Cost-Benefit analysis of environmental health interventions: present issues and future steps.

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Declaration that the work presented in the thesis is the candidate's own.

'I, Carla Guerriero, confirm that the work presented in this thesis is my own. Where information has been derived from other sources, I confirm that this has been indicated in the thesis.'

Signature [redacted]

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Abstract

Cost-benefit analysis (CBA) can help policy makers and legislators achieve the greatest social good. Despite the potential role that CBA can play, very little has been done to implement CBA of environmental health interventions (EHIs). The overall aim of this thesis is to improve the quality of CBA analyses of EHIs by addressing important research gaps in the literature.

This thesis has four objectives. The first objective is to illustrate a generic framework for CBA of EHIs. The methodological framework described is applied to the economic evaluation of remediating two contaminated industrial sites in Sicily (Gela and Priolo). Including children's health benefits in CBA is challenging. Compared to adults, children are more vulnerable to environmental hazards, however, due to the lack of child specific willingness to pay (WTP) measures children's health benefits are often excluded from the analysis or valued using adults WTP measures or cost-of illness estimates.

The second objective of the thesis is to investigate children's ability to understand WTP questions. In particular, the thesis investigates if children are able to understand health risk and money-related concepts.

The third objective of the thesis is to evaluate child (aged 7-18 years) and parental WTP for reducing children's environmental health-related risk of asthma attack using both a contingent valuation study (CV) and a discrete choice experiment (DCE).

The fourth objective of the thesis is to estimate the potential benefits to pupils of reducing traffic-related air pollution near primary schools in London using the WTP values quantified in the CV study and environmental and health data collected in London primary schools.

The results of this thesis show that that, despite the high remediation cost, the clean-up of Gela and Priolo in Sicily can be highly cost-effective. The findings of the studies investigating whether children are able to understand WTP questions show that even younger children are able to understand health risk information and money related concepts and that their ability to do so improves with age. Both the CV and the DCE study show that children are able to provide rational answers to WTP questions. Results of the contingent valuation study also show that parents' WTP estimates differ significantly from those of their children.

Including children's health benefits and preferences, as demonstrated in the practical case of improving air quality in proximity of London primary schools, gives more accurate and precise estimates of the real benefits arising from EHIs. It also provides a transparent and reliable source of information for decision makers. Findings from this thesis can improve the quality of CBA of EHIs and help future studies provide a sounder basis for policy making.

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This thesis is dedicated to the place where I had the fortune or the misfortune to be born: Napoli. Napoli has a beauty that words cannot describe. However, it is not its beauty and countless historical attractions that made this city famous worldwide but the mismanagement of environmental hazards (municipal solid waste mismanagement and illegal toxic waste trafficking).

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Contents

List of Tables

List of Figures

Abbreviations

CBA-Cost Benefit Analysis
CBAC-Cost Benefit Acceptability Curves
CI-Confidence Interval
CL-Conditional Logit
COI-Cost of Illness
CV-Contingent Valuation
DALY-Disability Adjusted Life Year
DCE-Discrete Choice Experiment
DOE-Dipartimento Osservatorio Epidemiologico
EHI-Environmental Health Intervention
EPA- Environmental Protection Agency
FSM-Free School Meals
GLM-Generalized Linear Model
I/O-Indoor to Outdoor Ratio
ISAAC- International Study on Asthma and Allergies in Children
MWTP-Marginal Willingness to Pay
NO_2-Nitrogen Dioxide
NPV-Net Present Value
OECD-Organization for Economic Cooperation and Development
OR-Odds Ratio
PAP-Population Attributable Proportion
PVB-Present Value of Benefits
PVC- Present Value of Cost
QALY-Quality Adjusted Life Year
S.E.-Standard Error
S.D.-Standard Deviation
SHR-Standardized Hospitalisation Ratio
SMR-Standardized Mortality Ratio
UK-United Kingdom
VSCA-Value of an Asthma Episode
VSL-Value of a Statistical Life
VOC-Volatile Organic Compound
WHO- World Health Organization
WTA –Willingness to Accept
WTP- Willingness to Pay
ISTAT-Istituto Nazionale di Statistica

Introduction

11.Rationale of the thesis

Over the last two decades, increased industrialization and rising standards of hygiene have reduced the risks of environmental hazards associated with vector borne diseases, pathogens and food contamination, but substantially increased risks associated with non-communicable diseases contracted through exposure to toxic physical and chemical compounds [1].

There is mounting epidemiological evidence showing that the health consequences of physical (e.g. noise, vibrations) and chemical (e.g. lead, asbestos) hazards constitute a serious threat to the health. According to Pruss-Ustun and Corvalan environmental exposures in general, are responsible for up to 24% of the global disease and 23% of global deaths[1].

A prospective study "The Benefits and Costs of the Clean Air Act from 1990 to 2020" by the U.S. Environmental Protection Agency (EPA) estimated the benefits of reducing fine particles and ground level of ozone pollution under the 1990 Clean Air Act amendments[2]. In 2010 alone, the study estimated that the 1990 Clean Air Act amendments prevented 160,000 cases of premature mortality, 13 million lost work days and 1.7 million asthma attacks. A similar analysis conducted in Europe "The Clean Air for Europe" quantified the potential health benefits of improving air quality in Europe between 2000 and 2020[3]. According to the study, the annual impact of particulate matter alone on human health accounts 3.7 million years of life lost and 700 infant deaths each year (using particulate matter exposure in 2000)[3].

The issues of resource limitations, economic efficiency and value for money comprise the essential criteria on which policy and regulatory decisions are made, and are also critical to understanding the impact of proposed environmental, health, and safety regulations. By comparing the benefits and the

costs of all available interventions, economic evaluation provides essential information for making optimal use of the limited budget[4, 5].

National and international governmental bodies are required to perform economic evaluation to assess new regulatory interventions [6, 7]. In 1993, President Clinton's executive order 12866 established that government and private parties should be fully informed about the costs and the benefits of regulatory options[8]. Similarly, the European Commission and the World Health Organization strongly recommend the use of economic evaluation to demonstrate the economic return on investments in interventions and also to compare competing interventions[4, 7]. In the UK, economic evaluation is part of the regulatory impact analysis which is mandatory for appraisal of new regulations[9].

Nevertheless, the use of economic evaluation to guide evidence based decisions is still in its infancy, and is mainly applied in high income countries. According to Hutton, there only a few completed economic evaluations assessing either the cost effectiveness or the cost benefit of environmental health interventions [10]. The majority of the published studies investigate interventions concerning occupational safety and health, and air pollution. There is limited evidence on the potential cost effectiveness of some environmental health interventions, such as ozone depletion and remediation of toxic waste sites [4]. A subsequent research reviewed the economic studies conducted in three environmental health areas: air pollution, water, sanitation hygiene, and vector control[10]. The review found a total of only 50 peer reviewed economic evaluations, of which 16 were on vector control, 21 on air pollution and 13 on water, sanitation and hygiene.

Both reviews found similar shortcomings in previous economic evaluations[10]. Firstly, they highlighted a lack of agreement on the methods used to assess EHIs, which makes comparing the results of studies results difficult [4, 10]. For instance, some economic evaluations fail to report key information such as the viewpoint adopted and the time horizon assumed for both the benefits and costs. Other major weaknesses highlighted in previous reviews were differences in the measures for assessing potential benefits of interventions (quality–adjusted life year, child cases of diarrhoeal

diseases, value of saved lives and productivity gains) and the lack of appropriate sensitivity analyses. [4].

In addition to these issues, another major challenge in conducting economic analysis of EHIs is the valuation of health benefits for children [11, 12]. Children are different from adults in respect to their risk, exposure and susceptibility to environmental hazards [11, 13]. Epidemiological evidence has shown that exposure to environmental hazards during the gestational period increases the risk of congenital malformations [14, 15]. During their first years of life children are also more vulnerable to environmental related risks than adults because their bodies are still developing and are less able to protect themselves from the effects of pollutants [16, 17]. In addition, their faster metabolism exposes them to higher doses of food, water and air per unit of body weight [16].

Perhaps the most difficult challenge to including benefits to children in the economic evaluation of EHIs is the monetary valuation of their health benefits [11]. In particular, Alberini et al. highlight three key methodological issues associated with the valuation of child health benefits: the elicitation of child preferences, the context of the valuation and the difficulties related to age, latency and discounting [13].

According to previous authors, the main obstacle in the evaluation of child health benefits is that children do not possess the necessary cognitive abilities to formulate preferences for their own health risk reductions [11, 13, 18]. Further, children are also not able to understand health risk and have no control over financial resources. Excluding the child perspective, previous studies have used three other types of perspectives to elicit child WTP estimates: the societal perspective, the adult as a child perspective and the parental perspective [11, 12]. The societal perspective consists of asking a representative group of the society (parents and non-parents) how much they are willing to pay for child health risk reduction [11]. The second perspective asks adults to imagine themselves as children and to assign a value to the health risks they faced when they were children [11]. The third, and most commonly adopted, perspective asks parents how much they are willing to pay for child health risk

reductions. According to Alberini et al. , the adult as a child perspective is the most challenging perspective. Respondents are required to reflect on their own childhood and value the risks they were facing at that time. Of the three, the parental perspective might seem the most workable given that parents are the most reliable proxies for their children and have the child's best interests at heart [11, 13, 19]. However, all three approaches have major limitations: firstly, they violate the principle of consumer sovereignty by failing to elicit WTP estimates from the individual who is actually facing the risk; secondly, adult individuals show greater risk aversion towards risks faced by children than towards risks faced themselves, and thus place greater value on risk reductions for child health compared with adults health. Thirdly altruism and particular non paternalistic altruism towards children, may substantially increase WTP estimates and lead to a higher than efficient provision of safety compared with other goods [20-22].

Paternalistic altruism refers to the situation in which parents care about the goods and services consumed by children (e.g. the level of consumption of goods contributing to safety). Non-paternalistic altruism describes a situation in which individuals care for the general utility level of others (e.g. a non-paternalistic altruist would transfer income to children that they can consume what maximizes their utility). If the marginal utility of additional consumption is zero for the person consuming the good, higher levels of consumption would not have a positive value to a non-paternalistic altruist but could have to a paternalistic altruist [20-22].

In the valuation of health benefits to children, another important element to be considered is the fact that decisions about child health are made within the household. Household related factors such as the household composition and the age structure may have a substantial influence on WTP to reduce children's health risk [11]. For instance Dickie found that the parents' WTP for risk reduction for children was higher in single parent households compared with two parents households [21].

Previous studies have found that the type of household allocation model assumed (e.g. collective vs. unitary model) affects the WTP estimates for child health risk reduction. If the unitary model is

adopted, it is assumed that parents have common preferences for child health risk reduction [5, 13]. If, on the other hand, a pluralistic model, such as the collective model, is used to determine the household WTP, several factors need to be taken into account when eliciting WTP for child health risk reduction. These factors include: differences between the preferences of mothers and fathers together with household structure and composition [23-25]. The majority of studies have used, either implicitly or explicitly, the unitary model [13, 25]. However, some studies have rejected the unitary approach, arguing that the assumption of household decisions based on a single preferences does not hold if tested with empirical data. For example, Bateman and Munro found that the valuation of dietary risk was significantly different where household values were estimated as joint rather than individual responses [26]. This study also found that women were more sensitive to changes in price compared with men [26]. Another relevant question when valuing child health benefits is whether WTP should be adjusted for the characteristics of the child, in particular, for their age [11]. Existing economic evaluations of the relationship between child age and parental WTP offer contrasting findings. According to Dickie and Messman and Hammitt and Haninger, parental WTP for child health risk reductions decreases as children grow older [27, 28]. However, Alberini and Scansy investigated parental WTP for child mortality risk reductions in Italy and the Czech Republic to find that WTP did not change with age in Italy, and that it increased as children grew older in the Czech Republic [29].

Finally, there are two other important elements to take into account in valuing children's health benefits, namely latency and discounting [30]. The majority of the health benefits arising from environmental health interventions occur in the future. Exposure to some hazards during childhood, such as heavy metals, will display effects only later in life when the child has become an adult [11]. Challenges associated with discounting child health benefits are also related to the issue of latency. If the EHI displays benefits over a period of time longer than one year, then the future health benefits should be re-expressed in terms of present value [11]. There is limited research on parental and child discounted future health benefits, and also regarding the rate (fixed, or variable over time) at which future health benefits should be discounted [31-33]. A study conducted by Alberini et al. investigating

individual WTP for reductions in mortality risk associated with remediation policies found a discount factor of 7 %[34]. However, a subsequent study conducted on parental estimates of the WTP for reducing the mortality risk for themselves, or for one of their children, found a 0% discount rate [29, 34]. In conclusion, despite the important role that economic evaluation can play in guiding decision making, there are still many troublesome issues associated with methodology and the availability of economic benefit values that limit its use. The objective of this thesis is not to address all these issues, but to provide preliminary evidence on possible solutions to current challenges by focusing, in particular, on the valuation of child preferences for health risk reductions associated with EHIs.

1. 2 Aim

This research aims to expand the current literature regarding the methods and approaches most suitable for the evaluation of EHIs focusing on the challenges associated with the valuation of health benefits to children.

In particular, the research will address:

- Methodology of CBA of EHIs.
- Monetary valuation of children environment-related health outcomes.

Specific Objectives

1. Cost benefit analysis of EHI brief description of theory and a practical application.

The specific objectives of this section are:

- To review the stages of CBA of EHIs.
- To apply the theoretical framework described to a practical case: The cost benefit analysis of remediating two industrial areas Gela and Priolo in Sicily.

2. Can we elicit WTP estimates for health risk reductions directly from children?

The specific objectives of this section are:

- To provide preliminary evidence on the ability of children to understand health risk and to investigate whether there is an age gradient.

- To contribute to/update existing evidence of the understanding and use of money in children.

3. Eliciting WTP estimates for asthma health risk reduction form children and their parents.

The specific objectives of this section are:

- To conduct the first contingent valuation (CV) study for health risk reduction with children.
- To assess if they can provide rational answers to CV questions.
- To investigate their WTP for three different health risk reductions.
- To compare the WTP estimates of children with those of their parents.
- To investigate if children's characteristics (e.g. age, gender, pocket allowance) influence both parents' and children's WTP.
- To investigate whether children's and parents' attitudes and behaviours influence their WTP for child health risk reductions.
- To conduct a discrete choice experiment (DCE) with children aged 7-19 years to elicit their WTP for health risk reduction.
- To assess if children can provide rational answers to DCE questions
- To investigate children WTP for three different health risk reductions using DCE questions
- To compare CV and DCE WTP estimates

4. Including WTP estimates in CBA of environmental health intervention targeting children's health.

The specific objectives of this section are:

- To apply the theoretical framework for CBA to a practical case including health benefits to children in the analysis.
- To assess the potential benefit of reducing traffic-related air pollution near London primary schools.
- To compare the monetary estimates of benefit from a children's and parents' perspective.

1.3 Structure of the thesis

Chapter 1 provides a brief summary of the main steps to perform when conducting CBA of EHIs from the selection of the options to include in the analysis to the final step consisting in performing a sensitivity analysis on the model baseline results.

Chapter 2 of section 1 performs a CBA of remediating the two industrial waste sites of Gela and Priolo in Italy, thereby providing an empirical application of the described methodology.

Section 2 describes the results of two different studies conducted to investigate whether children can understand stated choice questions. In particular, Chapter 3 illustrates the results of two experiments conducted with children aged 6-13 years to investigate their understanding of health risk while Chapter 4 investigates children's use and understanding of money. The study described in Chapter 4 also collects information on children's financial resources at different ages. This information is used to estimate budget constraints to use with children in the stated choice studies.

Section 3 comprises the results of two stated choice experiments conducted with children aged 7-19 years and with their parents to investigate WTP for reducing children's risk of having an asthma attack.

Chapter 5 describes the results of a CV study conducted with children and their parents to investigate their WTP for three different reductions in the risk of having an asthma attack. Chapter 6 describes the results a DCE conducted with children to elicit their WTP for asthma health risk reduction. Since the DCE is conducted with the same sample of children as the CV study, the chapter also provides a comparison of the WTP obtained with the CV and DCE methods.

Chapter 7 of section 4 describes the results of a CBA evaluating the benefits of reducing children exposure to nitrogen dioxide (NO_2) in London primary schools. Using WTP estimates from the CV study, the CBA assesses the potential benefits associated with reducing traffic pollution exposure from both a parental and a child perspective.

The last part of the thesis presents a summary of the research findings and outlines the limitations of the methodology adopted in the analyses. The section concludes by discussing study's findings, limitations and areas for future research.

1.4 Funding and Ethical Approval

The research was sponsored for two years and three months by a Colt Foundation Fellowship. The Italian National Research Council provided additional funding for the fieldwork in Italy.

Ethics approvals for the studies conducted with children in Italy were granted by the Ethics Committee of the Italian National Research Council and also by the Ethics Committee of the London School of Hygiene and Tropical Medicine. Children are a vulnerable group and particular attention was paid to providing information about all relevant study details and obtaining consent. Written consent was obtained from parents of all children participating in the studies. Children of consenting parents themselves were also asked for oral consent before starting the experiment. Children were reminded before the beginning of each experiment that they were not obliged to participate and that they could leave the study at any time.

