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Air pollution and willingness to pay for health risk reductions in Egypt: A contingent valuation survey of Greater Cairo and Alexandria households

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ABSTRACT

Egypt ranks first worldwide for the number of deaths attributable to PM2.5 air pollution, yet the economic value of improved air quality and the value of reducing mortality risk due to industrial air pollution has never been evaluated using primary data for Egypt. In this paper, we fill this gap focusing on the Greater Cairo and Alexandria metropolitan areas, where more than 80 percent of the country's industrial activities take place. We find that 73% of the 1051 surveyed households are supportive of improved air quality strategy and a reduction by 50 percent from current level of pollution is valued between 212 and 302 LE per month (13.5–19.3US$). The health risk reduction is measured with Value of Statistical Life (VSL) measures that range between 3.81 and 7.0 million LE (242,675–446,000US$). The results confirm that residents are sensitive to environmental air quality levels. Furthermore, when provided with information about the health consequences of pollution, survey respondents increased both their level of support for the policy, and their Willingness to Pay for it.

1. Introduction

Similarly to other developing economies that have chosen a 'grow now, clean up later' strategy, Egypt has experienced rapid economic development at the cost of significant environmental degradation.[1] During the 1970 s and 1980 s, in particular, multiple heavy polluting industries emerged, often located along the banks of the river Nile, contributing to soil, water and air contamination (Ali, 1993; Abdel-Halim et al., 2003; Goher et al., 2019). Despite efforts[2] started in the early 1990 s to mitigate the environmental impacts of rapid economic growth, environmental quality remains stubbornly low, especially as refers to air pollution where Egypt is in the unenviable position of ranking first worldwide for the number of deaths attributable to $PM_{2.5}$ air pollution (Health Effects Institute, 2020).

In Egypt, as well as across the Global South, several constraints still limit progress in this area, such as the lack of an integrated environmental management approach, the low level of financial support, the poor level of environmental awareness among stakeholders, and – importantly – a generalized dearth of information about the economic value of environmental quality. Indeed, credible estimates of the environmental costs and benefits are crucial to underpin the implementation of effective environmental strategies (OECD, 2016). Unfortunately, such estimates remain lacking across much of the Global South, including Egypt, making a transparent, evidence-based policy debate all but impossible.

In this paper, we aim to partially fill this gap and to contribute to the policy debate by exploring the level of engagement with pollution reduction measures among the Egyptian population. Using a sample of

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[1] The Environmental Kuznets Curve model underpins the idea that environmental clean-up inevitably follows an early phase of rapid economic progress once societies reach middle-income status (Panayotou, 1993). Other authors, however, have warned against this simplistic interpretation and have highlighted the role played, for example, by institutions and governance structures in this context (Stern et al., 1996; Dasgupta et al., 2006).

[2] Egypt's Environmental Law (Law 4/1994) regulates land, air, and water pollution and creates the Environmental Affairs Agency (EEAA) responsible to enforce these requirements.

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over one thousand households in the Greater Cairo and Alexandria areas, we use the Contingent Valuation Method (CV) to capture residents' preferences for reducing air pollution and health risks. To the best of our knowledge, this is the first study to perform a primary valuation of the health risks associated with industrial air pollution in Egypt.[3] We add to the literature by first eliciting a general measure of the willingness to support policies aimed at reducing air pollution. Imagining a relocation of heavy polluting industries outside the urban area, we derive a generic willingness to pay (WTP) for reduction in particulate matter and finally, we investigate whether the willingness to pay responds to the provision of information about the damages caused by the exposure to air pollution and we focus on the health risk reduction benefits of air pollution abatement. Our results show that the mean WTP for reducing $PM_{2.5}$ air pollution from industrial activities by 50% from current level ranges between 212 and 302 LE per month (13.5–19.3US $),[4] which represents 4–5% of the sample average monthly income. The corresponding Value of a Statistical Life (VSL) estimates range between 3.81 million LE for the 10 in 10,000 mortality risk reduction to nearly 7 million LE for the 5 in 10,000 mortality risk reduction – equivalent to 242,675–446,000US$. These values are similar to those presented in Larsen (2019), who reports an average VSL of 3 million LE based on a benefit transfer methodology using secondary data.

Through our efforts, we hope to inform the policy debate in Egypt and other developing countries by providing reliable evidence that a substantial demand exists for environmental improvements, which likely offsets the costs of enforcing plausible policy measures such as the relocation of polluting industries away from population centers.

The rest of this paper is organized as follows: Section (2) provides a background of air pollution in Egypt and health consequences. Section (3) introduces the valuation setting and previous finding in the literature. Section (4) describes the survey design. In Section (5), we present the modelling strategy. Section (6) presents the empirical results. Finally, Section (7) discusses and concludes the paper offering some thoughts and implications relevant to the policy making process.

2. Background

Greater Cairo and Alexandria are the main metropolitan areas in Egypt and some of the most overcrowded cities in the world (Larsen, 2019). The combined population of these areas is more than 25 million – nearly 25% of the total population of Egypt – with a population density in excess of 100,000 persons per Km^2 (UNPD, 1990). Remarkably, these same areas also accommodate nearly 80% of Egypt's heavy industries such as cement, iron and steel, chemicals, ceramics, brick, and petroleum refineries (Nasralla, 2001; Moussa & Abdelkhalek, 2007), all of which have been closely linked to both air pollution and adverse health effects (e.g. Bergstra et al., 2018).[5] These industrial activities represent the major stationary source of air pollution, which is the most pressing environmental issue in Egypt (Larsen, 2019).[6]

Among air pollutants, $PM_{2.5}$ represents a persistent risk to human health being the main cause of deaths and disabilities attributable to cardiovascular and respiratory diseases, along with certain cancers, such as lung, bladder, liver, and kidney cancers (e.g. Cohen et al., 2005, Larsen, 2019). As mentioned above, Egypt ranks first worldwide for the number of deaths attributable to $PM_{2.5}$ air pollution (Health Effects Institute, 2020). According to recent estimates by the World Bank, 19,200 people have prematurely died and over 3 billion days were lived with illness in 2017 as a result of ambient $PM_{2.5}$ air pollution in Egypt (Larsen, 2019). The estimated annual cost of the health effects associated with ambient $PM_{2.5}$ air pollution in Greater Cairo alone was equivalent to 1.35% of Egypt's GDP in 2017 (Larsen, 2019).

UNDP (2020) indicates that the implementation of environmental policies in Egypt is still in its early stages, as priority is still often given to other policy goals, such as industrial development. The report also highlighted the factors that contribute to the poor air quality in Cairo, among others, the existence of a huge number of publicly-owned heavy industries (e.g., chemical, metallurgical) near populated residential areas, and the inadequacy of governance structures.

Despite these shortcomings, a series of projects have been conducted, aiming to mitigate the impact of air pollution in Egypt. The Egyptian Pollution Abatement Program (EPAP), for example, ran in three waves (1997–2005, 2007–2015, and since 2017) and was coordinated by the Egyptian Environmental Affairs Agency (EEAA) in corporation with the World Bank, the European Investment Bank, the European Union, the Government of Finland, and the Japan International Cooperation Agency (World Bank, 2017). The aim of the project is to encourage cleaner production through providing financial support for pollution abatement in private and public industrial companies. The emphasis of the program was on fuel-switching, clean technology abatement and, importantly, on industry relocation away from population hotspots. Similarly, the Cairo Air Improvement Project (CAIP), supported by the United States Agency for International Development, aimed at relocating factories involved in lead processing (smelting lead scrap), iron and copper foundries and decontaminating the sites of these smelters in Shoubra El Kheima (the north most part of Cairo). By 2004, the lead smelters in Shoubra El Kheima had been upgraded to become environmentally friendly, and were relocated to either the north of Nile Delta away from residential areas or to the Abu Zaabal industrial site (USAID, 2004).

