious environmental disasters. A panel of social scientists was to consider the criticisms of contingent valuation and make recommendations to the National Oceanic and Atmospheric Administration (NOAA). The panel legitimated the use of CV studies for damage assessment, including lost passive use values, provided they follow a number of stringent guidelines [40]. The recommendations of this panel have influenced NOAA regulations ever since and remain the standard for conducting valid and reliable CV studies.

In the area of air pollution damage components, especially morbidity and mortality, CV studies have been used as a main source of estimates for most cost-benefit studies on pollution control [16, 41]. In recent years many studies in the field have been conducted in developing Asian countries. Lee et al. (2011) estimated a WTP amount for reducing the mortality rate in order to evaluate a statistical life value in Seoul, Korea. The monthly average WTP for 5/1,000 mortality reduction over 10 years is $20.20 US, and the implied value of statistical life (VSL) is $485,000. The damage cost estimate due to risk from PM2.5 inhalation in Seoul is about $1,057 million per year for acute exposure, and $8,972 million per year for chronic exposure [42]. Huang et al. (2012) estimated the adverse health effects of particulate matter pollution in the Pearl River Delta in southern China. They found that in 2006 the total economic loss of the health effects from PM10 pollution in PRD was 29.21 billion Chinese yuan, which is equivalent to 1.35% of the regional GDP. The economic loss due to premature death and chronic respiratory disease accounted for more than 95% of the total loss [43]. Sun et al. (2016) estimate a WTP for reducing air pollution in the urban area of China. They found that nearly 90% of the respondents are willing to pay for reducing air pollution, and the average amount of WTP per individual is 382.6 RMB per year [44]. The study conducted by Gupta (2016) for three metropolitan areas of India (Delhi, Mumbai, and Bangalore) also revealed that people of India generally are willing to pay for improved air quality [45]. In contrast, in a study of Indonesia's Semarang Urban Area, Gravitiani and Kristanti (2015) found that the level of WTP of society was still low, as only 38% of the people were willing to pay a proposed maximum of 40,000 rupiah every year to reduce mobile pollution sources [46]. For North America, Barrington-Leigh and Behzadnejad (2016) estimated the impact of air pollution on the well-being of Canadians. They found that higher air pollution significantly reduces life satisfaction. The value of improving air quality by one-half standard deviation throughout the year is about 4.4% of the average annual income of Canadians [47]. Filippini and Martinez-Cruz (2016) estimate WTP for improved air quality among residents of Mexico City [16]. For South America: Markandya et al. (2009) present a contingent valuation study conducted in Sao Paulo (Brazil) to estimate the population's WTP to reduce risk of death, and the correspondent value of a statistical life (VSL). Results ranged between $0.77-6.1 million [48]. Examples in Europe include Nielsen (2010) finding the value of a life year (VOLY) to be in the range of €9,000-30,000 for Denmark [49]. Istamto et al. (2014) assess the WTP for traffic-related air pollution on health in five European countries: the United Kingdom, Finland, Germany, the Netherlands, and Spain [50]. In Poland there are few such original valuation studies. The first studies were conducted on a local scale in urban hot spots [51]. The first nationwide CVM study on air quality was conducted by Dziegielewska and Mendelsohn (2005) in October 2000 to estimate the willingness to pay of Polish citizens in order to harmonize Polish air pollution standards with EU standards [52]. Markowska et al. (2007) conducted contingent valuation survey within the European Commission NEEDS project on valuation of life year gained (VOLY) in the context of air pollution [53]. Markowska et al. (2011) estimated VOLY for the EU by conducting a CV survey in nine European countries: France, Spain, the UK, Denmark, Germany, Switzerland, the Czech Republic, Hungary, and Poland [54]. Ligus (2010) conducted a nationwide CVM survey on air quality, encompassing a much wider range of air pollution damage components [55]. The survey was repeated in October 2015.

Primary Research on Valuing Benefits from Improving Air Quality in Poland

The contingent valuation survey was held on a nationwide random sample of 1,000 adults. Face-to-face interviews were carried out by Ipsos, a professional polling agency in October 2015. The sample selection was quota, while the proportions were tested in five layers: sex, age (12 age groups), education level (four levels), size of residence (five levels), and voivodship (16 voivodships). Since the shares of the social groups defined by these charasteristics in the sample are practically the same as those of the relevant population groups, the analysis will be conducted as if the stratified selection was performed with a proportional allocation of sample in the layers. The main goal of the research was to find the household's average monthly willingness to pay in addition to electricity bills in order to improve air quality in Poland. The payment card elicitation format was applied.