1.5 Contribution of the candidate to the thesis

This thesis consolidates a number of activities including a literature review of methodology for the conduct of CBA of EHIs, the development of questionnaires, data collection, statistical analysis and also involved collaborative work with national and international research institutions.

In the first part of the thesis, the candidate conducted the literature review of current guidelines for the economic evaluation of EHIs. The CBA for remediating the two polluted industrial sites of Gela and Priolo was conducted in collaboration with the Institute of Clinical Physiology of the National Research Council in Italy. In performing the CBA for Gela and Priolo, the candidate was solely responsible for the data analysis and for drafting the CBA manuscript. John Cairns(JC) supervised the analysis and reviewed the manuscript for publication. Fabrizio Bianchi (FB)and Liliana Cori(LC) contributed to the data provision and also the descriptions of the environmental hazards and the epidemiological data in the two industrial areas.

Sections 2 and 3 report the results of the project *Respiriamolacitta* (translated from Italian "Breathing the city"), which is a pilot study designed by the candidate with the specific aim of providing answers to the two key objectives of this thesis:

- Investigating whether it is possible to elicit WTP estimates for health risk reductions directly from children.
- Eliciting WTP estimates for asthma health risk reduction from children and their parents.

Respiriamolacitta is an interdisciplinary research project involving health economists (Carla Guerriero and Prof. John Cairns), epidemiologist (Dr Fabrizio Bianchi), psychologist (Prof. Antonella Brandimonte) and an expert in environmental health risk communication (Dr. Liliana Cori) from three research institutions the LSHTM, the Institute of Clinical Physiology of CNR in Italy and the Laboratorio Brandimonte of the University Suor Orsola Benincasa in Naples. *Respiriamolacitta* was

conducted in Naples between May 2012 and November 2013. The different stages of the project are outlined in Table 0.1.

The candidate promoted the collaborations across the different institutions involved in *Respiriamolacitta,* and was responsible for raising the project's research questions and also for developing the study's questionnaires under the supervision of the interdisciplinary team. The candidate also carried out all of the data collection. In terms of data analysis, the candidate was responsible for the analysis of the results reported in Chapters 4, 5 and 6. In Chapter 3, the analysis of the second experiment performed by Michele Santoro (a statistician at the Italian National Research Council).

The work presented in the Chapter 7 is the result of an interdisciplinary collaboration between two UK institutions: LSHTM and the Faculty of the Built Environment at the University College London. In particular, the cost benefit analysis used environmental and health data collected by another PhD candidate, Lia Chatzidiakou, to populate the CBA model.

Table 0.1. Description of the Research project *Respiriamolacitta*

Tool	Data Collection Process	Objective	Brief description	Use made of the data	Study sample	Chapter where tools and data are presented in details
Questionnaire	First Stage of the study May-September 2012	To assess which of the two visual aids specifically developed for children lead to higher health risk understanding.	A questionnaire using one of the two visual aid was administered in class to children	Objective 2	Children aged 7-13 Sample Size: 102 children	Chapter 3
Questionnaire	Second Stage September-November 2012	To test understanding of absolute health risk and change in absolute health risk.	A questionnaire with 10 questions testing risk understanding was administered in class.	Objective 2	Children aged 7-13 Sample Size: 113 children	Chapter 3
Questionnaire	Second Stage September-November 2012	To test children use and understanding of money.	A questionnaire was administered in class to test children's comprehension of money related concepts.	Objective 2	Children aged 6-13 Sample Size:112 children.	Chapter 4
Questionnaire	Second Stage May-September 2012	To test children use of money.	A questionnaire was administered in class to test children's financial resources and use of money.	Objective 2	Children aged 6-13 Sample Size:103 children	Chapter 4
Contingent valuation study	Third Stage February-April 2013	To elicit children WTP for three health risk reduction using CV method.	Three CV questions using payment card set with a age specific budget constraint for children were administered in class. The questionnaire also collect information on children socio-demographic characteristics , attitudes and behaviours	Objective 3	Children aged 7-19 Sample Size: 370 children.	Chapter 5
Contingent valuation study	Third Stage February-April 2013	To elicit parents WTP for three health risk reduction using CV method.	Self-administered questionnaire was sent to children home for parents. The questionnaire included three CV questions using payment card elicitation format. The questionnaire also collected information on family income, composition and on parents' attitudes and behaviours	Objective 3	Parents Sample Size:173	Chapter 5
Discrete Choice Experiment	Third Stage February-April 2013	To elicit children WTP for asthma health risk reduction using DCE method. To compare the results of the DCE with those of the CV study.	Unlabelled choice experiments presenting a series of 7 choice sets, each choice set with three alternative and two attributes: risk reduction and cost of the intervention.	Objective 3	Children aged 7-19 Sample Size: 370 children	Chapter 6

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Section 1

The aims of this section of the thesis are twofold: firstly given the variety of methodologies that have been adopted in cost-benefit analysis of environmental health interventions (EHI), this section aims to provide an overview of the major steps necessary to conduct a cost-benefit analysis(CBA) of EHIs. The theoretical framework described will be then applied in chapter 2 of this section to a CBA evaluating the potential benefits of reducing adult mortality and morbidity associated with exposure to environmental hazards in the two industrial areas of Gela and Priolo.

1.Chapter [1]

1.Introduction

Different types of economic analysis can be performed to provide evidence on the cost and on the effectiveness of interventions affecting human health. If the intervention has only health benefits, cost-effectiveness analysis and cost-utility analysis are the most commonly adopted forms of economic evaluation[1]. Cost effectiveness analysis compares the cost of an intervention with the health outcomes, e.g. life years saved. Cost utility analysis assesses the cost-effectiveness of an intervention converting the health outcomes averted in terms of common utility index such as Quality Adjusted Life Year (QALY) or Disability Adjusted Life Year (DALY)[2].

EHIs, such as air pollution interventions or toxic waste site remediation, are different from core health care interventions because they can also bring non-health benefits[3]. The total economic value, the sum of any change in wellbeing arising from an EHI, can be divided into three main categories: human health improvements (mortality and morbidity risk reductions); ecological improvements such as improvements to market products (e.g. harvest of food), recreational activities (e.g. wildlife viewing), valued ecosystem functions (e.g. biodiversity) , non-use values (e.g. ecosystems communities etc.) and finally "Other benefits" such as, visibility improvements or reduced damage to monuments[3, 4].

Cost-benefit analysis (CBA) evaluates the social gain associated with a given intervention by comparing the benefits (any increase in welfare) and the costs (any decrease in human wellbeing) using a common monetary metrics[5]. Compared with other forms of economic evaluation, CBA is preferable because it allows utility gains and losses not related to health to be included in the decision

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making process. Another key advantage of CBA over other economic evaluation methods (e.g. cost effectiveness analysis and cost utility analysis) is its capacity to determine the optimal scale of the policy and thus whether interventions should be undertaken at all[3].

CBA can be used:

1. To determine acceptable levels of risk defined as the risk level that maximizes the difference between total social cost and total social benefits, or in other words, where the marginal social benefits associated with the risk reduction are equal to the marginal social costs of pollution abatement.
2. Demonstrate the economic return of investment
3. Compare the cost-effectiveness of competing interventions
4. Allocate limited resources efficiently

According to Pearce the theoretical foundations of CBA are[3, 5]:

- Preferences of individuals are considered and included in the analysis as a source of value and are considered "sovereign" as a fundamental value for judging a project cost beneficial.
- Benefits are defined as any increases in utility and are measured by how much individuals are willing to pay for securing that gain.
- Costs are defines as any decrease in human wellbeing and are measured by how much individuals are willing to accept to tolerate the loss.
- If costs and benefits occur in different time periods, in order to make them comparable, they should be discounted and reported as present values.
- For a project to be potentially acceptable the present value of the benefits must exceed the present value of the costs. If the decision involves choosing two or more projects

from a set of projects, ranking projects by their net benefits or benefit-cost ratios may help maximise net benefit.

The procedure for CBA consists of six main consecutive steps: one, specifying the decision problem; two, quantifying the benefits; three, assigning monetary values to each benefit; four, quantifying the costs of the intervention; five, including considerations of the life span for costs and benefits and re-expressing these as present values; and six, performing uncertainty analysis to assess the robustness of the study results[3].

2. Identifying the decision problem to be addressed.

The first step in CBA involves some key decisions about the analysis, in particular, identifying policy alternatives, including non-action. The selection of the policy(ies) or intervention(s) to include in the economic evaluation is made according to their availability/feasibility, and is also based on political factors [3]. Another important preliminary decision for the first stage of CBA is the selection of the relevant viewpoint[3, 6]. According to the selected perspective different costs/benefits (e.g. health service, societal, employer) may or may not be considered in the analysis. For example, if the Minister of Health perspective is adopted, then the benefits in terms of visibility improvements associated with air pollution interventions will go unaccounted. According to Hutton, given the broad range of possible benefits, the best approach is to estimate the benefits and the costs for all the relevant perspectives, and to present them separately in the final results in order to leave the decision about the most relevant perspective to the politicians[7]. However, this approach is both challenging and time consuming, and, in practice, the perspective is likely to change according to the type of intervention selected. A societal perspective is useful where the intervention has a wide range of benefits/stakeholders[3]. Alternatively, a narrow perspective (e.g. employer) is commonly adopted where the application of the intervention is specific, such as: improving ventilation and thermal control in an office building. The first stage of CBA should also set out which benefits and costs will be included in the analysis. This issue will be discussed later and in further detail. Finally, this stage of the CBA should also determine how long the period for purposes of evaluation should be. However,

determining the relevant time period often depends on the characteristics of the intervention itself. In the case of infrastructure, such as roads and ports etc., the typical time horizon usually ranges between 30 and 50 years[3]. In the case of polluted sites, for example, excavation eliminates the hazards forever, but capping the contaminated land has a shorter life span[8].

3. Benefits analysis.

There are many types of benefits arising from undertaking EHIs. As mentioned in the introduction section, in many cases EHIs involve non-health benefits such as saving time, amenity, productivity etc. The non-health benefits arising from EHIs can be significant and should be included in the economic evaluation if a societal perspective is adopted[7]. There are many types of non-health benefits arising from EHIs. Thus, their evaluation is challenging and discussing the different methodologies for assessing these non-health benefits is not an objective of this thesis. Indeed, the scope of the thesis is limited to a focus on the assessment of the health benefits arising from EHIs, with particular attention to child valuation of changes in environmental-related health risk. The implications of excluding non-health benefits will be further discussed in Chapter 2 and Chapter 7 which consider the potential benefits from remediation of industrial areas and reduction of traffic related air pollution. In both cases non-health benefits are excluded thus underestimating the overall benefits of the EHIs.

Three types of data are required to estimate the health benefits arising from EHIs: environmental data to identify the potential hazards/pollutants; epidemiological data to identify and quantify the health effects associated with the intervention; and, economic data for assigning a monetary value to negative health outcomes associated with exposure to hazards.

The first step involves estimating the health effects caused by pollutant exposure. The second step evaluates the number of health outcomes that can be averted by the pollution policy. And the third step multiplies the estimated number of avoidable health outcomes resulting from the regulatory strategy (number of deaths averted per year) by the economic value per health unit (e.g. value of a statistical life)[9].

In the majority of cost benefit analyses, the baseline number of health outcomes attributable to pollution exposure is determined using a dose-response function. This function is "an estimate of risk per unit of exposure to pollutant"[10]. The dose-response functions can have different shapes. They can be linear, meaning that any change in the pollutant concentration produces a corresponding change in the health outcome; or they can be non-linear, meaning that health outcomes increase proportionately to pollutant concentrations, but then level off ; and/or, they can present a threshold dose, meaning that there is a level of pollution at which health outcomes become apparent[10]. Where the health outcomes attributable to pollution exposure result from a single pollutant (e.g. asbestos), the population attributable proportion (PAP), or in other words, the number of cases that would have not occurred in the absence of pollutant, can be estimated using the following formula[11]:

1. PAP = (p-(RR-1))/(1+p*(RR-1))

Where RR is the relative risk of developing the health outcome given the pollutant concentration and p is the proportion of the population exposed (e.g. workers only).

In the majority of cases, identifying the individual pollutants responsible for the health effects in the exposed population is problematic. As for example in the case of landfills or illegal waste disposals, impacts are likely to result from different compounds discharged in the same site. Thus, the PAP is estimated using primary epidemiological data and according to the following formula:

2. PAP = Observed number- Observed number / SHR

Where SHR is Standardised mortality/hospitalisation ratios (SMR, SHR), which are estimated by dividing the observed cases (e.g. individuals with lung cancer) by the expected cases. SHR and SMR are adjusted for population characteristics, such as: socioeconomic class and other risk factors (e.g. prevalence of smokers etc.).

4. Monetizing health benefits

There are two main methods for placing a monetary value on changes in health: the human capital approach and the willingness to pay approach (Table 1.1)[1]. The human capital approach assumes that an individual's life can be valued in terms of future production potential. The willingness to pay (WTP) approach, measures a priori how much individuals are willing to pay to reduce the likelihood of an adverse event.

Table 1.1 Methods for valuing health

Basic approach	**Main subsets**	**Evaluation methods**
Human capital		Cost of illness
Willingness To Pay	Revealed Preferences	Hedonic wage method
		Averted expenditures
	Stated Preferences	Contingent Evaluation
		Stated Choice

Source: [12]

Within human capital approach, the Cost of Illness (COI) method is a measure of the monetary loss due to a negative health outcome (e.g. case of liver cancer)[1]. COI has several advantages over WTP. COI is straightforward. It is an objective measure of direct monetary costs of a given health outcome. In other words, it does not depend on personal preferences. However, COI also tends to underestimate the true value of a health outcome, in that it does not consider the intangible aspects associated with illness such as stress, pain and suffering. Moreover, given that COI values can be estimated only *a posteriori*, it is impossible to elicit the values that individuals assign to future environmental health risk reductions [1, 13].

As a result, the most popular approach adopted in cost-benefit analyses is the WTP approach. The WTP method can be divided in two main categories: revealed and stated preferences. The revealed preferences approach uses information from actual behaviors to elicit how much individuals are willing to pay (e.g. price of a bicycle helmet) for reducing health risks, or how much they are prepared to accept for facing a health risk (e.g. Wage rate relate to the risk of fatal accident while at work).

It has been suggested that revealed preference techniques provide the most reliable indicator of preferences because estimates are based on actual decisions, rather than on individual choices under hypothetical scenarios [1]. In many cases, however, WTP information cannot be inferred from the market. Sometimes markets do not yet exist for the effect or cost being evaluated. Or, where EHIs target children and the elderly, the subjects are outside the workforce[14].

Stated choice methods are another approach that can be used to elicit WTP/WTA values for changes in environmental-related health risk. In stated choice studies individuals are directly asked how much they would be willing to pay for an improvement in their health status, or their willingness to accept values for an increased risk. Compared with the revealed preference approach, stated preference methods can be used to value any type of risk including latent risks, risks for which there is a lag between the exposure and the onset of the health outcome, and hypothetical risk reduction scenarios (changes in risk arising from policy interventions not yet implemented).

Compared with the COI, stated preference approach has the advantage of taking into account the intangible consequences, for example: premature death and the suffering from an illness. In addition, stated preferences methods can also be used to elicit WTP estimates from individuals who are not in the labour force, and can easily account for different types of risk context.

There are two stated preference techniques for estimating WTP/WTA for environmental health risk reductions, these are: contingent valuation and discrete choice experiments. The Contingent Valuation (CV) approach asks respondents to make a monetary evaluation of the change in health risk presented. Among the many methodologies for eliciting WTP/WTA values from CV studies, the most common

methods are dichotomous choice, open-ended and payment card format[1]. All the elicitation formats have certain advantages and disadvantages. For example, compared with dichotomous choice and payment card format, the open-ended format has several major advantages, which include: avoiding starting point bias, avoiding range bias and also avoiding anchoring bias [1]. However, this method is rarely used given its wider cognitive demands, which often produce non-response or a high proportion of protest and zero answers [1]. The payment card elicitation method presents respondents with a series of ordered amounts (from the smallest to the largest) and usually asks respondents to indicate the maximum bid they would likely pay for the health risk reduction [1]. But the payment card is also subject to bias because it requires the analyst to make assumptions about the range and the number of price bids. Compared with open-ended and payment card formats, the single and double bounded elicitation methods are less cognitively demanding. However, both these approaches also have weaknesses. Close ended formats leave less freedom to the respondents to select the exact amount they are willing to pay [15]. And both approaches are also subject to anchoring [1].

Unlike CV studies that directly ask respondents how much they are willing to pay for a specific change (e.g. in health risk), discrete choice experiments (DCEs) present respondents with a number of choice sets in which alternatives, described as a set of attributes, are mutually exclusive [16]. The alternatives presented in each choice set vary in one or more attribute levels. The selected combination of attributes is used to infer indirect information on individual preferences about the parameters considered. Compared with the CV technique, DCEs are able to describe a choice situation with a range of attributes that reflect the different characteristics of the particular good being valued and, when the cost factor is included, they allow WTP estimates to be made for changes in different attributes [15].