Their effectiveness in reducing the burden of diseases caused by $PM_{2.5}$, notwithstanding, these relocations remain isolated events. With this mind, we aim to investigate whether the residents of Greater Cairo and Alexandria are prepared to support and financially contribute to the relocation of heavy industries with the aim reducing $PM_{2.5}$ air pollution by 50%.

3. Valuing changes in environmental quality and health risk

Economic estimates for environmental air quality and health risks (e.g., revealed preferences, stated preference and benefit transfer) may be assessed with a variety of methods (e.g., hedonic pricing, savings in health costs, etc.). However, when the aim is to value future policies such as relocation of heavy polluting industries outside urban areas, stated preferences emerge as the only viable option. Indeed, stated preference methods aim at assessing future policy options by directly asking citizens to express their preferences and willingness to pay for

[3] We are aware of two previous studies. Abou-Ali and Belhaj (2005) test the validity of transferring benefits using the mean WTP for a 50% reduction in air pollution caused by road traffic using Rabat-Salé (Morocco) as the study site and Cairo (Egypt) as the policy site. The second is a study by the World Bank – Larsen (2019) – that also transfers air quality measures using benefit transfer techniques from previous studies.

[4] Based on the exchange rate during the study period of 1USD = 15.7LE.

[5] For example, in Egypt, lung cancer is one of the common types of cancers, representing between 5% and 7% of all cancers, strikingly, 47.2% of the patients are workers in construction and in cement production (El-Moselhy and Elrifai, 2018).

[6] According to the Environmental Egyptian Agency Affairs (EEAA) data, emissions from industrial activities represent almost 25% of the total polluting emissions from all sources. In areas with heavy industrial activities, the national standards for pollution emissions are highly exceeded. These areas are mainly concentrated around the Greater Cairo metropolitan area, especially in Qaliubeya Governorate, and in Alexandria.

Table 1
Selected CV studies on air quality and health risk reduction.

Study	Country	Sample Size	Aim of the study	Attributes that affecting the WTP	Estimates (US$)	Estimates adjusted by PPP exchange rate in 2020* (US$)
Vassanadumrongdee and Matsuoka (2005)	Bangkok, Thailand	680	Mortality risk reduction	Severity, controllability and personal exposure to air pollution, income, education, age, gender, family size, and health insurance status	VSL: $0.87–1.6 *m* for 3 in 100,000 & $0.63 1.3 m for 6 in 100, 000	VSL: $381,000–700,320 for 3 in 100,000 & $275,750–569,000 for 6 in 100, 000
Wang & Mullahy (2006)	Chongqing, China	500	Mortality risk reduction	Exposure to air pollution, income, education, age, gender, marital status, family size, and health status	VSL: $34,458 for 5 in 100,000	VSL: $26,790 for 5 in 100,000
Hammitt and Zhou (2006)	China (Beijing, Anqing, and rural areas near Anqing)	3700	Morbidity and mortality risk reduction	Risk magnitude, pollution level (indoor PM_{10} and SO2 concentrations), age, gender, income, household size, education, health-insurance coverage, current health status, smoking and exercise status, perceived life expectancy and risk of chronic bronchitis	VSL: $15–180,000 for 1 in 10,000 and 2 in 10,000 $3–6 WTP for avoiding one episode of Cold. $500–1000 WTP for chronic bronchitis risk reduction	VSL: $11,240–134,882 for 1 in 10,000 and 2 in 10,000 $2.25–4.5 WTP for avoiding one episode of Cold. $375–749 WTP for chronic bronchitis risk reduction
Ortiz et al (2009)	São Paulo, Brazil	545	Mortality Risk Reduction associated with improved air quality (reduce ambient air pollution)	Income, age, gender, education, health insurance coverage, marital status, having children, smoking habit, subjective expected age of death, and degree of faith in religion	VSL: $ 0.77–6.1 m for a 5 in 1,000 and 1 in 1,000	VSL: $439,262 – 3,479,866 for a 5 in 1,000 and 1 in 1,000
Wang & Zhang (2009)	Ji'nan, China	1500	Improved air quality	Income, age, gender, household size, education, expenditure on the treatment of respiratory diseases, employment, pollution level (PM_{10} and NO2 concentrations), and health status	$ 15.5 WTP per person per year	$9.37 WTP per person per year
Hoffmann et al (2012)	Mongolia, Ulaanbaatar	629	Mortality risk reduction associated with PM10 air pollution	Income, age, gender, education, health status, and risk perception	VSL: $500,000 for 5 in 10,000	VSL: $443,500 for 5 in 10,000
Wang et al (2015)	Shanghai, China	975	Reducing air pollution to improve children's health	Children age, parents' education, parents' age, gender, income, family size, expenditures towards air pollution-related illnesses in their children, and respondents' perception of the current air pollution level in their residence area	WTP for parents who have sick children $80.7 WTP for parents who have healthy children $68.5	WTP for parents who have sick children $47.21 WTP for parents who have healthy children $40
Akhtar et al (2017)	Pakistan, Lahore	250	Improved air quality	Income, gender, age, household size, symptoms of respiratory diseases, and self-observed air pollution (PM, SOx and NOx)	$118 WTP per year	$108.8 WTP per year

* In our study, the WTP for reducing $PM_{2.5}$ in Egypt adjusted by PPP exchange rate ranging from $4.65 to 6.62 per month, and the VSL estimates are ranging from $153,374 to 740,798 for 1 in 1000 & 5 in 10,000 risk levels.

gaining potential environmental benefits. Among, the stated preference techniques, the CV is the most frequently used, especially in rapidly growing countries (Whittington and Pagiola, 2012).[7]

Table 1 provides details on some of the main CV studies conducted in fast growing economies similar to Egypt. The WTP for reducing air pollution mortality and morbidity risks varies from $15,000 to more than $6 million with risk reduction from 5 in 1000 to 2 in 100,000. Willingness to pay for morbidity due to air pollution is between $3–1000 and the generic WTP for air pollution strategies ranges between $15–118 per year. This review also reveals that Middle Eastern countries have been completely overlooked in the existing literature and that current estimates from Asia and South America differ widely. This brief review underlies the importance of conducting a primary study in Egypt to assess public support and WTP for environmental air quality strategies to complement the evidence on air pollution benefits (see table SM1 in Supplementary Materials).

The CV requires that a clear and credible contingent scenario be established – in this case the relocation of heavy polluting industries outside urban area to reduce by 50% $PM_{2.5}$ levels – to elicit the respondents' support and WTP for it. The strength of this method is in its ability to credibly estimate the average WTP for improving air quality and, once this assessment is coupled with information on health risk reductions, the VSL can be retrieved. Both estimates can help decision makers to identify the public's preferences, guide cost-recovery and gauge the financial sustainability of environmental regulation policies and projects.

Both advantages and limitations (e.g. Hausman 2012; McFadden and Train 2017, Johnston et al., 2017) of this method are well recognized in the literature and multiple improvements have been proposed over time. More than thirty years of research (i.e. Diamond & Hausman, 1994; Hanemann, 1994; Rakotonarivo et al., 2016) and two sets of international guidelines (Arrow et al., 1993; Johnston et al., 2017), have convincingly established the credibility, reliability and validity of CV estimates to support policy decision making. The current consensus is that the main biases may be mitigated by a careful design of the survey instruments. In this study, the most problematic biases – the hypothetical and strategic ones, and the scope sensitivity – are moderated by adhering to the latest guidelines in designing and conducting CV survey (Johnston et al., 2017).

4. Study design, questionnaire and sampling

Our questionnaire was organized in sections (see Supplementary Material SM2). Sections were designed to screen out respondents for the quota sample, capture the perception of risk related to air pollution, gather willingness to support and pay for $PM_{2.5}$ policy reduction options and profile respondents accordingly to their socio-economic characteristics. We tested the structure and wording of the questionnaire, the credibility of the air pollution management scenarios and the payment vehicle in one-to one interviews, in both English and Arabic. We piloted the questionnaires revisions helped to reduce the hypothetical and strategic biases. Subsequently, the final survey was prepared in Arabic and coded in Qualtrics.