Methodology of the Survey

In the analysis the author applied a system of contingent valuation questions in order to valuate the total effect of air pollution emissions (the methodology was based on [52 and 55]). The study is valuating the benefits from air quality improvement from the current situation defined as some welfare function, f, of current prices p^0, wages w^0, and air quality q^0 to a new situation described as function, f, of new prices p^1, wages w^1, and air quality q^1:

$$f(p^0, w^0, q^0) \rightarrow f(p^1, w^1, q^1)$$

For simplicity it was assumed that prices and wages are constant: $p^0 = p^1$ and $w^0 = w^1$.

Air quality was defined in terms of the damage it causes. Damage is a composite good and has six distinct components c_k, $k = 1...6$, where each is a function of air pollution level q^j, for $j = 0,1$. The components are mortality, morbidity (bronchitis, asthma, minor health symptoms), visibility loss, material damage, damage to historical buildings and monuments, and ecosystem damage. It was assumed that each damage component, along with income m, prices p, and wages w are elements of a utility function u:

$$u(q^j(c_k), m, p, w)$$

The proposed air quality improvement, from $j = 0$ to $j = 1$, leads to a change in each component such that $u(q^0(c_k) < u(q^1(c_k)$. A system of WTP questions is applied, one for each damage component:

$$(1)\, u\{c_1^1; c_2^0; ...c_6^0; m - CV^1, w, p\} = u\{c_1^0; c_2^0; ...c_6^0; m, w, p\}$$
$$\vdots$$
$$(k)\, u\{c_1^0; ...c_k^1; ...c_6^0; m - CV^k, w, p\} = u\{c_1^0; ...c_k^0; ...c_6^0; m, w, p\}$$
$$\vdots$$
$$(6)\, u\{c_1^0; c_2^0; ...c_6^1; m - CV^6, w, p\} = u\{c_1^0; c_2^0; ...c_6^0; m, w, p\}$$

…where c_k^j denotes, for simplicity, $q^j(c_k)$, and CV^k stands for compensated variation, a measure of willingness to pay, for component k, given j air quality. It was assumed that the change will impact all of the damage components and thus it is needed to assess total CV as a willingness to pay for the proposed change:

$$u\{c_1^1; c_2^1; ...c_6^1; m - CV, w, p\} = u\{c_1^0; c_2^0; ...c_6^0; m, w, p\}$$
[52]

The system approach helps minimize the embedding effect [52], a term popularized by Kahneman and Knetsch (1992), meaning that willingness to pay for a particular good may vary over a wide range depending on whether the good is assessed on its own or embedded as part of a more inclusive package [56-57]. This is usually connected with misinterpretation of a presented scenario. For example, it is well documented that respondents valuing visibility improvement frequently assume that such an improvement will also affect health and other air pollution damage [58-59].

Thus, in each question respondents value a change that affects only one of the damage components at a time, keeping the other components unchanged. The value of the overall reduction in air pollution is equal to the sum of the values of the individual components:

$$\sum_{k=1}^{6} CV^k = CV$$

The sum, however, may be quite different from the WTP to change all the components simultaneously [57]:

$$u\left(\sum_{k=1}^{6} c_k^1, m - CV, p, w\right) = u\left(\sum_{k=1}^{6} c_k^0, m, p, w\right)$$

In this survey, the author tested empirically whether the components are independent. The respondents were

Table 1. Primary statistics of the WTP responses in the entire sample and in the sample without protest voters.