Despite the advantages of stated preference methods (e.g. elicit WTP for policies not yet implemented) several authors have suggested that their use of hypothetical scenarios may lead to significantly biased WTP estimates. Hypothetical bias refers to difference between the real payments that respondents make and a stated hypothetical willingness to pay provided in the questionnaire. Hypothetical bias

has been found in stated preferences experiments for both private and public goods [1, 17]. Evidence from previous studies suggests that hypothetical bias is positively related to the size of the estimated values, it is smaller for WTP compared to WTA studies and it is highly affected by the presence of uncertainty [1, 18, 19]. Recent research investigating methods to reduce hypothetical bias suggest that the use of entreaties such as cheap talk may significantly reduce hypothetical bias in stated choice experiments. For instance the study conducted by Brown et al. showed that the content of 'cheap talk' used before asking WTP questions such as urging respondents to act as if they were really asked to spend the money , explaining what is hypothetical bias and how it can influence the study results, can significantly reduce the degree of hypothetical bias[18].

5. Cost analysis

It is difficult to evaluate *a priori* the cost of EHIs. According to Pearce et al. there are three major cost components to consider in CBA: the compliance cost, the regulatory costs and the damage cost [3]. The compliance costs include all the resources necessary for implementing the policy such as the cost of remediating a polluted site, including both the capital and the operating cost associated with the intervention.

Given the information asymmetries between the intervention provider (e.g. Government) and the intervention supplier (e.g. contractors in charge of the remediation activities), initial compliance costs estimated a priori may be overestimated or underestimated compared with the final cost incurred to implement the policy [3, 20]. Predicting the compliance cost ex ante is even more difficult when the intervention is new and there are no previous cost estimates available[3]. The estimation of compliance cost is even more complex in the case of large projects or regulatory interventions that involve significant spillovers in different economic sectors [3].

In CBA, the second cost component to consider are the regulatory costs, which are the costs to the government of implementing the policy. Regulatory costs are often substantial, and particularly where the project involves a large area (e.g. European regulation)and/or a large number of industries [3].

The transaction costs associated with new regulation involve the cost of gathering information, and also implementing and monitoring the new regulation[4]. Sometimes new regulation may even require the creation of property rights for previously non-marketed goods (e.g. emission trading in California) and establishing institutions to control the newly created markets[4]. Finally, additional regulatory costs may be incurred as a result of changes to the institutional and legal system to create the new policy [4].

In CBA, the third cost to consider is the damage cost, or environmental loss arising from the intervention. The monetary value of environmental loss is quantified using the different approaches described in the benefits section. Once this cost is quantified it must be subtracted from the total economic value attached to the intervention.

6. Time adjustment for environmental benefits and costs

The cost and the benefit of EHIs may materialise over lengthy periods. Thus, discounting plays a crucial role in estimating the value of future costs and benefits[3]. Where different types of interventions are compared, discounting future costs and benefits to present values renders them more easily comparable. Discounting implies that the further in the future the benefits and the costs occur, the lower the weight that should be attached to them.

The general formula of discounting is the following[3]:

3. $$w_t = \frac{1}{(1+s)^t}$$

Where w_t is the discount factor for time t and s is the discount rate.

Thus, the conversion of future benefits to a present value can be estimated with the following formula[3]:

4. $$\text{Present Value} = \Sigma\ \text{Future Value}_t \times w_t$$

Where economists use discounting to adjust the value of costs and benefits occurring in the future, the standard approach is to assume a constant discount rate common to both costs and benefits[14]. For example, since 1992 the US discount rate suggested as the base case for cost-benefit analyses was a fixed at 7% for both cost and benefit estimates[9, 21]. A 3% discount rate was also suggested for

sensitivity analysis[9, 21]. The European Commission recommends the use of a discount rate of 4% for environmental cost benefit analyses and a lower discount rate of 2% for sensitivity analyses[22]. However, there has been extensive discussion of whether the discount rate for health benefits should be lower than that applied to monetary costs. Also, where the effects under consideration are long-lived, a case has been made for discount rates declining over time[14]. There is also an ongoing debate whether the normative discount rate should account for the discount rate estimated directly from individuals in stated choice studies. Recent studies suggest that individuals' discount rate is not fixed but varies over time [23-25]. Economists are paying increasing attention to hyperbolic models that reflect time inconsistent models of discounting. According to Cairns, hyperbolic models presents two major advantages over traditional exponential models: they seem to reflect real individual time prefaces and compared with a constant discount rate they do not attach very low weight to benefits occurring in the distant future. Empirical studies results seem to support hyperbolic models [29,30]. For example, Viscusi and Hubert found that the discount rate shown for improvements in environmental quality do not follow the standard discount utility model; rather its pattern is consistent with the hyperbolic model[26]. Also, Alberini et al. found that discounting rates for saving lives in the hazardous waste context are not constant over time. For time horizons longer than 10 years, in particular, they found that the discount rate was decreasing [27]. For policy that displays health benefits occurring in a distant future, there is a strong incentive to consider inter-generational equity. Indeed, using a constant discount factor would highly depreciate benefits occurring in the distant future. Given the uncertainty surrounding the future discount rate, together with the necessity to ensure inter-generational equity, UK government departments introduced new guidelines recommending the use of a time-varying discount rate[6]. The UK Treasury's guidance document for central government authorities (The Green Book) recommends the use of a 3.5% discount rate for projects with short term impacts (≤30 years)[6]. In order to account for the uncertainty about the future the Green Book also recommends use of declining long term discount rates (ranging from 3.5% for projects shorter than 30 years and 1% for projects with impacts for more than 300 years)[6]. The main rationale behind the use of declining discount rate for long term projects is the uncertainty about

the future and the requirement to address the negative effects of the constant discount rate (e.g. the issue of intergenerational equity and sustainability)[6]. Time lags between the policy and its related benefits are also an important issue[6]. When a policy is implemented, there may not be immediate reductions in the number of health outcomes (e.g. cancer cases). Following this "cessation lag", there will be a gradual (proportional/non proportional) decline in the effects of the reduced emissions on health up to the point where the number of health outcomes is the same as observed in the general population.

The formula to estimate the present value of an annuity *a* given the discount rate *d* is reported below [28]:

5. $Present\ Value\ (a)=a/(1+d)+a/(1+d)^2+a/(1+d)^3.....+a/(1+d)^t$

Because Equation 5 is a geometric series it can be re expressed as follows:

6. $Present\ Value\ (a) = a*((1-1/(1+d)^n)/d)$

Where *n* is the number of years in which the policy is expected to display its benefits. Substituting *a* with the product of the estimated annual number of health outcomes averted by the policy, Xa, and the WTP for the health outcome (λ) the above formula can be re-expressed using the following short cut:

7. $Present\ Value\ of\ Benefits = Xa*\lambda*((1-1/(1+d)^n)/d)$

If the policy is expected to display its benefits (e.g. decrease in number of cancer) only after a given number of years, *l* , then present value of the annuity should be discounted to account for the latency period (See equation below).

8. $Present\ Value\ of\ Benefits = Xa*\lambda*1/(1+d)^l*((1-1/(1+d)^n)/d)$

Where: X_a is the number of health endpoints averted by the intervention, t is the number of years over

which the benefits accrue, and d is the discount rate. λ is the WTP for the health outcome a and l is the which is the time occurring between the reduction of the exposure and the improvement in the health of the population.

7. Cost-Benefit evaluation

The main condition for the adoption of a EHIs is that the present value of the benefit (PVB) exceeds the present value of the cost (PVC), or, that the: Net present value >0[3]. In theory, the net present value (NPV) rule can be used to decide whether to accept or reject a policy, to rank different projects and to choose between mutually exclusive projects. In practice, the decision of whether or not to implement a project will depend on the available budget and on careful consideration of the project's sustainability. Distributional issues regarding the intervention and the risk and uncertainty associated with the benefits and costs estimates may also weigh upon the decision [3]. An equivalent feasibility test is the benefit cost ratio test:

9. PVB/PVC >1.

However, there are differences between the two tests. The first evaluates the excess in benefits and is a more direct way of measuring the social benefits of the intervention. The second evaluates the benefits per dollar of cost incurred. For example, a cost ratio of 2.2 means that for each dollar invested, $2.20 of social benefit is realized.

8. Risk and Uncertainty

As with economic evaluation of health-care interventions in cost utility and cost effectiveness analyses, extensive sensitivity analyses can be used to address the lack of certainty, and also allow an assessment of the robustness of the results of economic evaluations and their comparability[3]. As mentioned above, costs and benefits are difficult to ascertain a priori. As a consequence, they are associated with high degrees of risk and uncertainty. Few authors treated risk and uncertainty in main standard CBA textbook[29-31]. Also, governmental agencies and international bodies discussed the need for accounting for risk and uncertainty in the CBA models[7, 9, 32]. Risk denotes the possibility of

attaching a probability to costs or benefits that are not known with certainty. Uncertainty denotes a case in which the probability distribution is not available; but in which crude end points, like the minimum and maximum values, are known. Despite the importance of addressing risk and uncertainty in CBA there is still a lack of core methodologies for conducting uncertainty analysis to facilitate the comparison between CBA results[33].

If the objective of sensitivity analysis is to assess the degree of uncertainty associated with single model parameters, then deterministic sensitivity analysis, and in particular one-way or multi-way sensitivity analyses, can be used [2, 33].

One way deterministic analysis tests the sensibility of the expected NPV to changes of a single variable in the model[2, 33]. Alternatively, multi-way sensitivity analyses tests the effect of changes to two or more variables on the expected NPV of the EHIs[2, 33].

The main advantage of deterministic sensitivity analysis is that it is computationally easy. Moreover, it allows assessments of which specific parameter values the expected NPV changes. The main disadvantage, however, is that deterministic sensitivity analysis does not account for cases in which many variables change simultaneously. Monte Carlo analysis is a computational method that uses statistical sampling and probability distributions to show how parameter uncertainty affects model results[34]. In CBA of EHIs, Monte Carlo simulation can be used to model the effects of the key variables such as policy associated health risk reduction on the NPV of a given proposal[34]. Compared with crude deterministic methodologies that generate a single point estimate, Monte Carlo method can be used to account for parameter variability and uncertainty. Monte Carlo simulation is carried out in two consecutive steps: firstly, it requires the analyst to select and assign a probability distribution to the variables used for the NPV calculation; secondly, it requires the simulation of a large number of draws, usually between 1.000 to 10.000 simulations, from the distributions selected. The most difficult task in performing Monte Carlo simulation is the selection of the appropriate

probability distribution, which depends on the characteristics of the variable (e.g. bounds of the variable and symmetry of the distribution) and also on information available about the variable [35].

For example, the Briggs et al. suggest the adoption of a Beta distribution for binomial data, such as proportion and probabilities, as these are naturally bounded between 0 and 1; while the Gamma probability constrained between 0 and positive infinite is the perfect candidate to use for simulating uncertainty in the cost parameter [35].

Once the Monte Carlo simulation results have been obtained they can be presented using Cost-Benefit Acceptability Curves (CBAC). CBACs are a modified version of the cost-effectiveness acceptability curves used in health care decision making to represent uncertainty within economic evaluation of health care technologies [36, 37]. In pure health care decision making, CEACs indicate the probability that an intervention is cost-effective compared with the alternative(s), given a range of λ willingness to pay values. In the case of CBA of EHIs, both cost and benefits are reported in monetary values. Thus, the condition for the pollution control policy to be implemented is the following [37]:

10. NPB=PVB-PVC >0

Where NPB is the net present benefit and PVB and PVC are the present value of benefits and costs associated with the intervention.

An application of the CBAC to describe uncertainty in CBA results has been provided in the following Chapter.

9. Summary

This Chapter provides a brief description of the main steps involved in estimating the costs and benefits associated with EHIs. In particular, the chapter describes the main steps for assessing the health benefits and costs associated with EHIs. The first step in conducting CBA consists of identifying the decision problem to be addressed, specifically, determining the perspective and the time horizon

for the analysis together with the relevant types of benefits and costs. The second step of CBA aims to quantify the health benefits arising from the intervention using environmental, demographic and epidemiological data. Once these benefits have been quantified, the following steps consist of assigning a monetary value to the data. Monetization of the health benefits is probably the most challenging step in CBA. The most commonly used method for assigning monetary value to environmental health benefits is the stated preferences technique. However, WTP estimates elicited using this approach are associated with a high degree of uncertainty because they are calculated on the basis of respondent answers to hypothetical scenarios rather than real decision making. The fifth step of CBA is to assess the cost of the intervention. Depending on the type and size of the intervention, cost can vary significantly. For this reason, ascertaining a priori costs can be difficult. Further, establishing costs and benefits arising from EHIs requires analysts to fix a period of time in which these are expected to occur. If the relevant time horizon is longer than one year, discounting can play a crucial role in the CBA as it allows translating both future costs and benefits to their present value. Given the uncertainty associated with estimates of benefits and costs, the last step of CBA requires the conduct of a deterministic and/or probabilistic sensitivity analyses. The previous paragraph of this chapter provides a brief description of the different techniques, such as one-was sensitivity analysis and Monte Carlo simulation, used to account for risk and uncertainty in CBA estimates.

One quarter of the global burden of disease is associated with environmental risk factors[38]. In this context, CBA offers a transparent source of information for national and international decision makers. CBA provides policy makers with estimates and comparisons of the overall benefits and costs associated with EHIs using monetary metrics. Since Depuit introduced marginal analysis in 1844 , CBA methodology has improved significantly through the years[39]. Nevertheless, methodological issues still exist, mainly in regard of the monetization of the health benefits for children arising from EHIs. Furthermore, with respect to some other areas, such as remediation of toxic waste sites, there is still limited economic evidence on the cost effectiveness of EHIs. Both these issues will be covered in the following chapters of the thesis.

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Research Paper 1. Policies to clean up toxic industrial contaminated sites of Gela and Priolo: a cost-benefit analysis.

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2.Chapter

1. Introduction

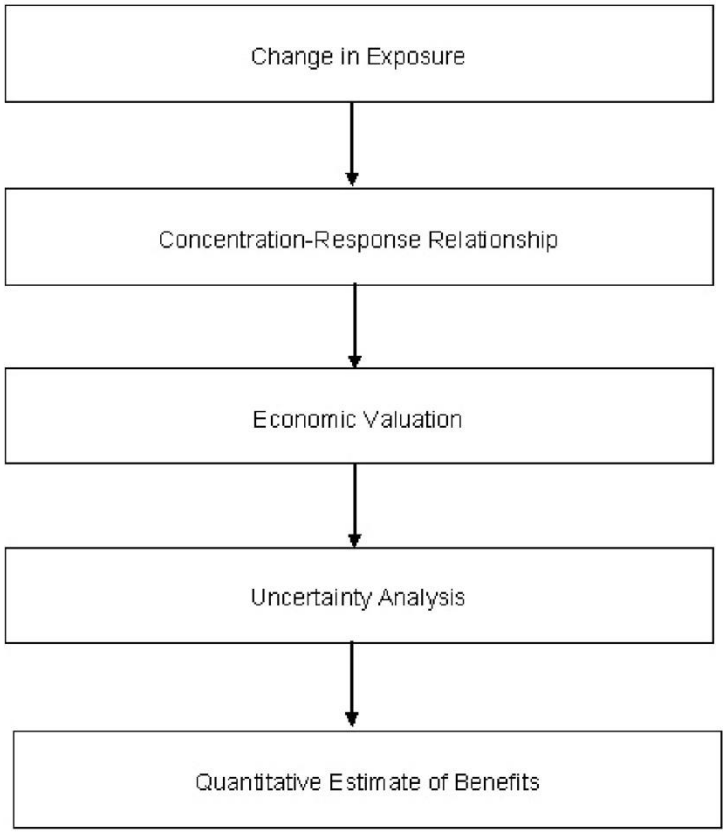
It is estimated that approximately one-quarter of the global disease burden, and more than one-third of the burden among children, is due to modifiable environmental factors [1-3]. Materials, once widely used in industrial activities for their physical qualities, have proved carcinogenic, mutagenic and/or teratogenic for human health [4-8]. Priolo and Gela, in south-east Sicily, provide extensively documented cases of toxic contaminated sites where, due to the presence of large petrochemical industrial plants and to widely diffuse environmental pollution, several negative health effects have been observed. High levels of many chemical compounds have been detected in soil, water, groundwater, air sediments, fish and shellfish of both areas [9-13]. One recent descriptive study conducted in Gela and Priolo by the Dipartimento Osservatorio Epidemiologico (DOE) of the Sicilian Region showed excesses of overall mortality, of all cancer mortality and of many cancer and non-cancer cases when compared with regional and local reference levels [10]. These factors cause increasing concern in the local communities [14]. Nevertheless little has been done to reduce the exposure of the local population to pollution. Cost-benefit analysis provides a common metric for evaluating costs and benefits arising from a given health policy and enables policy makers to pursue evidence-based strategies, to allocate resources efficiently and to prioritise the most beneficial interventions [15]. Importantly, the aim of cost-benefit analysis is not to assign a price to environmental-related health outcomes (e.g. cost of deaths) that have already occurred but to estimate, in monetary terms, the net benefits for society of averting future pollution-related health effects [16]. To date, there is a paucity of studies evaluating the net benefit arising from the reduction of environmental health hazards. The majority of published cost-benefit analyses focus on quantifying the monetary health benefit, and in particular the reduction in respiratory ailments, through air

pollution control policies [17]. A few evaluations have considered other environmental-related health outcomes, such as cancer and hospital admission, but there have been no studies evaluating the potential net monetary benefits of reducing industrial pollution exposure[18-21]. This study, aims to quantify the long-term benefits resulting from the remediation of two highly polluted industrial sites: Gela and Priolo.