The questionnaire includes a question about the generic support for implementing air pollution control strategies, and it is further organized with a split-sample strategy in mind (See Figure 1 for an overview). The respondents were randomly assigned to two valuation scenarios aimed at capturing the willingness to contribute to air pollution mitigation in alternative settings. The first scenario outlined a reduction of air pollution (specifically $PM_{2.5}$ air pollution) by 50%, resulting from relocating polluting industrial activities, without reporting any specific health related risk. The second scenario further provided details on the associated reduction in mortality risk from $PM_{2.5}$ by either 10 or 5 in 10,000. In both cases, respondents were asked to financially contribute to these scenarios through an increase in sales taxes. In all cases a budget constraint reminder was included to reduce the hypothetical bias and strengthen the incentive compatibility of the valuation questions. The two sub-samples were further split to test the role of information and the sensitivity to scope. In the first sub-sample, where the reduction by 50% of $PM_{2.5}$ was tested, group (1) received no information about the impacts of air pollution, whereas group (2) were provided with information about the health consequences of air pollution in Egypt. This split implies that respondents in group (1) based their preferences on their personal belief and knowledge about air pollution, while the respondents in the second sub-group were provided with objective information on the adverse health impacts of air pollution.

In the second sub-sample on health risks due to $PM_{2.5}$, two risk reduction options, drawn from national and international statistics, were included to assess the respondents' sensitivity to risk (See tables SM3 and SM4 in Supplementary Material). In both sub-groups, respondents were provided with information about the adverse health risk due to air pollution. In sub-group (3), the risk reduction was of a reduction of 10 in 10,000; for sub-group (4), instead, the risk was reduced to 5 in 10,000 relatives to the current level. In other words, for this sub-sample we aimed to test the scope sensitivity and to estimate the marginal rate of substitution between income and the mortality risk associated with air pollution-induced diseases. This information was then used to derive the implied estimate for the VSL.

Fig. 1 summarizes the structure of the questionnaire with the four sample splits.

WTP questions were elicited using a double-bounded dichotomous choice format (Hanemann et al., 1991). The dichotomous choice format is considered incentive compatible since it reduces the hypothetical bias and increases the validity of the results (Carson & Groves, 2007). Respondents were randomly assigned a first bid amount and offered a higher or lower bid accordingly to the answer to the first bid question. Respondents whose first and second answers were both "no" would be offered an open-ended question format. The bid vectors were: (LE 100, LE 50, LE 200), (LE 200, LE 100, LE 300), (LE 300, LE 200, LE 400). These are equivalent to an increase in the annual costs of living by 600, 1200, 2400, 3600, and 4800 LE (about 38, 76, 153, 229, and 306 US$ respectively).[8]

5. Modelling strategy

The questions related to the willingness to support and pay for air pollution reduction strategies were analysed within a Random Utility Theory framework (Carson and Hanemann, 2005). The theory postulates that the respondent (i) maximizes their utility following standard consumer economic theory while the researcher observes the choice (v) that is driven by the difference in indirect utility functions. McFadden and Leonard (1993) formalize the choice as:

$$v_i = \alpha + \beta Y + \varepsilon_i \quad (1)$$

where v represents the choice (yes/no), Y is bid offered and/or socio-economic features and the error term. The latent factor of the choice is the individual utility (u_0 if the respondent says no and u_1 otherwise). Therefore, $\alpha \equiv \alpha_{1-}\alpha_0$ is the constant and β is the parameter of interest which captures the sensitivity of responses to independent variables. Both ε_0 and ε_1 are random variables with zero means. The willingness to pay measure can be then derived as:

[7] Other forms of stated preferences techniques include Choice Experiments (Hanley & Robert, 1998; Carlsson and Martinsson, 2001; Von Stackelberg and Hammitt, 2009), Contingent Ranking (Bateman et al., 2005), and Conjoint Analysis (Halvorsen, 1996; Roe et al., 1996) Contingent Behaviour.

[8] These bid amounts have been revised according to feedback from the focus group and the pilot survey.

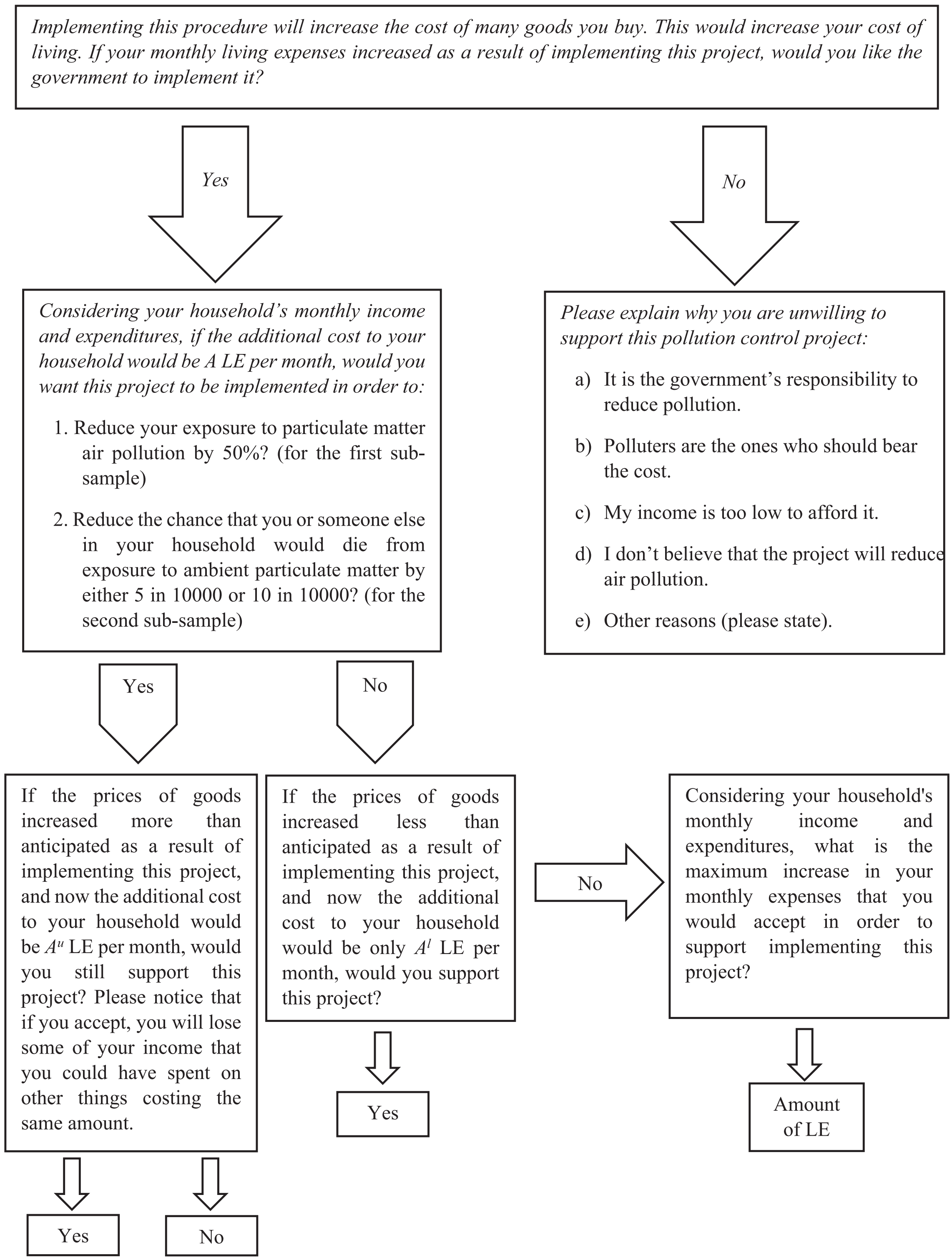

Fig. 1. The general form of the CV questions used in the survey.

$$WTP = \frac{\alpha + \eta}{\beta_p} \tag{2}$$

where $\eta \equiv \varepsilon_1 - \varepsilon_0$ and β_p is the coefficient of the bid and the WTP follows the same distribution of ε.