Estimated parameter	Mortality	Morbidity	Visibility	Materials	Historical	Eco-systems	TOTAL WTP	**TOTAL WTP after reconside-ration**	Diffe-rence
Whole sample									
Mean [PLN]	5.092	3.781	3.340	3.113	3.227	3.317	21.871	**19.604**	-2.267
% of total WTP	23.282	17.288	15.271	14.233	14.755	15.166	100	**89.635**	-10.365
Confidence interval 95%	4.167 6.017	3.350 4.211	2.864 3.817	2.657 3.569	2.733 3.722	2.831 3.800	19.114 24.627	**17.202** **22.005**	-1.912 -2.622
Median [PLN]	1	1	1	1	1	1	7	**6**	-1
Standard deviation	14.898	6.933	7.671	7.339	7.966	7.834	44.399	**38.683**	-5.716
Min [PLN]	0	0	0	0	0	0	0	**0**	0
Max [PLN]	300	70	100	100	100	100	520	**400**	-120
Sample without protest voters									
Mean [PLN]	5.500	4.083	3.608	3.362	3.485	3.583	23.621	**21.172**	-2.449
% of total WTP	23.284	17.285	15.275	14.233	14.754	15.169	100	**89.632**	-10.368
Confidence interval 95%	4.505 6.494	3.624 4.543	3.097 4.118	2.874 3.851	2.955 4.016	3.061 4.104	20.672 26.569	**18.605** **23.739**	-2.067 -2.830
Median [PLN]	2	2	1	1	1	1	8	**8**	0
Standard deviation	15.411	7.119	7.912	7.572	8.224	8.083	45.692	**39.786**	-5.906
Min [PLN]	0	0	0	0	0	0	0	**0**	0
Max [PLN]	300	70	100	100	100	100	520	**400**	-120

given the opportunity to reconsider their total WTP once they answered the system of questions.

Valuation questions were followed by a set of attitudinal statements about the WTP questions. These questions were designed to identify protest voters. Protest bidders are respondents who may actually place some value on the commodity in question but refuse to pay on the basis on ethical or other reasons. Protest voters should be excluded during analysis of CVM data because they can bias estimations of central tendency measures of WTP [60]. Protesters were identified as respondents who declared zero on all valuation questions, and held at least one effective protest belief. The protest beliefs were: that polluters (not respondents) should pay, that electricity bills should not be used as a payment vehicle, and that the proposed policy would be ineffective at reducing air pollution. Identified protest voters represent 7.4% of the sample.

Results and Discussion

The primary statistics of the WTP responses in the whole sample and the sample without protest voters are presented in Table 1.

The following analysis will concentrate on the sample without protest voters. Mortality has the highest mean WTP (23.3% of the total WTP). The mean WTP decreases further for each consecutive component: morbidity (17.3%), visibility (15.3%), and materials (14.2%). The mean WTP then rises for the last two components: historical buildings (14.8%) and ecosystems (15.2%). This demonstrates that the responses were not just a reflection of the order of questions (other systematic bias quite common in CV surveys [27]. Mean total WTP (after reconsidering final bids by respondents, in the sample without protest voters and after rejection of extreme values) is 21.172 PLN per month. Meaningful is that the median is definitely lower than the mean, which is due to the high percentage of zero bids (255 observations, or 27.6% of the sample). Mean total WTP after reconsideration of final bids by respondents is lower than the ordinary mean WTP. This means that part of respondents decided to change their original bids. Most of them declared lower bids. If all respondents changing their bids declared lower bids, this meant that an embedding bias occurred. However, 15% of respondents changing their bids decided to declare a higher bid, so the direction of change is ambiguous. This can be interpreted positively, as evidence of respondents' engagement in the valuation process.

Analysis of the relationship between the final average WTP and certain demographic groups was performed using one-way analysis of variance in the STATISTICA program. None of the socio-economic variables are significant (at significance level of 0.05), except for voivodships. However, at the significance level of 0.15, variables that significantly contribute to WTP for air pollution reduction include sex (men are willing to pay more), marital status (married are willing to pay the most), being professionally active, and settlement size. Education is statistically significant at significance level of 0.25. What is surprising is that income and age are not statistically significant.