2.Methods

The analytical framework used to estimate the monetary benefit arising from the remediation of these industrial sites is the Damage Function Approach described in Figure 2.1[22].

Figure 2.1 Damage Function Approach



This analytical framework combines both epidemiological and economic data to quantify how changes in exposure to environmental hazards affect the welfare of society. The first part of the study describes the environmental hazards present in the industrial sites of Gela and Priolo. In the second part, the health conditions attributable to environmental exposure are described, and quantified using recent epidemiological data. In the third part, monetary values are assigned to these health outcomes in order to estimate the monetary benefit arising from a comprehensive pollution control intervention in these industrial sites. The final part consists of performing extensive sensitivity analysis to account for parameter uncertainty.

2.1 Health hazards arising from industrial activity in Gela and Priolo

The environmental pollution data in Gela and Priolo were collected in the context of the Reclamation Sites of National Interest policy. The pollution detected in Priolo involves soils and water and results from the release of ammonia, fluorhydric acid, chlorine, sulphur hydrogen, mercury; from discharges of industrial waste, inside and outside the site. Air pollution is caused by emissions of sulphur dioxide, nitric oxide, carbon dioxide, volatile organic compounds in the air (VOC). Groundwater is subject to depletion, withdrawal, and salinisation. Hydrocarbons, organic compounds and heavy metals pollution have been detected. The analysis of pine-needles has detected the presence of heavy metals [11]. There is also evidence of ecological systems disturbance and food chain contamination [11-13]. The groundwater inside the Gela remediation site contains arsenic, benzene, 1,2 dicloroethane, vinyl chloride, and mercury greatly in excess of legal limits [11]. Only temperature, turbidness, colibacteria, and iron presence have been analysed in drinkable water, and no data are available for other chemical compounds[11]. There are several abnormal data: toxic compounds in the air (benzene, non-metanic hydrocarbons, ozone, PM 10, VOC). Again the analysis of pine-needles has detected the presence of heavy metals[11]. Marine sediments have been found to be polluted by copper, arsenic, mercury and Polychlorinated biphenyls, showing toxicity in ecotoxicological analysis; fish and benthic organisms

are polluted by heavy metals. The two rivers in the Gela plain are polluted by pesticides, copper, and zinc [11-13].

2.2 Health outcomes attributable to exposure to industrial pollutants

Since the early 1980s, several epidemiological studies have been conducted in Sicily to investigate the health status of the populations living near industrial sites [22-25].

As previously mentioned, industrial activity has contaminated soil, water and air in the areas of Gela and Priolo with different types of pollutants. Consequently, it is impossible to disentangle the effects of each pollutant on the health of the population living in each area. The approach used to estimate the population attributable proportion, the number of cases that would have not been observed in the absence of the environmental hazards in the industrial areas, is to estimate the number of excess cases for those health outcomes that have been found to be statistically related with the presence of industrial hazards based on epidemiological evidence collected on site.

The most recent DOE epidemiological study collected mortality data (from 1995 to 2002) and hospital discharges (from 2001 to 2006), for residents in the municipalities included in the high risk areas [10]. The DOE considered the following health outcomes: mortality from all causes, mortality by specific causes (e.g. infectious disease), hospital admission for all causes and disease-specific hospital admission (e.g. hospital admission for lung cancer). Tables 2.1 and 2.2 report these health outcomes with the estimated Standard Hospitalisation and Mortality ratios in the two areas of Gela and Priolo.

Table 2.1. Standard Mortality and Hospitalisation Ratios in the area of Gela.

	Area of Gela			
Health Oucome	**Standard Mortality Ratio**		**Standard Hospitalisation Ratio**	
	Male	Female	Male	Female
Non cancer related				
All Causes	106*	105*	104*	101
Infectious deisease	100	84	121*	112*
Blood and tissues related diseases	-	-	87	100
Respiratory diseases	80	91	106*	99
Digestive sistems diseases	105	97	102	100
Urinary system dieases	94	105	99	76
Trauma and Poisoning	119*	92	121*	121*
Overdose	-	-	76	68
Cancer related				
All Cancer	112*	109*	115*	111*
Stomac cancer	135*	70	123	129
Colorectal cancer	95	148*	101	103
Liver cancer	85	101	126*	145*
Larynx cancer	177*	79	76	92
Cancer of the trachea, broncus and lung	117*	154*	98	97
Pleura cancer	308*	87	261*	186
Bone cancer	159	124	112	60
Sarcomas	-	-	134	79
Melanoma	176	136	85	140
Breast Cancer	-	94	-	104
Uterine cancer	-	116	-	104
Prostate Cancer	93	-	111	-
Hodgkin Linfoma	23	0	123	109
Multiple Myeloma	101	86	149	102
Leukemia	120	105	88	122

*p value<0.05

Table 2.2. Standard Mortality and Hospitalisation Ratios in the area of Priolo.

	Area of Priolo			
Health Oucome	**Standard Mortality Ratio**		**Standard Hospitalisation Ratio**	
	Male	Female	Male	Female
Non cancer related				
All Causes	99	95	121*	124*
Infectious deisease	89	94	120*	126*
Blood and tissues related diseases	-	-	140*	177*
Respiratory diseases	105	105	124*	127*
Digestive sistems diseases	97	121*	123*	132*
Urinary system dieases	133	121	119*	135*
Trauma and Poisoning	83	124	125	130*
Overdose	-	-	36	40
Cancer related				
All Cancer	110*	96	115*	127*
Stomac cancer	80	93	94	95
Colorectal cancer	123	121	93	134*
Liver cancer	98	93	69	101
Larynx cancer	94	402	139*	387*
Cancer of the trachea, broncus and lung	124*	99	94	145*
Pleura cancer	529*	207	115	96
Bone cancer	39	281*	157*	156
Sarcomas	-	-	167*	150
Melanoma	97	91	214*	69
Breast Cancer	-	93	-	99
Uterine cancer	-	74	-	63
Prostate Cancer	118	-	121*	-
Hodgkin Linfoma	90	-	84	116
Multiple Myeloma	170	220*	148*	138
Leukemia	115	54	94	54

*p value<0.05

Standardised mortality/hospitalisation ratios (SMR, SHR) were calculated by DOE dividing the observed cases by the expected cases, number of cases that would have occurred if the rate of deaths/hospitalisation was the same as observed in an area nearby with similar age and socioeconomic characteristics but without the environmental hazards. For each of the selected health endpoints, the population attributable proportion (PAP) was estimated by subtracting the number of expected cases for each of the end points from the number of the observed cases:

1. *Population Attributable Proportion= Observed Cases- Expected Cases*

Estimates were reported for males and females separately and adjusted by age and socioeconomic deprivation [9,10]. The potential health benefits arising from a reduction in exposure to industrial pollutants are quantified for both Gela and Priolo, by considering the impact on total mortality, hospital admissions for cancer and non-cancer causes. The number of expected cases each year was not available from the DOE study and was estimated by dividing the number of observed health outcomes by the SMR/SHR. Given that the DOE reported observed cases were collected longitudinally (e.g. mortality data was collected over 8 years) the number of health outcomes was divided by the number of years over which epidemiological data had been collected (n) (See formula below).

2. *Population Attributable Proportion* $= (\text{Observed Cases}_{ab} - \text{Observed Cases}_{ab}/\text{SMR}_{ab} \text{ or } \text{SHR}_{ab})/n$

Where: a is the health outcome, b is gender and n is the number of years over which epidemiological data have been collected. Upper and lower values for each estimate are calculated using the 95% CIs of the SHR/SMR.

2.3 Economic evaluation

2.3.1 Monetary valuation of environmental health benefits: methodologies and issues

Two approaches are used to assign a monetary value to the adverse health effects in environmental cost-benefit assessment. The cost of illness approach usually considers the direct medical cost, third party costs and productivity losses [26]. The second and more common approach is the willingness to pay (WTP) approach, which measures how much individuals are willing to pay for a reduction in the risk of a given adverse event (e.g. reduction in the mortality risk)[26]. Unlike the cost of illness approach, WTP includes the evaluation of intangible costs associated with adverse health events, for example, pain and fear, and account for individual preferences [26].

Environmental health interventions such as reduction of air pollution in urban areas and remediation of contaminated waste sites affect health risks of individuals independently from their characteristics such as baseline health status, income and age. WTP studies are conducted to elicit the value ofa statistical life independently from the baseline risk of the individuals. However as suggested by Alberini et al. WTP values may be influenced by baseline health risk [27]. Those who are most at risk of mortality in general may be willing to pay less for environmental health interventions because the competing risk reduces the likelihood that they will benefit for the policy intervention. Previous studies show that contextual factors, such as individual characteristics, nature of the health outcome and number of individuals affected by the clean-up policy (e.g. death for cancer) influence WTP [28]. Finally, another important issue to consider in the evaluation of the benefits of a clean-up policy is the time lag (also referred to as the "cessation lag") between the clean-up policy and the onset of its related benefit.

2.3.2 Value of future reductions in mortality risk

An extensive literature search was conducted to find studies evaluating the value of a statistical life (VSL) for individuals exposed to environmental hazards. The Italian Government have not recommended values to use in Cost Benefit analysis of environmental health interventions. The

baseline and the upper values, €5,800,000 and €6,300,000, selected for the analysis have been taken from a study conducted in four Italian cities with significant problems related to contaminated sites. Both values reported have been inflated to 2009 prices using the Harmonised Index of Consumer Prices. The Alberini et al. study presents several novel elements. The study took into account for the first time how the WTP for mortality risk reduction is affected by the permanence of clean-up intervention and the size of population affected by the intervention [27]. The upper value used in this study was estimated assuming that the population living in the area covered by the program is 1 million, while the intermediate estimate is the baseline estimate suggested by Alberini et al.[29, 30]. The lower estimate used, €2,100,000 is the European Commission's value of a statistical life (VSL) for environmental cost benefit analysis inflated to 2009 prices [31]. It is based upon a number of Contingent Valuation studies. Although it adjusts for the age of victims of environmental hazards it probably underestimates the VSL because it was estimated in the context of transport fatalities and does not consider fatalities specifically as a consequence of environmental hazards [30].

2.3.3 Value of reductions in risk of future negative health outcomes

Individual WTP might vary according to the cause of the hospital admission (e.g. cardiac versus respiratory hospital admission). As Pearce suggests, the WTP to avoid cancer is higher than with other types of diseases because of the dread and pain effects associated with this pathology[32]. For this reason, in the present study the two health end-points, cases of cancer and non-cancer hospital admissions, are considered separately [31]. Estimates of the value of a statistical case of cancer were retrieved from a conjoint choice analysis conducted among 400 individuals who live in the industrial complex and contaminated site of Marghera (Venice) [28]. The baseline estimate of €2,656,000 is used in the present analysis. The upper estimate of €5,312,000 is the value of a case of cancer for high income individuals (annual household income more than €32,000). The lower estimate, €1,647,000 is for those individuals living farthest (more than 2.5 Km) from the contaminated sites [28]. Unfortunately, no studies have been conducted to estimate the WTP to reduce the risk of a hospital admission in the context of exposure to toxic pollutants. The estimated WTP to avoid a hospital

admission comes from the ExternE Project (€9,500 inflated to 2009 prices) [31]. Although this value is heavily dependent on US studies, it is the only WTP estimate of the monetary benefit of averting a hospital admission [32, 33].

2.4 Cost of reclaiming Gela and Priolo

It is difficult to establish whether a remediation strategy will attain the forecasted health improvements within the planned budget. The costs of long term remediation projects accumulate over years and effectiveness is only observable after a long time [34]. Further, sometimes it is not possible to identify all the sources of environmental externalities to be addressed by the intervention (e.g. toxic waste from illegal dumping is often not visible). Frequently the estimated cost of a regulatory intervention is only the abatement expenditure (e.g. the cost per ton of emission reduction) which, as Kopp et al. suggest is a narrow measure of the cost of regulatory compliance[35].

In the case of the Italian Reclamation Sites of National Interest, a budget was established for each intervention plan, which was approved by the Ministry of the Environment. The polluter is supposed to implement and pay for the clean-up. If the polluter is not identified, or is not acting to reclaim the site, the closure of the process and cost of negotiation is established by means of a Memorandum of Understanding. Under this approach, however, the final cost of clean-up for Gela and Priolo remains uncertain. To date the agreed document identifies €774.5 million for Priolo and € 127.4 million for Gela. But these estimates cover only some of the required interventions [36-38]. In the case of Gela, where there is soil, air and ground water pollution, different interventions have been suggested [39]. The first intervention proposed was the renewal of the petrochemical plant based on the least polluting technologies . The second intervention, now completed, was the characterisation of the area which was implemented by the Arpa Toscana[39]. The third intervention targeted the ground water pollution, and involved the construction of waterproof barriers along the coast line to limit the pollution from the contaminated groundwater. Several interventions targeting the soil pollution have also been planned, and mostly involve excavation of the contaminated soil. However, since the

inclusion of the site in the national priority list little has been done to reduce soil contamination[39]. The use of new technologies, such as the air sparging and the soil flushing for the removal of volatile organic compounds (VOCs) from groundwater have also been proposed, but as yet remain unimplemented. The area of Priolo is smaller than the industrial area of Gela. According to Legambiente, the few interventions performed in the area of Priolo have been the characterization of the pollutants in the different matrix, and the construction of bores to collect the ground water contaminated with hydrocarbons [39]. For the future, interventions will focus on the remediation of the landfills created as a consequence of different industrial activities in the area. These will include the excavation of soil and the pumping and treatment of the contaminated ground water [39].

The formula used to estimate the present value of the health benefit arising from the reclaiming of polluted waste sites in the two industrial areas estimates the present value of an annuity (a) given a discount rate (d) and the number of years over which the policy is expected to display its benefits (n) [40]:

3. *Present Value (a)*$= a*((1-1/(1+d)^{n})/d)$

Given that the clean-up of the industrial areas is expected to produce benefits only after a certain number of years the annuity must be discounted to account for the latency period l:

4. *Present Value (a)*$= a* 1/(1+d)^{l}*((1-1/(1+d)^{n})/d$

In the case of Gela and Pirolo the annuity *a* is equal to the product of the number of health outcomes averted by the policy intervention, Xa, and the WTP value for the health outcome λ. The formula can be re-expressed as follows [19]:

5. *Present Value of Benefits* $= Xa*\lambda*1/(1+d)^{l}*(1-1/(1+d)^{n})/d)$

There is uncertainty regarding the length of time over which a clean-up intervention will display its benefit. The permanence of clean-up depends on two elements: the intrinsic composition of the

contaminated site and the type of remediation technology adopted. For example, if the cheapest technology is implemented, e.g. capping the contaminated site, the benefit will last for the shelf-life of the cap [41]. Another important element to consider is how long it will take to observe a decline in the number health outcomes associated with contaminated sites (also referred as cessation lag). The duration of the cessation lag is likely to vary by type of health outcome (shorter for mild adverse events such as asthma and bronchitis, and longer for more severe events such as cancer). A recent US study assumes that four years after clean-up it is possible to observe a 20-25% decline in the number of congenital anomalies [42]. There is currently uncertainty regarding the type of clean-up technology to adopt in both sites. In order to facilitate comparison with previous studies the period of time over which policy benefits arise and the policy latency in the baseline scenario are assumed to be 50 and 20 years respectively [19]. Extensive one way sensitivity analyses have been performed to evaluate the robustness of the results to these model assumptions. Discounting plays a crucial role in determining the future monetary benefits/costs of environmental health interventions, especially for long-lasting health benefits (e.g.100 years). While there is a broad consensus that future costs and benefits should be discounted, there is little agreement on both the discounting model and the discount rate to use [43]. According to the discounted utility model (also known as the constant rate or exponential model) individuals' intertemporal preferences are time consistent [44, 45]. Although this model is generally used in economic evaluation, studies of animal and human behaviours generally show that individual preferences are dynamically inconsistent. Individuals tend to display higher discount rates over short time horizons and lower discount rates over long time horizons [45-48]. Such a relationship conflicts with the discount utility model's assumption of a constant discount rate, and is a characteristic of hyperbolic models. Despite the potential descriptive relevance of hyperbolic models they have rarely been used normatively in the evaluation of the consequences of environmental decisions and the discounted utility model remains the standard [40]. According to Gravelle and Smith, the majority of the studies use a discount rate ranging between 3 and 5%, and usually extensive one way sensitivity analyses are performed to assess results robustness to variation of discount rate [49]. In the present study the future health benefits are discounted using a constant 4% discount rate as recommended by

the European Commission [30]. The final step of cost benefit analysis is the selection of the decision rule to evaluate whether the intervention is worth-while [50]. The information on costs and benefits is combined in a single indicator the Net present Benefit (NPB):

6. $NBV=PVB-PVC$

Where PVB is the present value of the health benefits (averted deaths, hospital admission for cancer and non-cancer causes) and PVC is the present value of the cost of cleaning up industrial pollution in Priolo and Gela clean-up. If the NPB is positive the intervention is cost beneficial otherwise the clean-up option is not deemed socially worthwhile. NPB values can be also use to rank the clean-up of different sites within for example the Superfund budget and to prioritize those sites with higher NPB values [47].