Given the assumption of a utility maximizing respondent, the WTP cumulative distribution function (CDF) for an individual specifies the probability that the individual's compensating variation (C) or WTP for an improvement in air quality is less than a certain amount A: $G_C(A) \equiv \Pr(C \leq A)$. Because each respondent (i) is being asked two questions, there are four possible outcomes: the answer for both questions is "yes", the answer for both questions is "no", the answer for the first question is "yes" followed by a "no" for the second question, and the answer for the first question is "no" followed by a "yes" for the second question. Following Alberini (1995), the general formulae for the probabilities for these responses are:

Table 2
Population and Sample descriptive statistics.

Variable		*Population %	Sample Count	Sample %
Gender	Male	49%	686	65.27%
	Female	51%	365	34.73%
Location	Cairo	65%	681	64.8%
	Alexandria	35%	370	35.2%
Age (24 +)	Group1 (24 to 39)	47%	497	47.29%
	Group2 (40–59)	47%	484	46.05%
	Group (60 +)	6 %	70	6.66%
Household Income level	Under National Poverty Line	29%	0	0%
	Low Income (<3200 LE)	22%	240	22.84%
	Middle Income (from 3250 LE to 6000 LE)	42%	402	38.25%
	High Income (More than 6000 LE)	7%	409	38.92%
Education	Illiterate	19%	0	0%
	Informal Education (Read & Write without Certificate/Literacy Classes/Cognitive Education)	11%	0	0%
	Primary school (6 years of schooling)	8%	2	0.19%
	Preparatory school (9 years of schooling)	10%	6	0.57%
	Secondary school (General, Al-Azhar, or technical) (12 years of schooling)	27%	23	2.19%
	Two-year institution (14 years of schooling)	5%	110	10.47%
	University degree (16/17 years of schooling)	19%	747	71.08%
	Graduate degree (Professional Certificate, Diploma, Masters, or Ph.D.)	1%	163	15.51%

* Source: Household Income, Expenditure, and Consumption Survey, HIECS 2019/2020. The Central Agency for Public Mobilization and Statistics (CAPMAS) The CAPMAS is the official statistical agency of Egypt that collects, processes, and analyzes data, and provides statistics and conducts the census.,https://www.capmas.gov.eg.

$$\left.\begin{array}{r} \Pr(v \text{ is yes/yes}) = \Pr(C \geq A^u) \equiv 1 - GC(A^u), \\ \Pr(v \text{ is no/no}) = \Pr(A^d \geq C) \equiv GC(A^d), \\ \Pr(v \text{ is yes/no}) = \Pr(A^u) \geq C \geq A) \equiv GC(A^u) - GC(A), \\ \Pr(v \text{ is no/yes}) = \Pr(A \geq C \geq A^d) \equiv GC(A) - GC(A^d). \end{array}\right\} \tag{3}$$

The binary-valued indicator variables for these expected responses can be denoted as:

$$\left.\begin{array}{l} I_i^{yy} = 1(\text{ith respondent response is ''yes} - \text{yes''}) \\ I_i^{nn} = 1(\text{ith respondent response is ''no} - \text{no''}) \\ I_i^{yn} = 1(\text{ith respondent response is ''yes} - \text{no''}) \\ I_i^{ny} = 1(\text{ith respondent response is ''no} - \text{yes''}) \end{array}\right\} \tag{4}$$

where I(•) is an indicator function, whose value is one if the argument is true, and zero otherwise. The function GC(•, θ), depends the vector of parameters θ. Given a sample of N respondents, where A_i,A_i^u, and A_i^d are the bids used for the i^{th} respondent, the log-likelihood function takes the form:

$$\ln L = \sum_{i=1}^{N} \{I_i^{yy}\ln\left[1 - G_c\left(A_i^u, \theta\right)\right] + I_i^{nn}\ln[G_c\left(A_i^d, \theta\right)] + I_i^{yn}\ln\left[G_c\left(A_i^u, \theta\right) - G_c(A_i, \theta)\right] + I_i^{ny}\ln\left[G_c(A_i, \theta) - G_c\left(A_i^d, \theta\right)\right] \tag{5}$$

Once the WTP in Eq. (2) is derived Delta or the Krinsky and Robb Confidence Intervals are normally reported (Krinsky and Robb, 1986; Jeanty, 2008). Furthermore, using the WTP result is possible to derive the VSL as follows:

$$VSL = \frac{WTP}{\Delta r} \tag{6}$$

The VSL measures the aggregate economic value to prevent one expected (in the statistical sense) fatality due to $PM_{2.5}$ risk. This measure is frequently used in policy decision making (Alberini 2005).

6. Empirical findings

The survey was administered online by a professional survey company.[9] 1051 Egyptian respondents were surveyed, and Table 2 synthetizes the sample characteristic and contrasts it with the Census statistics. The sample matches well the age and spatial distribution of the population, but it under-represents specific groups, due to the online sampling strategy (e.g., we have no respondents in our sample who are illiterate or living under the poverty line). This is of course a direct consequence of our choice to conduct the experiment online since it has been proved to produce comparable estimates to mail survey (Boyle et al., 2016). We make no claim that the sample is representative of the whole population. On the one hand, the relatively more educated and affluent segment of the population that we sample is at the same time more likely to be aware of the health benefits linked to lower air pollution and less likely to be quite as exposed as other groups to the ravages of pollution (for example, they are more likely as a group to work in an office, rather than in an outdoor environment, and to have air filters installed in their offices and homes). From this point of view, it is not clear whether we would expect a higher estimate of their willingness to support air pollution reduction measures. On the other hand, given their higher level of income, we would expect them to be able to express a higher level of willingness to pay than their less affluent counterparts. Overall, we believe it likely that the estimates we obtain from our sample might be an upper bound on the true WTP of the general population. Arguably, however, this same demographic is also the group that the Government would be looking to for both political support and financial contributions towards the type of air quality enhancements that we are suggesting as possible policies in this context. Therefore, while it is important to keep in mind the nature of our sample, we see this lack of representativeness not as a shortcoming of our approach, but rather as a feature that makes it more policy relevant.

Figure 2 illustrates the distribution of survey responses by subsamples and sub-groups. For each group we report the willingness to support the air reduction strategies (WTS). The Kruksal-Wallis test was applied to test subsamples with and without health risk information differences. The test reveals that there was a statistically significant difference in the WTS ($\chi^2(1) = 6.762$, and $p = 0.0093$), confirming that information plays a crucial role in supporting environmental policies.[10]

On the other hand, for those who were unwilling to support air pollution projects, their main reason was their belief that the government, along with the polluters, are responsible for controlling pollution (See Figure 3). Low income is a significant reason for female respondents

[9] The company name is "Marketeers Research & Consultants''. The company, which has been working in Egypt for more than 26 years, is a member of the European Society for Opinion and Marketing Research (ESOMAR) and works under both the EU General Data Protection Regulation (GDPR) and the Egyptian personal data protection law No. 151 of 2020.

[10] The analysis of the survey responses shows that about 67.5% of the households in the first sub-group, where no information has been given to the respondents about the adverse health effects of air pollution have expressed a positive willingness to support pollution control projects compared with nearly 75% of the households in the other three sub-groups, where the respondents are presumably well informed about the adverse health impacts of air pollution.