This paper attempts to compare the final estimates with the research results of other studies. Results presented in this paper cover all air quality components while available studies usually concentrate on one or selected air quality components. Comparability is therefore impeded. A similar study was conducted by Dziegielewska and Mendelsohn (2005) [52] within the scope of damage components, but scenarios differ. Dziegielewska and Mendelsohn (2005) [52] estimate WTP to harmonize Polish air pollution standards with EU standards (testing 25% and 50% reduction in air pollution). This research scenario is to reduce air pollution to a level that causes practically no harm to human health and the environment and does not reduce it by a certain level (i.e., 25% or 50%). However, a precise indication of the level of reduction in air pollution might not be a significant problem in terms of comparability due to the fact that people experience difficulty in distinguishing between differences in quantity and the scale of provision of a good, which has been suggested by a study of Desvousges et al. (1993) [61]. What people value is a significant reduction in air pollution despite the reduction being precisely quantified as 25% or 50%. This is also the finding of [52]. Markowska et al. (2007) and Markowska et al. (2011), eliciting WTP for six- and three-month gains in life expectancy, also did not pass the scope test. The results show that WTP does not increase proportionally with an increase in life expectancy gain. Thus, for the pooled sample the 6/3-month ratio is 1.3 rather than 2. The main reason was that the respondents did not see much difference in a life expectancy gain of six versus three months [54]. The authors state that typically WTP increases far less than the proposed benefit. This lack of strict proportionality is notorious in CV studies. They suggest, however, that this is the correct valuation because people probably perceive the magnitude of their WTPs on a logarithmic rather than linear scale. Perception in relative terms may be especially likely when the good in question is not at all familiar [54].

The parameters that can be compared accurately are shares of WTP bids for every damage component in the total WTP. Mortality followed by morbidity are considered the most valuable damage components, similar to [52]. However, percentage values are more evenly distributed between the damage components than in [52]. Damage to ecosystems and cultural heritage compose almost 30% of the total value (almost 16% in [52]), while their omission in other studies in the field significantly underestimates total benefits.

Dziegielewska and Mendelsohn (2005) [52] propose as a payment vehicle a one-time increase in taxes, whereas in this research the payment vehicle is a monthly additional payment to an electricity bill declared to be paid for the period of 15 years. The latter was dictated by the lifespan of a typical investment in the energy sector in order to facilitate the construction of indicators useful for project evaluation. To compare WTP estimates, there is a need to convert WTP as a one-time payment (total value, TV) for a change in amenity (cleaner air) that lasts many years in [52] to an annualized payment in the author's study. TV must be amortized, or annualized, over 15 years. This annualized payment (AV) is equal to full asset value (or one-time payment, TV) multiplied by an annualization factor (AF) [62]:

$$AV = TV \cdot \frac{i}{1-(1+i)^{-T}}$$

…where AV is the annualized WTP of households, and the last term on the right-hand side is the AF. Assuming an annual interest rate, i, for household investments as 3.7 percent (based on long-term bank deposit rate in 2000) [63], with a term, T, of 15 years (a period of payment obligation in the study), the annualization factor is 0.088065. Median WTP values expressed in PLN'2000 was increased of the CPI, and the GDP growth rates in the years 2001-15 [64-65]. The annualized total median WTP in [52] (50% reduction in air pollution scenario) is 33.4 PLN'2015, whereas in this study annual total WTP median is 96 PLN. It should be noted that these values are not fully comparable. It seems that answers to the question about an immediate one-time payment will represent a lower value (due to budgetary constraints) than answers to the question about payment in installments. The second reason is that in 15 years (2000-15) there has probably been a change in social preferences and an increase in environmental awareness (above updating for inflation and growth in society's wealth, measured by GDP).

This is also the finding of comparing WTP values of survey research conducted in 2007 [55] and the survey repeated in 2015 by the author. The mean WTP value of Ligus (2010) increased with CPI and the GDP growth rates in 2007-15 is still 14.74% lower than the mean WTP of the survey conducted in 2015. This gives an average annual real increase in the average WTP between 2007 and 2015 of 1.79%.

Conclusions

This study valuates the benefits of improving air quality in Poland using CVM. A system approach that decreases embedding bias was applied in order to valuate the six damage components separately: mortality, morbidity, visibility loss, material damage, damage to historical buildings and monuments, and ecosystem damage. The payment vehicle is a monthly additional payment to the electricity bill declared to be paid for the period of 15 years, which was dictated by the lifespan of a typical investment in the energy sector in order to facilitate the construction of indicators useful in project evaluation.

The survey results were compared with Dziegielewska and Mendelsohn (2005) to confirm the consistency of the study. Probably the most important conclusion is that mortality and morbidity are the most valued air pollution damage components (as in literature studies), confirming that investment programs and policies should focus on reducing emissions that cause the strongest adverse health effects. But value estimates in this study (and in [52]) for damage components are much more evenly distributed than in the literature, e.g., USEPA (2011) [66]. These results could reflect differences in methodology. By including a complete set of impacts, the survey allows respondents to balance their concerns. Omission in literature of damage to ecosystems and cultural heritage seriously underestimates total benefits.

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