2.5 Sensitivity analysis

2.5.1 One-way sensitivity analyses

Environmental health benefits arising from a pollution control policy are not marketable goods and as a consequence their value is highly uncertain. Univariate deterministic analyses were performed in order to estimate the impact of uncertainty on the results. To estimate the impact of the discount rate and to facilitate the comparison of the study findings with other European studies, analyses are presented using a 7% discount rate, as estimated by Alberini et al. [27] and 2% and 4% as recommended for cost-benefit analyses by the EC [30]. It is unknown whether or not the clean-up interventions that have been planned in Gela and Priolo will produce a permanent or a temporary reduction in pollutant exposure. According to Alberini et al. [27] different types of remediation policies would lead to different degrees of permanence of the health risk reduction. The number of years over which the risk reductions would be observed would be higher for permanent remediation compared to temporary remediation (contaminant containment interventions). It is also uncertain for how long the emissions of toxic compounds will last if clean-up and stricter controls are not undertaken.

Improvements in the technology adopted by the factories (for example the introduction of the SNOx chimney stack in the Gela ENI factory) and the closure of several highly polluting industrial plants (e.g. the closure of the Eternit factory that used to produce asbestos and cement) suggest a decline in the emissions in the two areas. The presence of landfills (e.g. a 8 million m2 landfill of phosphogypsum) and the lack of ordinary maintenance (e.g. several leakages of oil from refinery holding tanks have been discovered) are the cause of current emissions and they are likely to continue for a long time. Environmental data collected in Gela and Priolo reveal that the concentrations of several harmful substances exceeded the limits established by the law. For instance, in the groundwater of Gela arsenic concentrations reached the value of 250.000 μg/L versus the law established limit of 10 μg/L [11]. A study conducted in Michigan found that the ingestion of arsenic can be fatal even at very low concentrations [51]. In the absence of further releases of this toxic substance, its concentration in the Gela groundwater will decrease with time. But, it is uncertain how long it will take to reach levels safe for human health. In order to explore differences in time to failure of the remedies a one way sensitivity analysis was performed assuming three time frames: 10 years (for a contaminant containment intervention), 50 years and 100 years (for permanent remediation policies with long lasting benefits).

2.5.2 Probabilistic sensitivity analysis

To further explore uncertainty a probabilistic sensitivity analysis was performed. Probability distributions were assigned to important components of the analysis [34]. WTP estimates were sampled from a gamma distribution. Parameters of the gamma distribution were based on the standard errors obtained from the contingent valuation studies from which the WTP values were retrieved[28, 29]. A Uniform distribution was assumed for the discount rate value (upper estimate: 7% ; lower estimate:2%) and for the duration of the benefit (upper value:100 and lower value 10 years). A lognormal distribution was used for SHRs and SMRs. The CIs for SHRs and SMRs values were retrieved from the DOE study [10] .Using a Monte Carlo simulation 10,000 samples were generated

from parameter probability distributions[52]. The costs, the benefits and the expected net benefit were calculated for each simulation according to the following formula:

7. *Expected Net Benefit =EB-EC*

The results of the simulations were presented as a Cost-Benefit Acceptability curve (CBAC) using standard methodologies [53]. A CBAC shows the probability that a reclaim policy is cost beneficial for a range of clean-up intervention costs by plotting the proportion of simulations for which the net benefit of the remediation policy is positive for reclamation costs ranging from €127.4 to €12,000 million in Gela and from €774.5 to €4,000 million in Priolo. The lower bounds are the sums agreed to date for the clean-up of the sites. The higher bounds are the cost at which the clean-up has a zero probability of being cost beneficial. The opportunity cost and the effectiveness of a clean-up policy on pollution-related health outcomes are difficult to estimate a priori. In the case of Gela and Priolo remediation is still at an early stage and epidemiological evidence on the effectiveness of clean-up interventions is not yet available. In order to account for the uncertainty around the cost and the effectiveness of remedial interventions in the two areas four CBACs were constructed assuming different levels of remedial effectiveness (20%, 50%, 80% and 100% of the health outcomes will be averted). The lower is the effectiveness (percentage of health outcomes averted) the lower is the probability that the remedial intervention is cost beneficial. When more specific epidemiological evidence is available CBACs will allow policy makers both to gauge the cost effectiveness of interventions and to improve environmental site remediation through performance based environmental management.

3.Results

The health outcomes attributable annually to industrial pollution exposure in Priolo and Gela were estimated using data from Cernigliaro et al. [9]. As shown in Table 2.3, a reduction in exposure to environmental pollution in Priolo would avert 8 (2-11) premature deaths, 118 (85-151) -cancer related hospital admission and 692 (587-780) non cancer hospital admissions each year; while in Gela

would avert 39 (12-64) premature deaths, 163(134-192) cancer and 2,010 (1,912-2,095) non cancer hospital admissions each year.

Table 2.3 Annual health outcomes attributable to pollution exposure in Gela and Augusta-Priolo areas

	SHR(95%CI)[1]	**Annual Cases**	**SHR(95%CI)[1]**	**Annual Cases**
	Gela		**Priolo**	
Mortality				
Male	106 (102-109)	23 (8-35)	110 (102-118)	8 (2-11)
Female	105 (101-109)	16 (4-29)	NS	NS
Cancer hospital admissions				
Male	115 (110,5-119,7)	53 (38-67)	116 (111.6-119.8)	69 (53-85)
Female	127 (122,8-131,9)	110 (96-125)	110 (106.3-114)	49 (32-66)
Non cancer hospital admissions[b]				
Male	121 (119-122)	909 (864-952)	107 (105.7-107.7)	413 (360-482)
Female	124 (122-125)	1,101 (1,048-1,143)	104 (103.5-105.4)	279 (227-298)

1 SHR: Standard Health Ratio; b Number of hospital admission for all causes minus cancer-related hospital admissions

Assuming a 20 year cessation lag, a 4% discount rate and that the benefits will last 50 years the potential monetary benefit from abating industrial pollution in Gela and Priolo was estimated for each health outcome separately (Table 2.4).

Table 2. 4**.** Annual health outcomes attributable to pollution exposure in Gela and Augusta-Priolo areas (million€)

Item	Gela	Priolo
Population living in the area	105,543	85,749
All death	2,203 (247-3,933)	455 (41-676)
Cancer hospital admissions	4,248 (1,918-10,000)	3,072 (1,372-7,864)
Non cancer hospital admissions	149 (149-160)	53 (47-76)
Total benefit	6,639 (2,314-14,093)	3,592 (3,167-3,802

As expected, due to the many health outcomes each year associated with exposure to pollution the potential monetary benefit of site remediation in Gela and Priolo is high. In Gela it ranges between €2,314 million (the low SHR and low WTP scenario) and €14,093 million (the high SHR and high WTP scenario), with €6,639 as baseline value. In Priolo, where the health outcomes, and in particular the number of premature avoidable deaths are lower, the potential monetary benefits of site remediation would be €3,592 million (3,167-3,802).

Given the predicted cost of clean-up policies in the two areas, €774.5 million in Priolo and €127.4 million in Gela, the potential net monetary benefits of reducing industrial pollution exposure were estimated to be €2,817 and €6,521 million respectively. This implies that if the pollution control policies that have already been identified are not effective in reducing the impact of pollution exposure on health, it would be worth spending up to €6,521 million in Gela and €2,871 million in Priolo on a completely effective reclamation.

Extensive one way sensitivity analyses were performed to assess the robustness of study findings to parameter uncertainty.

Table 2. 5. Net benefits (million €,2009 values) by time horizon over which the benefits accrue each year.

	100 year time	**50 year time**	**10 year time**
Gela			
7% discount factor	2,364 (1,332-3,305)	2,287 (1,285-3,193)	1,094 (591-1,562)
4% discount factor	7,403 (2,512-15,936)	6,474 (2,187-13,965)	2,365 (1,340-3,306)
2% discount factor	13,116 (7,667-18,187)	9,529 (5,556-13,226)	2,632 (1,497-3,689)
Priolo			
7% discount factor	576 (417-656)	528 (378-608)	-99 (-170;-53)
4% discount factor	3,419 (2,948-3,672)	2,806 (2,393-3,027)	613 (458-697)
2% discount factor	6,602 (4,091-8,253)	4,464 (2,592-6,077)	722 (239-1,107)

In Table 2.5 the net benefit of pollution control policies are reported assuming different time horizons for the benefits and different discount rates. Given an estimated cost of €127.4 million of reclaiming the area, the potential benefits are always higher than the cost in Gela, while in Priolo when benefits are discounted at a 7% discount rate, as suggested by Alberini et al. [27] the pollution control interventions are not cost effective if the benefits arising from the remediation only last 10 years.

Figures 2.2 and 2.3 report the probabilistic sensitivity analyses for Gela and Priolo respectively. The interpretation of the CBACs is straightforward. The different curves displayed in Figures 2.2 and 2.3 shows the probability of the intervention being cost-effective for different levels of effectiveness. The highest curve (e.g. the green curve in the case of Priolo) is for interventions that managed to prevent

100% of the health outcomes. Alternatively, the lowest curve shows the probability of an intervention that prevents only 20% of the environmental hazards associated health outcomes. For example, in Priolo a remedial intervention with low effectiveness (preventing only 20% of health outcomes) is unlikely to be cost effective if it costs more than €700 million. As expected in Gela, pollution control policies are more likely to be cost beneficial even for high clean-up costs. In this area, assuming that 100% of the health outcome attributable to pollution will be averted a pollution control policy costing €7,000 million has 50% probability of being cost beneficial. In Priolo, on the other hand, a pollution control policy costing more than €3,000 million is unlikely to be cost beneficial even if all the negative health outcomes attributable to industrial pollution exposure were to be averted.

Figure 2.2 Cost Benefit Acceptability Curves of Priolo clean-up assuming different remedial effectiveness.

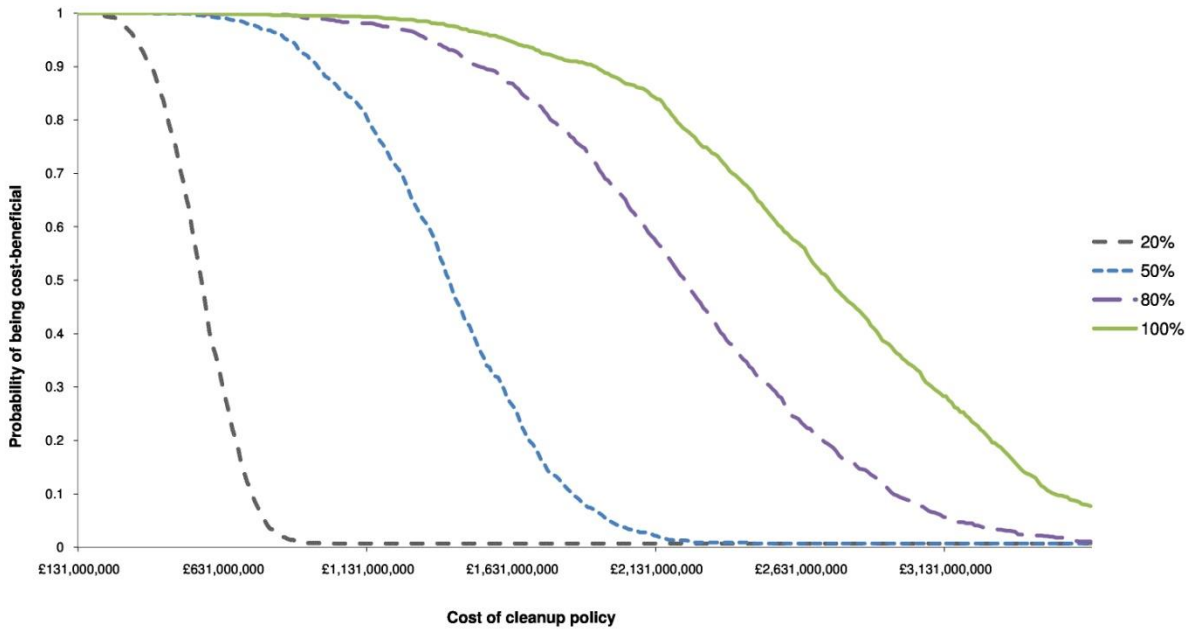
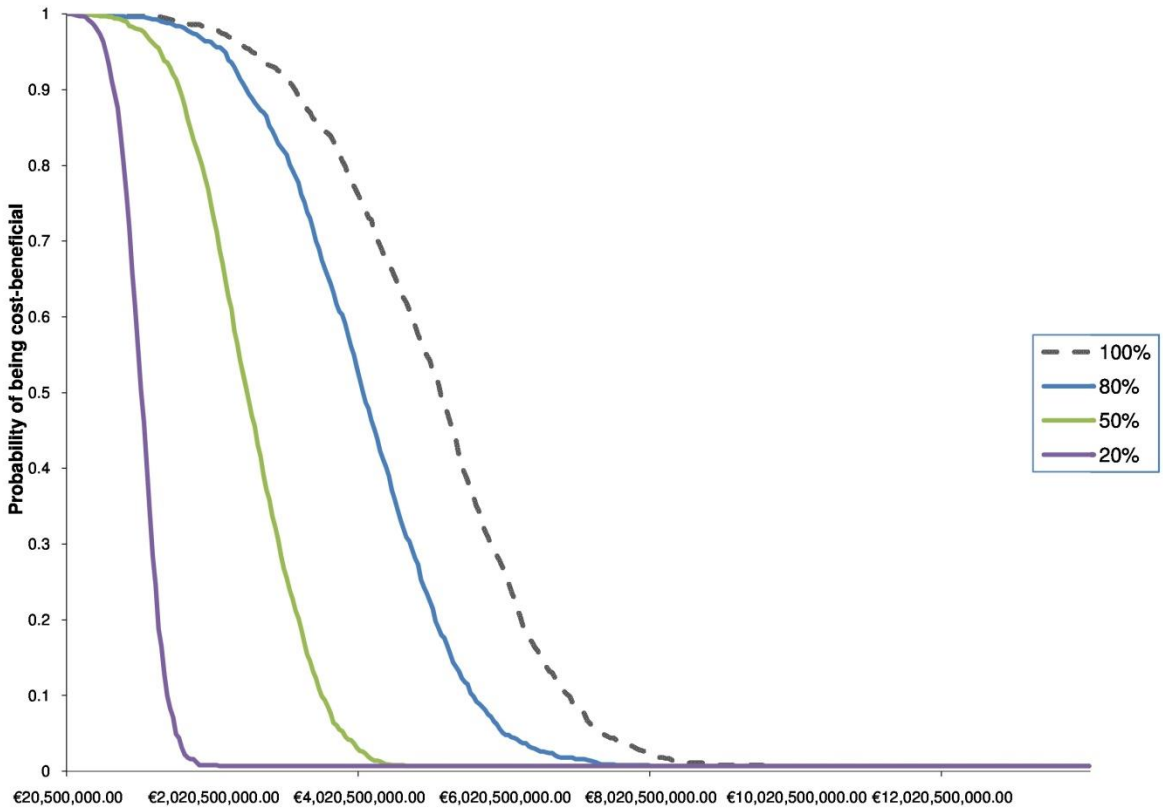


Figure 2.3 Cost Benefit Acceptability Curves of Gela clean-up assuming different remedial effectiveness.



4.Discussion

Assuming the excesses of standardized mortality or hospitalization ratios were attributable to environmental pressures documented in the areas, avoidable cases were estimated using regional health statistics [9,10]. Although these data are currently collected and controlled through standardized methods for epidemiological and public health purposes some limitations should be considered the existing studies design does not allow to assessing the causal relationship between industrial pollution exposure and health. However it should be noted that the proportions of deaths and non-fatal cancers attributed to the environment are comparable to those suggested by WHO and other authors [1,3]. Using epidemiological evidence from the DOE study this economic evaluation quantified the number of health outcomes attributable to industrial pollution exposure in the two areas of Priolo and Gela[9]. The present study suggests that, 47 premature deaths, 281 cancer related hospital admissions and 2,702 non-cancer hospital admissions could be avoided each year by

removing the environmental exposure of the communities in these two areas. Given the potential health benefits, the estimated monetary gain of an effective pollution control policy would be €3,592 million in Priolo and €6,639 million in Gela. The cost of removing contamination from the two sites is uncertain. To date, the cost of the clean-up interventions planned by the Ministry of Environment [35-37] are €774.5 million and €127.4 million for Priolo and Gela respectively. If these were the true costs of clean-up, then the net monetary benefits arising from clean-up would be extremely high. If on the other hand, further investments are necessary to avert pollution related health outcomes, this study suggests that any further intervention costing less than €2,817 million in Priolo, and €6,521 million in Gela would be cost effective (the benefit outweighs the cost). The study has strengths and limitations. This analysis used only WTP estimates based on CV studies to determine the potential benefits of averting morbidity and mortality arising from pollution control policies. WTP is preferred to cost of illness because it takes account of all the costs associated with a given health effect (e.g. suffering, loss) and thus provide a better estimate of the potential benefits [54]. A further strength of this study is that it allows for differences in WTP for different health effects. In order to account for the cancer premium, the benefits of averting non-fatal cancers and hospital admissions were evaluated separately. A further advantage of this study is that it uses probabilistic sensitivity analysis to address simultaneously uncertainty regarding the parameters of the model. For the first time, in the context of environmental cost benefit analysis, this work used cost benefit acceptability curves in order to capture the uncertainty around the estimated net benefit and to show the probability that intervention will be cost beneficial, given a range of clean-up policy costs and different degrees of effectiveness of remedial interventions. Nevertheless, there are several limitations to the study. It was assumed that the excess mortality, cancer and non-cancer hospitalization are attributable to the environmental pressures, that represent the main difference between the study areas and the reference areas (not only the whole Sicily region but also a limited number of neighbouring municipalities) [9]. The absence of studies with an analytical design that would provide better evidence of the causal relationship between environmental pressure and health is a limitation for the present analysis. Extensive deterministic and probabilistic sensitivity analyses were conducted to address this element

of uncertainty. For example, this study provides only a partial estimate of the overall benefit obtainable with the clean-up of the two contaminated sites in Gela and Priolo. Excess congenital malformations, mainly uro-genital anomalies and particularly hypospadias, in these areas suggest a plausible association with exposure to documented pollutants [55, 56]. However, because there are no conclusive etiological studies, or studies estimating the WTP to avert cases of congenital malformation these potential benefits were not included. Furthermore, the analysis excludes the potential benefits for the ecosystem related to increased agricultural and fishing productivity and also the increasing quality of environmental resources such as rivers and ground waters and the sea [52]. Finally, although results were presented separately, in terms of average, high and low estimates, it was not possible to adjust the WTP values for characteristics of the Gela and Priolo populations (e.g. income and education) and by the nature of the clean-up interventions (e.g. temporary versus permanent) [28,27]. In 1993, President Bill Clinton's executive order 12866 established that government and private parties should be fully informed about the costs and the benefits of regulatory options [57]. While a significant volume of work has evaluated the cost effectiveness of air pollution regulations; cost effectiveness analysis has rarely been used to prioritise contaminated sites and select clean-up interventions [55]. As long as the true benefits of clean-up interventions are unknown it will be impossible to allocate efficiently the limited funds available.