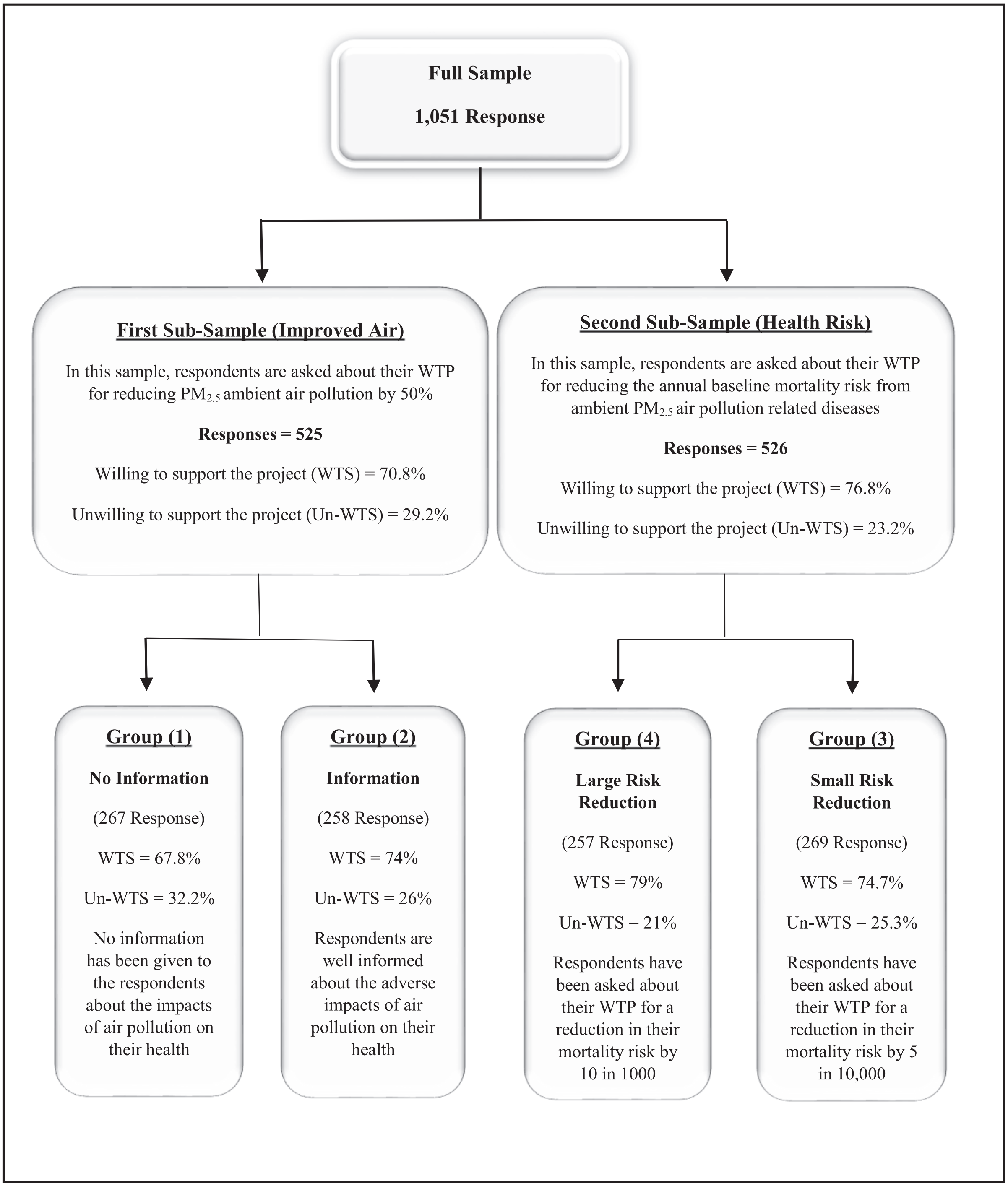

Fig. 2. The distribution of responses by sub-samples and sub-groups.

not to support pollution control projects (for about 29% of them).[11]

The percentage of support for reducing larger risk is higher than the small risk and revealing sensitivity to scope although a formal test on WTP estimates will be reported below.

Overall, we collect a quite diverse sample that reports distinct attitudes towards environmental policies. These features are formally tested in the modelling strategy and qualitative discussed in the Supplementary Material (SM5).

6.1. Modelling analysis

The statistical analysis of the willingness to support air pollution reduction projects was conducted on the full sample, whereas the willingness to pay analysis is organized by subsamples. A detailed description of the variables characterizing the respondents is given in table SM5 in the Supplementary Material.

6.1.1. Modelling the willingness to support air quality projects

73.8% of respondents were willing to support pollution control

[11] Although exploring the impact of income inequality on the WTP is beyond the scope of this work, it is worth mentioning that comparing males and females' incomes within this sample shows some sizable gender pay gap in Egypt.

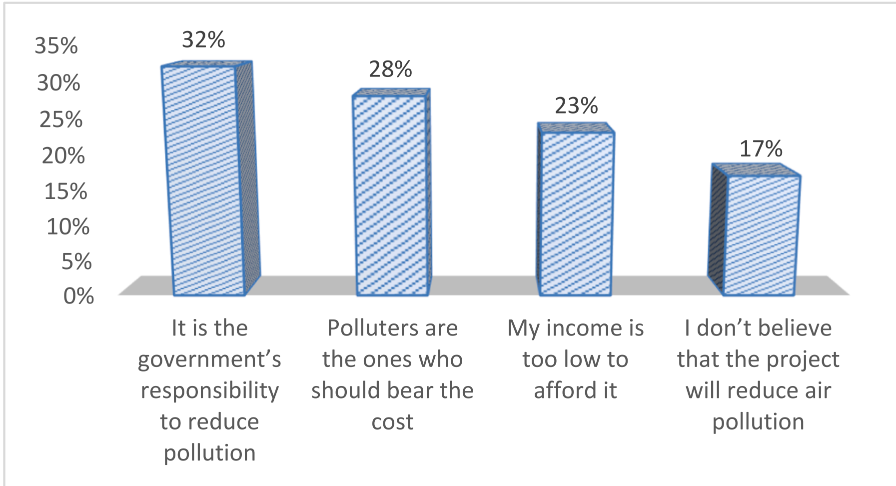

Fig. 3. Reasons for unwillingness to support pollution control projects.

Table 3
Factors affecting the WTS for pollution control projects in the pooled sample.

WTS	Coef.	Marginal Effects
No Information	−0.35***	−0.098***
	(0.10)	(0.028)
Residency	0.47***	0.132***
	(0.09)	(0.026)
Gender	0.03	0.008
	(0.11)	(0.030)
Residential	0.076	0.021
	(0.11)	(0.030)
Both residential and industrial	0.27**	0.076**
	(0.13)	(0.036)
Age Group (24–39)	0.34***	0.095***
	(0.10)	(0.027)
Age Group (over 60)	−1.2***	−0.336***
	(0.186)	(0.046)
Years of Schooling	0.04	0.011
	(0.04)	(0.011)
Low Income	−0.61***	−0.170***
	(0.17)	(0.046)
High Income	0.32***	0.090***
	(0.11)	(0.031)
Good Health	−0.17*	−0.049*
	(0.10)	(0.028)
Poor Health	−0.15	−0.042
	(0.16)	(0.044)
Air Quality (residency)	−0.31***	−0.086***
	(0.11)	(0.029)
Protective Behaviour	−0.30**	−0.084**
	(0.15)	(0.042)
Having Health Insurance	−0.26**	−0.072**
	(0.11)	(0.032)
Job type	0.43***	0.121***
	(0.12)	(0.034)
Constant	−0.47	
	(0.63)	
Number of Obs.	**1051**	
Log likelihood	**−520.8**	
Pseudo R^2	**0.1379**	

Robust Standard errors in parentheses.
***p < 0.01, **p < 0.05, *p < 0.1.

projects (776 households) and to unravel reasons for supporting environmental policies we modelled the yes/no response in a Probit framework as follows:

$$WTS_i = \beta_i X_i + e \tag{7}$$

where WTS_i equals 1 if the respondent is willing to support the prospected project and zero otherwise,X_i is the vector of independent variables (age, gender, income, educational level, exposure to air pollution, environmental awareness, and health status), β_i denotes the coefficients to be estimated, while e represents the disturbance error term, and $i = 1,2,3,\dots N$, where N is the number of respondents.

Results in Table 3 indicate that a variety of factors have a significant positive influence on our respondents' decisions to support air pollution control policies including income, working in outdoor jobs, age and place of residence. Residents of Greater Cairo as well as people of younger age (<40 years old) are more likely to support pollution control projects compared to Alexandria's residents and to elderly people. In addition, living in highly polluted areas[12] has been found to positively correlate with the willingness to support pollution control efforts.

Our results also emphasize that, as expected, the estimated coefficient of the variable for the lack of information is statistically significant and negative, which means that people are less likely to support pollution control projects when they are not sufficiently informed about the negative consequences of air pollution on their health. This result is also confirmed by the negative sign of the estimated marginal effects of the lack of knowledge about the adverse health effects of air pollution on the probability to support pollution control projects.

The second valuation exercise focuses on both willingness to pay for $PM_{2.5}$ and for reducing the health mortality risk for $PM_{2.5}$. In both samples, the control for legitimate zero bidders and protest bidders was based on the reasons provided by respondents to refuse to pay (i.e. protesters). 72 respondents (6.85% of the total) were considered zero bidders, while 203 (19.3%) were excluded by the sample as protest

[12] We have classified the districts where the survey has been conducted into three categories, according to their level of exposure to possible sources of pollution, both in Greater Cairo and in Alexandria. The first category is residential areas which have moderate or low population densities and limited nearby sources of pollution, such as Al-Maadi in Greater Cairo and San Stephano in Alexandria. The second category is residential areas with small industries (such as lead smelters) which have high population densities, high traffic volume, and are downwind from industrial sources of pollution, such as Shobra El-Kheima in Greater Cairo and Camp Shizar in Alexandria. The third category is residential-industrial areas which have moderate population densities, and many nearby sources of pollution, especially cement, steel, or other heavy industries, such as Helwan in Greater Cairo and Al-Aamiryah in Alexandria.

responders.[13] Accordingly, in the next sections we estimate the WTP for the two sub-samples using alternative Parametric and Non– Parametric methods.[14]

6.1.2. *Sub-sample (1): WTP for a 50% reduction in industrial PM2.5 air pollution*

525 respondents validly participated in this subsample. 74% of respondents agreed on supporting the project in the subgroup with information group and only 67.5% in the other subgroup. A statistical comparison of these proportion reveals that the provision of information increases the participation in air pollution projects (*t*-test, significant at 5%).

The distribution of responses per bid levels is reported in Table 4 and as expected the proportion of yes responses decreases as the bid increases.

WTP responses were analysed using both a standard double-bounded choice model as suggested by Hanemann et al (1991) the so-called Interval-Data Model (Haab and McConnell, 2002), a Bivariate Probit Model, and also the Turnbull nonparametric estimator (McConnell, 1997). Parametric estimates are comparable (see table SM6 in Supplementary Material) and in Table 5 we report the double bounded estimates and WTP value. Although this is an encouraging results, caution is needed as these measures depend on the assumptions about the error term of the indirect utility function (Bishop & Heberlein, 1979; Hanemann, 1984). To mitigate this problem, we apply the non-parametric Turnbull estimator (see table SM7 in Supplementary Materials) that produces a lower WTP values equals to 212 LE, with a variance equals to approximately 84 LE. Interesting these estimates for reducing $PM_{2.5}$ by 50 percent in Greater Cairo and Alexandria are very similar to that obtained by Abou-Ali and Belhaj (2005). These authors report that a 50% reduction in air pollution caused by road traffic in Cairo is worth between 18.07$ (283 LE) and 15.9$ (249 LE).

Table 5 reports the marginal effect of each variable on the estimated WTP value. Factors that positively impact the willingness to pay for reducing $PM_{2.5}$ include living in Greater Cairo, particularly living in the most polluted areas, having a higher educational level, having children, and whether the respondent is applying some protective environmental measures (e.g., having an air purifier installed in his/her house). In addition, respondents who are females and those at a younger age (24–39 years old) are more likely to be willing to pay additional amounts for improving air quality. On the other hand, the negative coefficients indicate that respondents who have low income, and those who do not consider air pollution to be a problem (have rated air pollution in their area of work as good or very good), are less likely to pay an additional amount for reducing $PM_{2.5}$ air pollution.

6.1.3. *Sub-sample (2): WTP for reducing annual baseline mortality risk attributable to ambient $PM_{2.5}$ air pollution*

526 valid responses, divided into two sub-groups were used for this analysis. The percentage of households who are willing to support pollution control projects is nearly 77% in group (3) were risk reduction was 10 in 10,000 from the annual baseline risk and 74% in group (4),

[13] Mitchell and Carson (1989) indicated that it is a common practice in the vast majority of CV surveys, particularly those conducted for benefit-cost analysis, to identify and drop protest responses. Also, Loomis et al (2011) have found no statistically significant differences in the WTP between the different approaches for dealing with protest responses (whether including protests or dropping them).

[14] In general, the Parametric approaches for estimating WTP measures from double-bounded dichotomous choice data are classified into two main categories. These are, either binary-response models which estimate the probability of a "yes" response as a function of bid values and selected covariates, or interval-data models which use the WTP intervals defined by bid values and responses as a dependent variable.

Table 4
Proportion of responses for air quality improvement in the two subgroups.

Group	With Information Total Sample Size: 258 Yes Responses: 191 (74%)						Without Information Total Sample Size: 271 Yes Responses: 183 (67.5%)					
Starting Bid	100 LE (N = 66)		200 LE (N = 62)		300 LE (N = 63)		100 LE (N = 57)		200 LE (N = 57)		300 LE (N = 69)	
First Response	Yes (89.4%)	No (10.6%)	Yes (74%)	No (26%)	Yes (68%)	No (32%)	Yes (87%)	No (13%)	Yes (72%)	No (28%)	Yes (65%)	No (35%)
Second Bid	200 LE	50 LE	300 LE	100 LE	400 LE	200 LE	200 LE	50 LE	300 LE	100 LE	400 LE	200 LE
Second Response	Yes (68%) No (32%)	Yes (71%) No (29%)	Yes (63%) No (37%)	Yes (62%) No (38%)	Yes (67%) No (33%)	Yes (45%) No (55%)	Yes (64%) No (36%)	Yes (71%) No (29%)	Yes (59%) No (41%)	Yes (37%) No (63%)	Yes (67%) No (33%)	Yes (38%) No (62%)
Follow up for "No-No" Response (open-ended)	Mean = 22.5 LE		Mean = 41.7 LE		Mean = 71 LE		Mean = 22.5 LE		Mean = 39.5 LE		Mean = 67.3 LE	

Table 5
Estimates of the WTP for improved air quality and the factors affecting it using the Interval-Data Method.

WTP	Coef.
Gender	−42.1*
	(24.9)
Residency	42.4**
	(20.9)
Residential with small industries	52.9**
	(24.6)
Both residential and industrial	29.7
	(27.6)
Age Group (24–39)	54.61**
	(21.78)
Age Group (over 60)	−26.86
	(65.1)
Years of Schooling	22.98**
	(10.39)
Low Income	−50.62*
	(29.83)
High Income	19.98
	(24.1)
Having children	48.52**
	(21.73)
Good Health	−21.66
	(27.92)
Poor Health	6.52
	(7.43)
Low Medical expenses	−47.81**
	(21.1)
High Medical expenses	−56.1
	(41.98)
Information	25.99
	(21.9)
Air Quality (work)	−64.78***
	(21.17)
Protective Behaviour	154.98***
	(42.16)
Constant	−116.55
	(169.02)
Log likelihood	**−425.02553**
Mean/Median WTP (Full Model)	**301.8 LE**
	CI: (281 LE, 322 LE)

Standard errors in parentheses.
***$p < 0.01$, **$p < 0.05$, *$p < 0.1$.

where the risk level is reduced to 5 in 10,000.