In 1998, law 426/98 established Priolo and Gela among the first 15 Italian sites included in the National Reclaim Program [58]. Nevertheless, the damage caused to the environment and the impact on human health by industrial pollution has yet to be fully assessed sufficient to address the complete continuum of public health, from pollutants emission to human exposure to disease [57]. In this situation where "facts are uncertain, values in dispute, stakes high and decisions urgent" Funtowicz and Ravetz , it is very difficult to reduce the uncertainties, for example, regarding causal mechanisms in environmental health, consequently it is necessary to accept uncertainty and move forward[59]. The present study proposes a methodology for the economic evaluation of the health effects of environmental pollution and can contribute a basis for the prioritisation of interventions. This study

suggests that clean-up policies costing up to €3,592 million in Priolo and €6,639 million in Gela would be cost beneficial. Given the cost of the planned clean-up interventions -€127.4 million in Gela and €774.5 million in Priolo these results suggest that if additional spending was required in order to eliminate the impacts on health, as long as the total expenditure required was less than €6,521 million in Gela and €2,871 million in Priolo, reclamation would continue to be a cost-effective investment.

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Section 2

Based on the welfare economics principle of consumer sovereignty, children are the best judges of the value of reductions in the risks that they face. Nevertheless, previous authors have suggested children might be unable to value changes in their own health risk reduction because they do not possess the necessary cognitive abilities to be considered rational decision makers. On this basis, they are usually not considered able to understand health risks, and are also thought incapable of making trade-offs between income and health risk reductions. Moreover, it has also been suggested that, compared to adults, children are not aware of budget constraints, and that they also lack the financial resources "to purchase" health risk reductions. However, there are few studies that actually investigate whether children have sufficient cognitive abilities to understand health risk. There is also a significant body of literature in the psychology domain showing that children's understanding and use of money develops from younger ages and increases significantly as children grow older. Understanding health risk and the use of money is indeed essential to provide reliable WTP estimates. The aim of the present section is to investigate whether children (aged 6 to 13 years) are able to understand health risk and money related concepts such as, budget constraints and the use of change when making purchases. The third objective of this section is to investigate children's use of money. Since WTP is bounded to an individual's budget constraint, it is critical to identify how much the individuals can afford to pay for a given health risk reduction when conducting a WTP experiment. In WTP experiments conducted with adults, annual income is usually considered as a variable for deciding the range of possible WTP values to be elicited (individuals cannot offer to pay more than what they earn). Similarly, in the case of children, it is important to estimate their available budget as this will allow analysts to establish the range of WTP values for use in subsequent stated choice experiments described in section 3.

Research Paper 2. If we tell children about their health risks will they understand?

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Status: To be submitted to Risk Analysis

Contribution: CG led the conception of the research question, designed the experiments, carried out the data collection under the supervision of JC. The data analysis was performed by CG (First Experiment) and MS (Second experiment). The candidate wrote the first draft of the manuscript. LC, AB and FB contributed to design of the questionnaire and provided critical inputs to the interpretation of the results. CG managed each round of comments and suggestions from the co-authors, in collaboration with JC. All the authors read and approved the final draft prior to inclusion in this thesis.

The candidate _____ The supervisor John Cairns

3.Chapter

1. Introduction

Understanding health risk is a necessary (but not a sufficient) condition for children to provide reliable willingness to pay estimates for their own health risk reductions [1]. It is commonly thought that children (of all ages) are unable to grasp information related to their own health [2].Given that adults are responsible for their children, establishing whether or not children understand health risk is commonly consider an unimportant question. For instance, a study on genetic risk communication within families showed that parents believe that is better for children to delay discussion about the genetic condition affecting their family as long as possible [3]. Nevertheless, children, even the younger ones, often make decisions about their health autonomously. Therefore helping them understand the consequences of their decisions may have important consequences for their health. Children suffering from food allergies, for example, need to understand why they have to refuse specific food when it is offered to them in such situations (in which the parent is not present) as at school, during holidays or during social occasions [4]. For children receiving treatment (e.g., after organ transplantation), understanding the seriousness of the risks associated with health conditions and the benefits of the treatment can influence their adherence to treatment regimens [5]. Finally, communicating health risk effectively to young individuals can also decrease the likelihood of them engaging in risky behaviours such as crime, smoking, drug and alcohol consumption. According to Reyna and Farley, the likelihood of adopting risky behaviours starts during early adolescence, increases over time during adolescence and then decreases with aging [6]. Thus, targeting effective health risk communication during pre-adolescence may be a powerful prevention tool. Despite the importance of communicating health risk to children and pre-adolescents, no study has measured

either their ability to understand health risk information or the most appropriate aids for use in communicating health risk information to this target age group.

Understanding probabilities is essential to the comprehension of health risk information. Different theories have been proposed to explain the development of probability thinking in children. According to Piaget and Inhelder's theory, there are three stages of understanding in young people: between 4 and 7 years, children have no understanding of chance and probability concepts; between 8 and 10 years they start developing these concepts, of which they become fully aware only in the third stage, when the individual is aged 11 to 12 years [7-9]. In contrast to the Piagetian logicism, the fuzzy trace theory, suggests that intuition and informal reasoning are present even in younger children. There is an increasing body of research confirming the theory of children's intuitive understanding. This research shows that young children are able to make judgments about risk information and also to use risk information in decision making [10, 11]. A study investigating pre-schoolers' ability to complete probabilistic tasks correctly showed that children aged 4 to 6 are able to identify the most likely outcome, and that they also understand the concept of randomness [11]. Most recent studies have also shown that young children show intuitive understanding of complex concepts, such as expected value, and that they are able to use posterior information to make judgements about random outcomes and to make probabilistic decisions [12, 13]. For instance, Denison et al. showed that infants as young as 12 months are able to use probabilistic information to make decisions suggesting that humans may have an innate ability to make probabilistic inference [14].

The objective of the current study is to test health risk understanding in children. According to Feldman-Stewart et al. when applying health risk information to medical decisions, patients often need to perform two tasks: A gist task, which is defined as the ability to identify "the essential meaning" of the risk information (e.g., to identify which of the two treatments displayed is associated with the lower risk of side effects), and a verbatim task, which represents the ability to correctly report, using the information provided, the actual benefits and/or risks of the interventions presented (e.g., if 100 individuals were randomized to treatment B how many will experience the side effects) [15, 16].

The present study is composed of two experiments. The first experiment aims to test the efficacy of two types of visual displays in communicating gist information to children aged 7-13. There is paucity of studies investigating the best way to communicate health risks to children. The study conducted by Ulph et al. tested the effect of different probability formats (pie chart, verbal label, percentage and proportions) on children's risk comprehension[17]. Ulph et al. found that pie charts produced the highest proportion of correct answers (84 %)[17]. However, the study did not test understanding of health risk.

The use of colour and visual representations of the health outcomes might be important in attracting the attention of children, thereby increasing their concentration while considering several alternatives. As with adults, the best type of visual aid to adopt with children may depend on children's characteristics such as their numeracy skills or their language fluency and their school curricula. For example, in Italy histograms and pie charts are first used in the fourth elementary grade (when children are 8-9-year old). The first experiment described in this study developed and compared two visual aids specifically designed to communicate health risk, which were suitable to be used across the age range considered. The first visual aid involved comic characters; a second, more abstract, visual aid was a pictograph displaying human figures.

Experiment 2 was aimed at extending previous research by examining children's understanding of health risk. In the health context, the goal of communication generally involves the comparison between absolute risk magnitudes[18]. For example, the absolute risk of experiencing side effects with different types of treatment. However, another common goal of risk communication involves communicating changes in absolute risk given baseline health risk. For example, the change in risk of symptoms following an intervention or the increase in the likelihood of experiencing health conditions due to the adoption of a risky behaviour [18, 19]. It is also investigated whether the relative size of health risk influences children's ability to comprehend risk information[20].

2.General Method

Two experiments were conducted to investigate children's comprehension of health risk information. The first experiment explored children's health risk comprehension by comparing two different visual aids, namely, a comic visual aid and abstract visual aid. The second experiment tested children's understanding of absolute health risk, following the results of the first experiment.

The same group of children took part in both experiments, with the exception of those children who were absent from school on one of the days of the experiment.

The sample of children involved in the study was homogeneous in terms of school performance, socioeconomic status and exposure to environmental hazards. All children included in the sample were eligible for free meals; and, living close to the school, they were exposed to the same environmental hazards. From a preliminary discussion, it emerged that the majority of children interviewed were familiar with the symptoms associated with the medical conditions mentioned in the experiment and were not intimidated/scared during health risk communication. The school performance of the children in the sample was in line with regional trends.

2.1 Participants

The study was conducted in Naples (Italy), a city with serious air pollution problems[21]. The study involved children from a school, the Bovio-Coletta school, located in one of the most polluted districts in the city centre of Naples (San Lorenzo). In previous studies, eligibility for free school meals has been used as a measure of disadvantage [22]. All the children included in the study were eligible for free meals, and some children belonged to first or second-generation immigrant groups who did not speak Italian at home. All the children involved were enrolled in regular school programs; none had any intellectual, visual or auditory impairment. Children with known learning disabilities whose parents gave consent to their participation were asked to complete the questionnaire with their classmates, but their answers were excluded from the analysis planned for the present study. Students' average school performance was in line with regional (Campania) trends. Pupils were

assured that their answers were anonymous and strictly confidential, and would not be assessed by their teacher or recorded by the school.

2.2 Ethics

The research received ethical approval from the National Research Council (Italy) and the London School of Hygiene and Tropical Medicine ethical committees. Informed written consent and informed assent were obtained from parents and children, respectively.

2.3 Experiment 1

Both visual aids used in the experiment were designed by a comic designer together with a team of experts, using feedback from the children. As illustrated in Figure 3.1, the numerator of the comic visual aid is the depiction of a sick child (a child suffering from a cold) while the denominator uses a class as a unit of measure (in the legend it is specified that each class is composed of 25 pupils, which is the average class size in Italy). Studies conducted with adults reported that individuals with low numeracy skills, find it easier to recall medical risks if these are expressed in ratios involving small denominators than large denominators [23, 24]. Preliminary discussion with children indicated that even the younger ones use the class as a unit of measure and know that each class is composed of 25 pupils on average. Thus, it was expected that children who received the comic visual aid would be more accurate in grasping the denominator by just counting the classes displayed in each of the alternatives presented (see Figure 3.1 A). The abstract visual aid is a pictograph using human figures all of the same size, but with different colours (blue for healthy and red for sick) (see Figure 3.1 B). Fagerlin et al. and Burkell suggest that pictographs are the best format when the task requires the respondent to estimate the magnitude of different risks[25, 26]. Previous studies conducted with adults who show poor numeracy skills suggested that pictographs with highlighted icons indicating sick patients were more effective in communicating health risk as compared with other formats, such as bar charts, histograms, pie charts and risk ladders [16, 20, 27, 28]. There is no conclusive evidence about the best type of pictograph (e.g. ovals, asterisks, smiley faces and human figures) to use with adults in order to inform them about health risk [29]. For example, Stone et al. found no differences in

the behaviour of individuals who were shown asterisks or faces in a pictograph [30]. A qualitative study conducted by Shapira et al. found that women prefer pictographs with human figures as they are more meaningful and easier to understand compared with continuous probability format using bar charts [31]. Furthermore, we expected human figures to be more attractive compared to other types of icon arrays such as dots and squares and thus more effective in catching younger pupils' attention. As shown in Figure 3.1 B, the sick figure was always placed at the bottom right corner in both alternatives.

The questionnaire was administered in class. During a preliminary conversation, pupils were encouraged to consider the relevance of their answers by emphasising the research aims and the need to provide better information to children/adolescents by involving them in the decision making process. Then, pupils were assigned randomly to one of the two versions of the questionnaire: the comic visual aid or the abstract visual aid. The two visual displays being tested are shown in Figure 3.1. The same gist question was asked in both of the visual display formats: "In which of the two examples, A or B, is it easier for the child to become ill?". The numerator was held constant (1) while the denominator was 75, in one option (A) and 600 in the alternative (B). Both types of visual aid presented two possible choices (A and B) while the answer framings were held constant in the two versions in terms of boxes position (See Figure 3.1). Children were asked to put a cross in the box corresponding to their answer.

2.3.1 Analyses

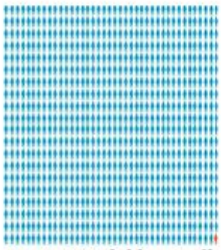
Statistical analyses were performed using STATA 12. Children's answers were coded as correct or incorrect. Children were divided into two age groups: childhood (7-9 years) and pre-adolescence (10-13 years)[6] . The percentage of correct answers by age, gender, and visual aid used were estimated. Next, a logistic regression model with correct answers as a binary dependent variable was used. Type of visual aid was included as a binary independent variable; age and were included in the model. Results from the logistic regression were presented as Odds Ratios with 95% CIs.

Figure 3.1. Questions used in Experiment 1

A. Comic Visual Aid

	Question: In which of the two examples a child is more likely to get ill?
Alternative A	 **One child in 24 classes is ill**
Alternative B	 **One child in 3 classes is ill**

B. Abstract Visual Aid

	Question: In which of the two examples a child is more likely to get ill?
Alternative A	 **One in 600 children is ill**
Alternative B	 **One in 75 children is ill**

2.3.2 Results Experiment 1

As shown in Table 3.1, there were more children assigned to the comic visual aid and overall more males than females participated in the study for both the age groups considered. Overall, 57 males and 45 females participated in the study. Only three children did not reply to the questionnaire and their data were removed from the analysis. Table 3.2 reports the number and the percentage of correct answers by visual aid, age and gender. The number and percentage of correct answers, independent of the visual aid used, was high even for the younger age group (66% correct answers in 7-9 year olds). The differences between the percentage of correct answers by age group was not statistically significant (Chi square test: 0.3437, p=0.558). As expected, there was no significant difference

between males and females regarding the number of correct answers (Chi square test: 1.7952 p= 0.180) while the number of correct answers by visual aid was statistically higher for the abstract (Chi-square test:4.6775, p= 0.031). The logistic regression confirms the descriptive analysis suggesting that independently of age and gender, children who were asked to respond to the question with abstract visual aid were more likely to provide a correct answer. Children's characteristics, such as age and gender, do not appear to be related to their ability to answer correctly, irrespective of the type of visual aid adopted.

Table 3.1. Samples profile (N of the children sample = 102).

Variables	***Gender***		***Visual aid***	
Age	***Female***	***Male***	**Comic**	**Abstract**
7-9 years	20	33	27	26
10-13 years	25	24	27	22
Total	45	57	54	48

Table 3.2. Number and percentage correct by age, gender, type of visual aid.

Variables	***Number (%) Correct Answers***
Age	
7-9 years	35 (66%)
10-13 years	35 (71%)
Gender	
Female	34 (75%)
Male	36 (63%)
Type of visual aid	
Comic	32 (59%)
Abstract	38 (79%)

Table 3.3. Logistic regression modelling

	Odds Ratio(S.D.)	***95%CI***	***P value***
Constant	0.67(0.51)	0.15-2.93	0.599
Type of visual aid	2.76(1.27)	1.13- 6.79	0.026
Age	1.23(0.55)	0.51- 2.97	0.640
Gender	0.53 (0.24)	0.21-1.31	0.168

S.D. Standard Deviation

2.4 Experiment 2

In the second experiment, we tested children's gist understanding of absolute health risk and change in absolute risk. Each child was asked to complete a pencil and paper questionnaire. In order to avoid

anxiety about their own health and personal involvement in the questionnaire, the decision making task was presented as a game in which each child was asked to take decisions on behalf of a fictitious character: Jack. Jack, a child living in a city abroad with serious pollution problems, was designed specifically for this study by a comic designer and was introduced to the children on the first page of the questionnaire (See Figure 3.2).

Figure 3.2. Experiment 2 Preliminary description

Jack is a boy living in a very polluted city. Because of air pollution he wants to move to a new city that is better for his health. Help Jack deciding in which city to go!

The health risks mentioned in the study were those associated with three medical conditions: asthma, bronchitis and allergy. These three medical conditions in terms of symptoms and severity were displayed to the children by means of graphic pathographies before starting the questionnaire (see Figure 3.3)[32].

Figure 3.3. Example of graphic pathography used to describe an asthma attack

The first five questions investigated children's understanding of absolute health risk (See Figure 3.4 A). Three tasks tested children's understanding of "high" absolute health risk (risk ≥ 1%) and two tasks tested children's understanding of "low" absolute health risks (risk ≤ 1%).

The last five questions investigated children's understanding of changes in absolute health risk (See Figure 4.B).

As shown in Figure 3.4, only the abstract visual aid was used for Experiment 2, given the results of the first experiment.

In each task, gist understanding was tested using three questions. First, children were asked to indicate which option, A, B or C, was the best for Jack's health. Next, the children were asked to justify their answer in order to reduce the likelihood of guessing. Third, the children were asked to indicate the worst option for Jack's health. The details of the questions asked in the experiment are reported in Appendix.3.

Individual information on children's graph understanding and numerical literacy before the study was not collected. However, post-hoc interviews with teachers and carers established that all the children included in the sample had normal or above normal numerical skills.

2.4.1 Analyses

All data entry, validation, and statistical analyses were performed using SAS software (SAS version 9.2). Percentages of correct answers are reported separately by age, gender and type of questions (absolute risk and change in absolute risk). Mean difference in percentage of correct answers for absolute risk, change in absolute risk and for high and low absolute risk questions were compared using Wilcoxon Signed-Rank Tests.

Multivariate Poisson regression analyses were performed to identify covariates influencing health risk understanding.

Figure 3.4. Example of questions used in Experiment 2

A. Absolute risk question example

	Alternative A	Alternative B	Alternative C
	In City A **1 in 50** children has an asthma attack because of air pollution 	In City B **1 in 30** children has an asthma attack because of air pollution 	In City C **1 in 25** children has an asthma attack becasue of air pollution 
1.1.1	Which aleternative is best for Jack's health?		
	A B C		
1.1.2	Why did you suggest him that aleternative?		
1.1.3	Which alternative is the worst for Jack's health?		
	A B C		

B. Change in absolute risk example

		In the town when Jack currently lives **1 in 25** children has an asthma attack 	
	Alternative A	Alternative B	Alternative C
	In Town A **1 in 4** children has an asthma attack because of air pollution 	In Town B **1 in 100** children has an asthma attack because of air pollution 	In Town C **1 in 50** children has an asthma attack because of air pollution 
1.1.1	Which aleternative is best for Jack's health?		
	A B C		
1.1.2	Why did you suggest him that aleternative?		
1.1.3	Which alternative is the worst for Jack's health?		
	A B C		

2.4.2 Results Experiment 2

Overall 113 children took part in the study, 65 (57%) females and 48 (43%) males. In order to have a fairly balanced sample in terms of gender and age, children at the intermediate level (11-13 year-olds) were grouped together (Table 3.4). The mean number of correct answers increased monotonically with age from 45% (average number of correct answers to absolute and change in absolute risk questions) at the age of 7 to an average of 82% for the age group 11-13 year old (Table 3.5). The increase is steeper for younger ages and seems flatter for older pupils.

The difference in the percentage of correct answers between genders was not statistically significant. In accordance with the study hypothesis, understanding of low absolute risk (≤1%) was poorer than understanding of high absolute risk (≥1%). The difference in the percentage of correct answers (85% for high absolute risk questions vs. 75% for low absolute risk question) was highly statistically significant (p value <0.0001).

Table 3.6 presents the mean number of correct answers for each gender and age. Results from multivariate Poisson regression confirm preliminary findings that there are no differences in understanding of probability between males and females, as in both cases the rate ratios were not statistically significant (p>0.05). There was no difference between the performance of 7 and 8 year olds (risk ratio: p value<0.05) and between second and third elementary grade, but once the children turn 9 there is a statistically significant increase in the number of correct answers. A linear trend (p=0.0001) for age indicates an estimated increase of 7% in correct answers as age increases by one year.

Table 3.4. Sample description(N of the children sample = 113)

Age	***Male***	***Female***	***Total***
7 years	*7*	*10*	*17*
8 years	*12*	*7*	*19*
9 years	*10*	*19*	*29*
10 years	*8*	*13*	*21*
11-13 years	*11*	*16*	*27*

Table 3.5. Percentage of correct answers by age and question type

Age	*Absolute risk*	*Change in absolute risk*
7 years	52.44	45.00
8 years	55.79	65.96
9 years	68.28	60.00
10 years	70.19	59.41
11-13 years	78.36	84.96

Table 3.6. Poisson regression analysis results, model including age, gender and total number of correct answers as depended variable

Variable	*Coefficient*	*S.E.*	*Rate Ratio*	*P value*	*95%CI*
Male (vs. Female)	0.001	0.048	1.00	0.998	0.91-1.10
8 years (vs. 7 years)	0.135	0.090	1.14	0.134	0.96-1.37
9 years (vs. 7 years)	0.188	0.081	1.,21	0.021	1.03-1.42
10 years (vs. 7 years)	0.196	0.087	1.,22	0.024	1.03-1.44
11-13 years (vs. 7 years)	0.305	0.081	1.36	0.001	1.16-1.59
Trend			1.07	0.000	1.03-1.11

S.E. Standard Error

3. Discussion

The results of the two experiments reported here provide further evidence of the ability of children to understand health risks. The first experiment explored whether the use of different visual displays affected children's comprehension of health risk. According to the fuzzy trace theory, even younger children may interpret risk correctly and may be able to identify the alternative with higher risk irrespective of the visual display used [7, 33].The results of the present study showed that the more schematic display showing systematic pictographs was more effective than the attention-grabbing comic display. The children who responded to the abstract visual aid questionnaire were almost three times more likely to provide correct answers. These results are consistent with the findings of previous studies conducted with adults, which suggest that the format used for risk communication affects the ability to understand risk information [34, 35] . As for adults with low numeracy skills, this study suggests that the use of systematic pictograph with human figures would enhance gist understanding among children[15, 36, 37].

The second experiment investigated children's understanding of health risk. In accordance with the intuitive theory, the results suggest that the majority of children, including children as young as 7, can comprehend health risk. However, there are significant differences between ages. Younger children, for example, answered 50% of questions correctly while older children answered almost 80% correctly. The age gradient was also confirmed by the regression analysis, in which age had a statistically significant correlation with the number of correct answers. The results suggest that the understanding of probability increases proportionately with age. It is worth noting that there is not a statistically significant difference between the performance of children within the younger groups (children aged 7-8), since it is only when children reach 9 years, and/or move to the fourth elementary grade, that there is an increase of health risk understanding [8, 38].

A previous study of adults understanding of health risk showed that low probability events were more difficult to interpret for individuals with low numeracy skills irrespective of the visual display adopted (pictographs or bar charts)[20]. According to Harbaugh et al. study, which investigated children's and adults' choices over small and large probability gains and losses, children tend to underweight risk, as compared to adults, when the probability is low[39, 40]. Conversely, they overweight high probability risks. However, little is known about study children's ability of understanding probability in the context of health risk. In line with results from adults with low numeracy skills, this study found that children and pre-adolescents had more difficulty understanding low probability health risks[20].

Although further research is needed to establish the generalisability of these findings, the experiments reported here represent an initial attempt to expand on knowledge regarding the ability of children to understand health risk.

In addition to the applied visual aid, another factor that may have influenced the ability to understand health risks is the numerical format. The numerical formats used in previous research, such as rates, percentages and proportions have been shown to influence adult health risk understanding and risk perception. However, it is now clear that any single format is better than any other and that the

optimal format depends on the task required and also on the characteristics of the respondent. Cuite et al., in testing the effects of different formats, found that using percentages aided respondents in performing addition, sequence and triple operations, while the 1 in X format was significantly better than the other formats for comparisons but it was worse in all other types of operations[41]. The format used has also been shown to influence risk perception. According to Pighin et al. if the 1 in X format is used, individuals perceive the health risk as bigger and more alarming[42]. However, the same study also shows that the 1 in X format effect disappears if, as in this study, this format is used together with visual aid. Little is known about the effect of different formats on children's understanding of probability. In the present study, we asked children to compare absolute risks and changes in absolute risk with the use of pictographs consistently using the 1 in X format. However, given previous evidence with adults, it is possible that the choice of the 1 in X format has influenced children's ability to compare different health risks. Further research is certainly required to investigate to what extent the format used to communicate risk with and without the use of visual aid affects children's ability to understand health risks. The present research may represent a first step toward a more sophisticated comprehension of this fundamental issue.

4.Conclusion

The results of this study support and extend previous knowledge about children's understanding of health risk. Consistent with the results of earlier studies conducted with adults, the results of this study show that displaying health risk using systematic pictographs enhances the assessment of health risk on a gist task. In accordance with the fuzzy trace theory, this study has also shown that even children as young as 7 are able to provide accurate answers to health risk questions and can therefore understand health risk [33]. The study also indicates that there is no difference between boys and girls in the accuracy of health risk understanding, but that the ability to understand health risk increases with age. In particular, it was found that there is a significant increase in the degree of risk understanding when children reach the age of nine.

It is difficult to establish an a priori threshold for the age from which it becomes possible to elicit WTP estimates directly from children. Previous willingness to pay studies show that even adults experience difficulties in grasping concepts about their own health risks. In a contingent valuation study conducted by Krupnick et al. 12% of the respondents choose the "Wrong person" when asked which person 1 or 2 was at higher risk of death (risks were presented using coloured squares scattered over a grid)[43]. The objective of this piece of work was to provide preliminary evidence on the ability of children to grasp health risk information and to provide reliable (e.g. scope-sensitive) answers to willingness to pay questions. From this study we may infer that the ability to understand risk information, when provided with appropriate visual aids in willingness to pay questions will be likely to increase as children get older. Given that health risk comprehension varies according to the characteristics of the presented task, the type of visual aid applied and also the respondents' characteristics, investigating the differences between levels of adults and child comprehension would require the application of the same experiment on children of different ages compared with a representative sample of parents. However the comparison of adult and child levels of health risk understanding is an interesting question for further research, not an aim of the present study.

This research tested children's gist understanding. Future work in the area needs to consider the possible effects of children's characteristics (e.g. socioeconomic class, language and numeracy proficiency) on the ability to understand both gist and verbatim risk information. Future research could investigate the effectiveness of a wider range of formats (bar charts vs. pie charts. vs. numbers) in communicating gist and verbatim tasks to children.

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Research Paper 3. Understanding and use of Money among children. Evidence from the South of Italy.

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Contribution: CG led the conception of the research question, designed the experiments, carried out the data collection under the supervision of JC. The candidate also performed the data analysis and drafted the manuscript, with help from JC. Both authors read and approved the final draft prior to inclusion in this thesis.

The candidate _____ The supervisor John Cairns

4.Chapter

1.Introduction

As for risk understanding, the ability of children to understand concepts related to the use of money, e.g. budget constraint, is a necessary prerequisite for understanding questions regarding willingness to pay. According to previous, authors child perspectives on willingness to pay questions are illusive because children "are not fully aware of the budget constraint to which they are subject and they have not control of the financial resource required"[1].

According to Calvert, children influence family buying decisions over a broad range of goods and services, including cars, vacations, and meals [2]. Young children regularly receive money from their parents; they earn money; and, especially in low income countries, they significantly contribute to household income [3-5]. Despite children's influence within the household, economists have paid sporadic attention to account for young people's understanding and use of money [6, 7].

In the household behavioural model, young children are considered bystanders [7]. Even where collective models are used in place of a unitary model to account for individual household members' preferences, the role of children is incorporated in the model thorough parents' "caring preferences", or in respect to the public goods children consume[7-9]. Economists justify the exclusion in two ways: children lack preferences for their own consumption, and they also lack the financial autonomy to buy what they prefer [7, 10]. To date, only one study has tested this hypothesis. Douphin et al. argued that children aged 16 and over contributed significantly to household decision making processes, and were also decision makers within the household[6].

The objective of the present study is to provide additional evidence about the understanding and use of money among Italian children aged 6-13. The study demonstrates that children have both the ability to understand and use money and, through parental allowances and presents, also have some control over financial resources.

The study consists of two parts. The first part updates the findings of previous research and tests whether children in this age group are fully aware of the basic economic notions required to function as an active economic agent. Specifically, the experiment investigates the capacity of children aged 6-13 years to understand money-related concepts such as the value of different coins and banknotes and the ability to estimate the change following a transaction. The second part of the study presents further evidence regarding the use of money at younger ages by analysing children's income sources and children's saving, borrowing and lending habits.

2. Study 1: the effect of age, gender and school class on children's understanding of monetary concepts.

Previous studies of school age children suggest that children of different ages collect, interpret and elaborate information in gradual sequential processes. According to these processes, children move from basic ideas, such as conducting elementary transactions, to complex ideas, such as understanding the concept of profits and the role of banks [11-13].

According to Piaget's theory, the development of economics notions in children follows a predefined stage framework [11]. When children are aged 3-7 years, also referred to as the pre-operational period, they learn basic economic phenomena by observing adult behaviours. Between the ages of 7 and 12 years, children move to the so called 'concrete operations' period, at which point they make connections between different aspects of money use [11]. As the children move into adolescence, Piaget suggests that they become aware of parental economic activity at the systemic level. For example, they begin to understanding the nature and purpose of banks, motivations for selling and buying, the concept of goods and resource scarcity, together with the ideas of supply and demand [14].

Confirming Piaget's hypothesis, Schuessler and Strauss showed that children need to pass through different stages before achieving an adult understanding of money [15, 16] . At stage 1 (3-4 ½ years), children know that coins are different from other objects; but they are not able to make a distinction between the different denominations of money [17]. At stage 2, when children become 4-5 years old, they know that money can buy things; but they are unable to make a distinction between different denominations of cash, believing that any coin can buy anything. According to Schuessler and Strauss, children acquire mathematical notions at primary school, where they become aware of the importance of the exact value of money in transactions. However, it is only when they reach 8-10 years old that they acquire a capacity to estimate the amount of change received in a transaction. At this age, they also gain an understanding that money is required to purchase goods, and that money is earned through work [15, 16]. Berti and Bombi explored children's understanding of economic ideas [18, 19]. Studying children between the ages of 3 and 8, Berti and Bombi suggest that there are six possible stages through which children acquire an understanding of money. In stage one, children have a vague understanding of the relationship between money and buying [19]. In stage two, children understand that money is used to buy goods. In stage three, children understand the different denominations of money. In the fourth stage, children acquire the concept of a budget, or, that often enough they lack sufficient money to buy goods. Up to this point, Bombi and Berti suggest that a child's ability to progress from one stage to another depends on the depth and level of the child's experience and their ability to draw conclusions. In stage five, children acquire the ability to understand the correspondence between objects and prices, and also the ability to understand the receipt of change following a transaction. In stage six, the child's arithmetic abilities and aptitude allow them to grasp the relationship between prices, the available budget, and the amount of change they will receive following the transaction [19].

More recent studies emphasise the role of children's intuition about abstract economic concepts. According to this intuitive approach young children develop informal theories of economics. As they grow older, they also move beyond them and produce a deeper economic understanding [20].

The objective of study 1 is to examine whether age and gender influences knowledge of money for children aged 6-12.

2.1 Participants

The study involved 112 children, 63 females and 49 males, from a state school in Naples (Italy). All children included in the study belong to lower-middle class families and were eligible for free school meals. None of the children involved in the study had any intellectual, visual or auditory impairment. The study was conducted after receiving ethical approval from the Italian National Research Council and London School of Hygiene and Tropical Medicine ethics committees. Informed consent was obtained from parents and children before the experiment commenced.

2.2 Instrument

An eight-item questionnaire, based on the study conducted by Berti and Bombi, was administered to each child to test their understanding of four economic notions: the ability to assign different values to money, the ability to identify a correspondence between an object's price and the money necessary for the transaction, the notion of a budget constraint, and the correct use of change during transactions [19]. A copy of the questionnaire is included in the Appendix 4.

2.3 Procedure

The questionnaire was completed in a classroom setting. Each child was asked to complete the questionnaire independently. Pupils were assured that their answers were anonymous and strictly confidential, and would not be assessed by their teacher, or recorded by the school. Overall, children found the instructions for the questionnaire easy to follow. There was no time limit for its completion and on average each class did not take longer than 15 minutes to complete the questionnaire.