In line with our theoretical priors, the proportion of positive answers goes down as the bid amount increases (See Table 6). From a theoretical perspective, the WTP should increase with the magnitude of risk reduction, and this assumption has been frequently used as an indicator of validity in VSL studies, since a failure to satisfy this condition reports a failure for the scope sensitivity test.[15] In order to test the sensitivity to scope, we apply some tests of sensitivity to the magnitude of risk reduction. We have conducted a statistical scope test by separately eliciting both the $WTP_{5\ in\ 10,000}$ and $WTP_{10\ in\ 10,000}$, then testing whether

[15] Therefore, the NOAA panel has recommended to test for scope sensitivity (Arrow et al., 1993). Scope sensitivity tests can be classified into two main categories: internal and external. An external test involves using independent sub-samples (which must be statistically equivalent) of respondents who are asked to place a value on different levels of a good (different scopes), while an internal test involves asking the same respondents to value the different levels of good. Within the CV literature, many studies have investigated the scope sensitivity hypothesis and various tests have been suggested (Heberlein et al., 2005; Poe et al., 2005; Desvousges et al., 2012; Whitehead, 2016; Lopes & Kipperberg, 2020). However, many efforts have been recently devoted to identifying the conditions that may lead to scope insensitivity. Also, another perspective has emerged which suggests that the inability to pass the statistical scope test does not necessarily imply the invalidity of the CV exercise, and that the reasons behind such inability may be consistent with economic theory (Heberlein et al., 2005; Desvousges et al., 2012; Whitehead, 2016).

Table 6
Proportion of responses for mortality risk reduction in the two subgroups.

Group	**10 in 10,000** Total Sample Size: 257 Yes Responses: 203 (79%)						**5 in 10,000** Total Sample Size: 274 Yes Responses: 204 (74.5%)					
Starting Bid	100 LE (N = 74)		200 LE (N = 64)		300 LE (N = 65)		100 LE (N = 59)		200 LE (N = 83)		300 LE (N = 62)	
First Response	Yes (93%)	No (7%)	Yes (75%)	No (25%)	Yes (69%)	No (31%)	Yes (91%)	No (9%)	Yes (69%)	No (31%)	Yes (68%)	No (32%)
Second Bid	200 LE	50 LE	300 LE	100 LE	400 LE	200 LE	200 LE	50 LE	300 LE	100 LE	400 LE	200 LE
Second Response	Yes (65%) No (35%)	Yes (60%) No (40%)	Yes (64%) No (36%)	Yes (75%) No (25%)	Yes (60%) No (40%)	Yes (45%) No (55%)	Yes (61%) No (39%)	Yes (40%) No (60%)	Yes (65%) No (35%)	Yes (46%) No (54%)	Yes (57%) No (43%)	Yes (20%) No (80%)
Follow up for "No-No" Response (open-ended)		Mean = 30 LE		Mean = 43.75 LE		Mean = 81.3 LE		Mean = 26.6 LE		Mean = 38.4 LE		Mean = 79.8 LE

Table 7
Factors affecting the WTP for mortality risk reduction using the Interval data model.

WTP	Pooled	5 in 10,000	10 in 10,000
Health Risk Level	41.2** (19.9)	———	———
Gender	−12.2 (22)	6.13 (31)	−73.8** (32.6)
Residency	68.9*** (20.6)	91.7** (36)	48.13** (24.5)
Residential	34.9 (21.8)	70.10** (30.6)	−11.29 (30.2)
Both residential and industrial	58.3** (25.3)	84.7* (46.27)	14.41 (28.42)
Age Group (24–39)	33.8 (18.9)	19.3 (29.46)	57.8** (24.7)
Age Group (over 60)	−23.7* (50.5)	−57.3 (56.25)	−41.7 (36.3)
University	31.3 (20.5)	82.74** (36.6)	21.4 (32.18)
Secondary	−57.4 (104.8)	−35.37 (66.1)	−7.17 (40.2)
Low Income	−1.32 (25.4)	−47 (39.5)	−118.4*** (41.94)
High Income	39.7** (22.1)	21.7 (33.3)	88.85*** (30.65)
Health Status	−36.1** (18.4)	−67.48** (34.2)	−24.7 (47.8)
Protective Behaviour	142.8*** (41.3)	215.5*** (58.53)	29.42 (55.8)
Number of Diseases	———	−16.84* (9.87)	−44.7** (20)
Full Health Insurance	———	11.3 (42.43)	13.5 (37.3)
No Health Insurance	———	−61.19* (33.2)	−67.8** (29.6)
Air Quality (work)	−51.3** (19.2)	———	———
Constant	218.7*** (40.2)	130* (67)	348.6*** (56.4)
Number of Obs.	**404**	**201**	**203**
Log likelihood	**−462.6**	**−227.44**	**−208.54**
AIC	**957.28**	**488.88**	**451.08**
WTP in LE (covariates)	———	**293*** CI: (265, 321)**	**317.6*** (280, 368)**

Standard errors in parentheses.
***p < 0.01, **p < 0.05, *p < 0.1.

$WTP_{10\ in\ 10,000} > WTP_{5\ in\ 10,000}$ under the null hypothesis of insensitivity to scope. The hypothesis that the WTP is insensitive to the magnitude of risk reduction (the weak test) can be convincingly rejected (*p* value of 0.0258).

Parametric and non-parametric WTP estimates are reported similarly to the previous sub-sample. Table 7 reports estimates from the double-bounded model considering the pooled and single risk models.

Table 7 reports WTP estimates for reducing the annual mortality risk by 5 in 10,000 (the smaller risk reduction) that is equal to 293 LE, meanwhile it equals 317.6 LE for the larger risk reduction (10 in 10,000). In order to account for the potential problem of distributional misspecification, we use the Turnbull estimator to obtain a distribution-free lower bound estimates that are respectively 203.8 LE and 219 LE, with a variance of around 141.8 LE for the smaller risk and 150 LE, for the 10 in 10,000 reduction (See tables SM8 and SM9 in the Supplementary Material).

Living in Greater Cairo, particularly living in the more polluted areas, having a higher income, and whether the respondent is applying some protective measures, in addition to the level of mortality risk reduction are the key factors to explain the willingness to pay for mortality risk reduction. In this regression, the negative coefficients indicate that respondents who already have a poor health status, those who are above 60 years of age, and those who do not consider air pollution as a problem, are less likely to pay an additional amount for reducing the mortality risk attributable to $PM_{2.5}$ air pollution. Table 8 illustrates the VSL for both $PM_{2.5}$ air pollution risk reduction level.

Table 8
The VSL estimations using Parametric and Non-Parametric methods.[1]

Method	10 in 10,000 risk reduction	5 in 10,000 risk reduction
Parametric (Interval Data Model)	3,811,200 LE (242.752 $)	7,032,000 LE (447.898 $)
Non-Parametric (Turnbull estimator)	2,628,000 LE (167.389 $)	4,891,200 LE (311.541 $)

[1] Since the WTP is estimated on per month basis, the VSL is calculated as follows: VSL = (WTP * 12)/Δr.

The VSL estimates range from about 3.81 million LE for the larger risk reduction to nearly 7.0 million LE for the smaller risk reduction. It is worth mentioning that Larsen (2019), used the benefit transfer method for valuing the mortality due to environmental health risks drawing from OECD countries results, to report a VLS for Egypt equals to 3.0 million LE for the year 2016/2017.

Finally, Table 9 summarizes WTP findings for the two sub-samples and cities. Respondents in Greater Cairo metropolitan area are more likely to be willing to pay additional amounts of money for improving air quality and for reducing the health risk associated with air pollution, compared with Alexandria's residents.

Contrary parametric WTP values for the two treatments are statistically similar and this reveals that independently from the consequences of $PM_{2.5}$ pollutant respondents are prepared to pay to reduce it.

6.2. *Results validity*

We conclude this section with a discussion of the validity of the results. Following Johnston et al (2017), the validity of CV studies may be tested from different perspectives considering (i) content validity, (ii) construct validity and (iii) criterion validity.

Content validity considers the quality of the questions and possible questionnaire biases and is addressed in the survey design and testing phase. For our investigation, one-to-one interview and pilot surveys were used to reduce cognitive biases, to ensure the neutrality of the payment vehicle and to strengthen the credibility of the policy scenario (see SM10 in the Supplementary Material). The split sample strategy allowed us to test for scope sensitivity, as the two levels of risk reductions were offered randomly to respondents in both cities.

Construct validity verifies the conformity of the survey results to economic theory and previous findings. Our results confirm the internal validity of the survey responses, as the WTP correctly correlates to the households' economic circumstances. We found that certain segments of the sample were significantly more willing to pay for improved air quality and for mortality risk reduction compared to others, such as those who are females, those at a younger age (24–39 years old), people living in the most polluted areas, those with children, and those who were already using protective measures against air pollution.

Economic theory dictates that WTP should increase with the size of the risk reduction. In our data, although the proportion of support for environmental policies increased with the size of the risk reduction, the WTP for the annual mortality risk reduction by 10 in 10,000 is only 7% larger than the WTP for the smaller risk reduction of 5 in 10,000. While this comparison reveals a weak sensitivity to scope, we note that the VSL literature consistently reports failure to find proportional differences in VSL in response to marginal changes of mortality risk reduction (Alberini et al., 2004; Hoffmann et al., 2012, Balmford et al 2019). At the same time, our results are comparable with those in Larsen (2019), who derived estimates for Egypt, and with those in both Hammitt and Zhou

Table 9
WTP estimates in Greater Cairo and in Alexandria.

WTP Mean Value	Improved Air Quality		Mortality Risk Reduction			
			10 in 10,000		5 in 10,000	
	Cairo	Alexandria	Cairo	Alexandria	Cairo	Alexandria
Parametric (Interval Data Model)	329.7***	263***	326.8***	277.7***	324***	220***
Non-Parametric (Turnbull estimator)	222.34	186.65	260	174.8	229.4	131
Number of Obs.	257	115	139	64	145	56

Standard errors in parentheses.
***p < 0.01, **p < 0.05, *p < 0.1.

(2006) and Hoffmann et al (2012) for other fast-growing economies (China and Mongolia, respectively, see Table 1). Our estimates overall show sensitivity to income and exposure to pollution, which conforms to theoretical expectations, thus confirming the construct validity of our results.

Criterion validity, namely that the SP values correctly reflect the presumed true value of the WTP we seek to identify is much more complicated to ascertain, as discussed at length in Johnston et al (2017). Indeed, while tests for content and construct validity are routinely conducted using data from the study at hand, criterion validity tests require data from other, parallel studies. In our context, this would require comparing our CV findings with results from independent experimental data for the same case study. Given the constraints we operate under, for example, the impossibility to conduct a large-scale field experiment, this type of test is therefore impractical to conduct for our case study.

7. Discussion and conclusions

Like many other countries, since the 1960′s Egypt has prioritized rapid economic growth over environmental protection. Consequently, Egypt's population is increasingly exposed to dangerous levels of pollution, and carries a heavy health burden, especially in terms of diseases associated with poor air quality levels. Unfortunately, policy responses have so far been limited, also due to a dearth of information on the value of the economic benefits associated with pollution reduction.

In this paper, we focus on air pollution in Egypt's two largest metropolitan areas, Greater Cairo and Alexandria, and estimate the willingness to support pollution reduction measures and the WTP to support the relocation of heavy industries away from densely populated areas, which would improve air quality and reduce the burden of air-pollution linked disease.

Our results suggest that most of the respondents in our sample (almost 74%) are prepared to support environmental policies and indicate that the WTP for $PM_{2.5}$ reduction strategies ranges between 131 LE and 330 LE per month (8.3US$ and 21US$, see Table 9). Overall, we find that the respondents' preference for reducing $PM_{2.5}$. levels are rather stable across treatments, independently from the information on $PM_{2.5}$ health risks. While some existing CV studies emphasize the role of 'information' in driving WTP (Bergsrtom, 1990; Carlsson and Johansson-Stenman, 2000; Venkatachalam, 2004), our results are more in line with findings reported elsewhere in the literature, that suggest that the impact of information is mixed (e.g., Giffoni and Florio, 2023). Our data shows that the effect of information is more nuanced than expected. The effect of information is rather weak when only generic information about health risk is provided to respondents (first subsample vs second subsample in Figure 2). When more specific information on the adverse health impacts of pollution is provided, however, the WTP values become statistically different (group 1 vs group 2; group 3 vs group 4). These results echo those in Istamto et al (2014). The results emphasize the importance of appropriate information campaigns in empowering citizens. Not surprisingly, the other crucial factor driving WTP that emerges from our work is income, a result fully consistent with economic theory.

Our WTP estimates are not trivial and become quite striking when put in the context of our case study. Considering that over six million households lived in the Greater Cairo and Alexandra areas at the time of the survey in 2020 (6,082,161 according to CAPMAS), even if we assume that only the 70% above the poverty line captured by our sample would be able to express a positive WTP, this gives us a potential contributing population of 4,257,513 households. If we assume, conservatively, that only 70.8% of the total number of households would be willing to support air pollution reduction measures as suggested by our data (see the percentage of WTS in Fig. 2), we are left with just over three million households willing to contribute. If each of these households were willing to contribute the lowest level of the average WTP we find in this paper (131LE or 8.3US$ per month) to contribute to a program of relocation for polluting industries away from residential areas, the aggregated monthly willingness to pay for such a measure would be in excess of US$ 25 million, or over US$ 300 million dollars each year!

It is informative to compare this, for example, to the cost of the Cairo Air Improvement Project, mentioned in Section 2, which aimed at relocating heavily polluting factories away from residential areas and into specifically designated industrial areas. According to USAID (2004), the cost of the project, which ran over eight years between 1997 and 2004 was US$ 56 million. Similarly, the whole of Phase I of the Egyptian Pollution Abatement Program, which had a nation-wide scope was US$ 235 million between 1997 and 2005 (World Bank, 2017). Even from this back-of-the-envelope calculations, it is clear that any cost-benefit trade off would appear very favourable for the introduction of a significant programme of industry relocation, modernization and pollution reduction in Greater Cairo and Alexandria. This case is even stronger if we acknowledge that our estimates are likely to represent lower bounds of the actual environmental benefits, and that we are not considering any of the significant ancillary benefits that are associated with air pollution mitigation (e.g., Garg, 2011).

Overall, our work leads us to the conclusion that, despite Egypt not having quite reached the upper-middle level of per-capita income commonly associated with the inflection point of the Environmental Kutznets Curve, a substantial demand for environmental improvements exists among its citizens. This suggests that Egypt may not be doing enough to provide a cleaner environment to its population simply due to a lack of information on the level of the potential demand for environmental quality. Indeed, the Egyptian authorities might need to reassess their policy priorities in light of the information we provide here. While our results are derived from our Egyptian case study, there is no reason to believe that our conclusions would only apply to Egypt. It stands to reason that investigations like ours in other lower-middle income countries with significant problems due to rapid urbanization and air pollution would reach similar conclusions. We hope that this type of rigorous empirical work will be conducted in other similar contexts to continue feeding useful information to policy makers in fast growing developing and emerging countries.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Data availability

Data will be made available on request.

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Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.worlddev.2023.106373.

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