2.4 Analyses

A descriptive sensitivity analysis was performed to provide an overview of the sample, and to estimate the mean score for each of the four tasks across the overall sample, and also the mean score for overall

understanding of money by age groups. A correlation analysis was carried out to assess the relationship between the scores obtained in the four money related domains. ANOVAs were computed to assess whether there were age and gender differences in the understanding of economic concepts. Possible interactions between age and gender were also investigated. A regression analysis was performed using STATA Statistical Software, Release 11.0.15 Confidence intervals and P values (significant at the $P<0.05$ level) were calculated with adjustment for clustering effects (each class was assumed to be a separate cluster).

2.5 Results

Table 4.1 provides a description sample included in the first experiment. The mean overall score by age and gender is reported in Table 4.2. Table 4.3 reports the results of the descriptive analysis for each of the four domains of money-related knowledge explored in the study. Independent of age and gender, the mean score for each question was high. The lowest average score reported was related to questions about the ability of subjects to identify the value of different banknotes and coins. The highest mean score was for questions that tested ability to identify the price of different objects. As seen in Figure 4.1, a highly significant correlation was found between the score for the ability to identify the correspondence between an object and its price, and the score related to the budget constraint.

ANOVAs testing the effect of age and gender on the total score revealed that age was significantly associated with money-related knowledge ($F(10, 13)=2.67$ $p=0.018$). Conversely, gender and interactions between gender and age were not significant. When considering the four domains separately, older children have a significantly higher understanding of the value of coins and banknotes ($F(1, 8)= 5.30$ $p=0.000$). In youngest age group (6-7 years), the average score for questions testing this ability was 1.11 (SD: 0.17). In the oldest group, the average score was 1.8 (SD: 0.13). Neither age nor gender was predictive of the ability to understand the correspondence between prices and objects. Even the youngest subjects demonstrated an ability to identify the approximate value of

different types of goods (mean score 6-7 years individuals: 2.8 SD: 0.11) and also to identify the budget constraint in transactions (mean score for the youngest group: 2.11 SD:0 .25). There were no significant age/sex interactions. Further confirming these results, the regression analysis suggested that the overall understanding of monetary concepts increased when children are 8-9 years old compared with the younger age group (6-7 years)(Table 4.4). In particular, children older than 7 years showed a higher level of ability in ordering banknotes and coins by value, and also a greater ability to understand the budget constraint in a monetary transaction. From the analysis, it also emerges that the overall ability to understand monetary notions doesn't differ by gender, however, girls had a better understanding than boys of the value of different coins and banknotes.

Table 4.1. Sample profile (N of children in the sample =112).

Variables	***Male***	***Female***	***Total***
Age			
6-7	6	11	17
8-9	22	25	47
10-11	14	24	38
12-13	7	3	10
Total	49	63	112

Table 4.2. Descriptive statistics. Average score by age and gender.

Variables	***Scale***	***Mean***	***S.D.***
Age			
6-7	0-10	7.94	0.42
8-9	0-10	8.70	0.17
10-11	0-10	9.07	0.23
12-13	0-10	9.30	0.39
Gender			
Female	0-10	8.87	0.17
Male	0-10	8.63	0.20

SD: Standard Deviation

Table 4.3. Descriptive statistics. Average score by type of question.

Variables	***Scale***	***Mean***	***S.D.***
Value of money	0-2	1.14	0.65
Price-object comprehension	0-3	2.91	0.42
Budget	0-3	2.55	0.74
Change	0-2	1.83	0.48

SD: Standard Deviation

Figure 4.1. Correlation measures between the scores of the four economic notions tested. Heavy solid line indicate significant relationship (p<0.000), dotted line indicate correlations that were not significant (p>0.05).

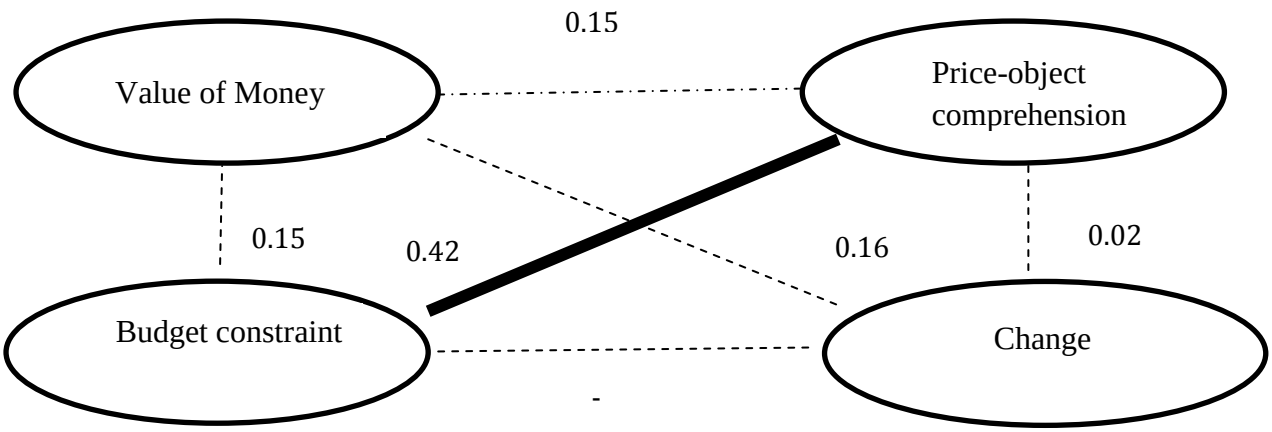


Table 4.4. Regression Analysis. Total and specific task score.

	All Questions	***Ordering cash and coins by value***	***Correspondence Price and objects***
	Coefficient(S.E.)	***Coefficient(S.E.)***	***Coefficient(S.E.)***
Age			
6-7 versus 8-9	0.79(0.37)*	0.33(0.16)*	0.07(0.12)
8-9 versus 10-11	0.23(0.27)	0.16(0.12)	-0.03(0.09)
10-11 versus 12-13	0.37(0.49)	0.25(0.21)	-0.13(0.18)
Gender			
Female_ Male	-0.31(0.25)	-0.40(0.11)***	0.01(0.08)

S.E.: Standard Error; *p<0.05; **p<0.01; ***p<0.001

...To continue

	Budget	***Change***
	Coefficient(SE)	***Coefficient(SE)***
Age		
6-7 versus 8-9	0.43(0.20)*	-0.05(0.13)
8-9 versus 10-11	0.09(0.14)	0.00(0.07)
10-11 versus 12-13	0.07(0.24)	0.18(0.11)
Gender		
Female_ Male	0.18(0.14)	-0.09(0.09)

S.E.: Standard Error;*p<0.05; **p<0.01; ***p<0.001

3. Study 2. Children's use of money.

Over the last few decades, the availability of spending money, together with the spending and saving habits of young individuals, has received increasing attention [12, 21, 22]. Previous studies investigating parental attitudes towards pocket money highlighted that nationality, age of parents and child, and social class influence allowance attitudes, such as: frequency and amount of money, and agreeing in advance what the money should cover [3, 13]. According to previous studies, parents introduce the allowance system quite early (on average when the child is 6 years old) and increase the amount given as the child ages. Cross country comparison of parental attitudes have also shown differences in parental attitudes towards money. For example, as many as 77% of Britons and only 40% of Germans believe that children should be given money on special occasions [21].

In 1984, Furham and Thomas investigated the saving and spending habits of young people finding no gender and class differences in respect to the source of income, but numerous age differences in money usage for children between 7 and 12 years. In 2001, a subsequent study conducted among adolescents found that young people aged between 11 and 16 years were very active economic citizens. The majority of those interviewed had a regular source of income (mainly an allowance from their parents), received money on special occasions and also saved money to buy something special. Unlike previous studies, Furham also found significant gender differences, indicating that females received less money, were less economically active and were often more economically conservative than males[3].

Among adults, saving, lending and borrowing habits are related to individual traits and social networks. For example, saving is related to more optimistic attitudes, and debts to moral issues. Livingston and Hut studied the relationship between individual saving and borrowing among adults and found that savers are more likely to see debt (borrowing) as a failure, while people who borrow and save at the same time were found to be optimistic and felt in control of their lives [23]. In line

with these findings, studies investigating parental attitudes towards the saving, lending and borrowing habits of their children found that parents tried to promote savings and were against children lending and borrowing money from others [21, 24]. According Furnham, three quarters of the parents interviewed believed that children should start saving a proportion of their pocket money as soon as the allowance regime was introduced. Only 1.4% and 3.3 % of the parents interviewed believed that children should be encouraged to borrow and lend money respectively [21, 24]. Studies investigating children's beliefs about saving have shown that while younger children see saving as an opportunity to realise short term goals, children aged 6 to 12 years display more abstract economic reasoning, and are able to understand the importance of saving money towards long term goals. In this way, older children have a better understanding of the trade-off between future and current consumption [25-27].

There have been several studies investigating parental beliefs about pocket money in different countries such as the UK, France, the US and the Netherlands [13, 28-30]. However, there is a paucity of studies conducted in Italy exploring child attitudes towards pocket money, the use of their allowance and their spending/savings/borrowing and lending attitudes [24, 28][24, 28][24, 28][24, 28][27,28].

The main objective of the second experiment of this chapter is to investigate the use of money among a sample of Italian children aged 7 to 13 years. In particular, the chapter examines whether gender, age and the number of siblings influenced how much and how often young children received money from adults (e.g. pocket allowance or as festivity presents) together with their saving, borrowing and lending habits.

3.1 Participants

The study involved 103 children, 58 females and 45 males. Of these 23 were 6-7 years old, 21 were 8-9 years old, 26 were 10-11 years and 33 were aged 12-13 years. The children were drawn from the same school as for the first study, and the research received ethical approval from the Italian National

Research Council and London School of Hygiene and Tropical Medicine ethics committees. Informed consent was obtained from parents and children before starting the experiment.

3.2 Instrument

Each child was given a 13 item questionnaire concerning their pocket money allowance from parents, and their saving, borrowing and lending habits. The questions included in the survey were derived and adapted from previous studies (cited above) conducted among similar age groups. A pre-test was conducted on a small sample of children to ensure that they understood the questionnaire items.

3.3 Procedure

As for the first study, children completed the questionnaire during class time. The average time taken to complete the questionnaire ranged from 15 to 35 minutes in the younger age group to about 10 minutes for the oldest groups. Only 2 out of 105 children did not complete the questionnaire. Skilled interviewers ensured that children understood the questions, and that they filled in the questionnaire autonomously with honest and accurate responses. The questionnaire is included in the Appendix 4.

3.4 Analyses

A descriptive analysis was conducted for the purpose of summarizing responses to the questionnaire. A series of ANOVAs were run to investigate the effect of gender, age and the interaction of gender and age on the questionnaire's items. The mean and median amount of money by source was estimated both by age group and by class attended. A correlation analysis was carried out in order to assess the relationship between pocket money and birthday (festivity) presents and the amount of savings. Potential factors influencing the probability of receiving pocket money, and money as birthday and festivity presents were explored using logistic regression. A Tobit regression was used to assess the factors influencing the amount of money received as pocket money and the overall amount of money received each month (including recurrence presents) the frequency, the amount of pocket money allowance and the amount of savings.

3.5 Results

Table 4.5 describes the characteristics of the sample of children. The number of children is balanced by age group with the exception of the oldest age group (12-13 years) which accounts for 33% of the overall sample. The first two columns of Table 4.6 show the results of the descriptive analysis for each item included in the questionnaire. 78% of children said they received pocket money, the majority of them (56%) received pocket money every week, 25% once every day and almost 20% once every month. The most usual amount of money children received was €5 (35%). As expected, it was unlikely that they received more than €20 (only 8% of the sample). Over 80% of children said they received money for birthdays or at festivities. The amount of money they received during festivities was less than €20 for 25% of children, between €20 and €50 for 41% of the sample and greater than €50 for the remaining 31% of children. Only 10% of children borrowed money from friends. However, this proportion tripled in terms of lending money to others. 78% of participants reported that they were currently saving money. The amount of money saved ranged from €5, among 15% of respondents, to €200 in 23% of cases. The most popular reason to save money was "Because if I need to buy something I will have money available" only 6% of children saved because their parents told them that saving is important.

The last three columns of Table 4.6 present the results of ANOVAs analysis of the effects of gender, age and age gender interactions on the items of the questionnaire. Gender was not a predictor of the use of money. Age, however, was found to affect the amount of money received as pocket money and as birthday presents. Older children were also more likely to lend money. Saving and borrowing attitudes were also influenced by age. Age-gender interactions were not significant for the items considered. Tables 4.7 and 4.8 report the mean and median amount of money children have available by age and by class attended. This figure increases significantly as children grow older and move to higher classes. The last columns of each table show the overall monthly income. Figure 4.2 shows the correlations between the amount of money from different sources and the amount of savings. Consistently positive and highly significant correlation is found between the money received from

pocket allowance and money received as birthday and festivity presents. No correlation was found between the amount of saved and the money received as pocket money each month. However, savings were highly dependent on money received as festivity and birthday presents.

Logistic regression analyses were performed to identify potential factors influencing the probability of receiving pocket money as either a birthday and/ or a festivity present (Table 4.9-4.10). The probability of receiving pocket money for a birthday present increases with age. Compared with children aged 6-7 years, older children are approximately 5 times more likely to receive a regular pocket money allowance. As expected, the presence of siblings decreases both the probability of receiving money both as birthday and a festivity present. The second regression investigated whether the child's characteristics influenced the probability of saving, lending and borrowing money. Neither age nor the presence of siblings was a predictor for saving and borrowing habits among children. Compared with boys, however, girls were less likely to borrow money. The probability of lending money decreases with age. However, it also seems to increase among the oldest age group (11-12 years). Table 4.11 and 4.12 show the results of Tobit regressions. Both the amount of monthly pocket money and the overall monthly income (including presents and savings) increases with age; and, in particular, when children arrive at pre-adolescence (turn 12 years old). Table 4.12 shows that age and gender do not influence the amount of savings. The frequency with which children receive money increases compared to the younger age group. The amount received as pocket money allowance on each occasion increases consistently by age group and does not vary according to gender.

Table 4.5. Sample profile (N of the children sample =103).

Variables	***Male***	***Female***	***Total***
Age			
6-7	9	14	23
8-9	12	9	21
10-11	6	20	26
12-13	18	15	33
Total	48	58	103

Table 4.6. Mean and percentage for each question of the questionnaire. The last three columns report results from the analysis of variance. (Gender*Age) and siblings.

Variable	*Yes*	*No*	*Gender* [1]	*Age* [1]	*Gender *Age* [1]
Do you regularly receive pocket money?	78%	28%	0.51	2.44	2.44
If yes please state how often you receive pocket money			0.02	1.26	2.04
Every day	25%				
Every week	56%				
Every month	19%				
How much do you receive each time?			1.03	5.44**	1.69
€2	15%				
€5	35%				
€10	24%				
€20	18%				
€50	4%				
€100	4%				
Do you receive money for festivities (e.g. Christmas and Easter)?	80%	20%	0.94	1.70	0.40
If yes please state how much money will you receive on average during festivities?			0.36	9.09***	1.16
€5	12%				
€10	13%				
€20	19%				
€50	20%				
€100	21%				
€200	15%				
Do you receive money as birthday present?	81%	19%	0.94	2.37	1.37
If yes please state how much money will you receive on average for your birthday?			0.65	6.78**	0.98
€5	8%				
€10	4%				
€20	23%				
€50	18%				
€100	27%				
€200	19%				
Do you usually borrow money?	10%	90%	0.57	0.56	0.15
Do you usually lend money to friends?	34%	66%	0.17	9.04***	0.61

Do you usually save money?	78%	22%	0.85	1.06	0.96
If yes what are your current savings?			0.65	2.19	0.39
€5	15%				
€10	16%				
€20	21%				
€50	15%				
€100	10%				
€200	23%				
Why do you save money ?					
For emergencies	21%				
To buy a toy	19%				
For holidays	14%				
Because they told it is important to save money	6%				
Because if I need to buy something I will have money available	41%				

1: F levels from two way ANOVAs; *p<0.05; **p<0.01; ***p<0.001

Table 4.7. Mean (S.D.) and median amount of money by Age.

	Monthly Pocket Money	***Savings***	***Birthday present***	***Festivities Presents***	***Monthly Income***
Mean (S.D.)	€10.45 (31.4)	€43.85(56.78)	€24.53(32.67)	€26.30(45.55)	€16.52(24.08)
Median	€0	€10	€10	€10	€10.08
Mean (S.D.)	€42.06(89.4)	€32.78(67.89)	€47.85(62.71)	€21.66(30.99)	€59.59(132.47)
Median	€20	€20	€20	€10	€21.25
Mean (S.D.)	€27.5(`5.67)	€67.90(90/81)	€85.39(23.67)	€70.77(73.13)	€74.29(91.52)
Median	€20	€20	€75	€50	€43.33
Mean (S.D.)	€143.57(201.33)	€49.39(72.42)	€96.06(72.97)	€88.33 (73.87)	€166.35(211.50)
Median	€40	€5	€100	€100	€65

S.D.: Standard Deviation

Table 4.8. Mean (S.D.) and Median amount of money available by class attended.

	Monthly Pocket Money	***Savings***	***Birthday present***	***Festivities Presents***	***Monthly Income***
3rd Elementary grade					
Mean (S.D.)	€9.39 (20.4)	€48.91(66.86)	€23.91(33.85)	€26.47(45.43)	€15.76(24.18)
Median	€0	€10	€10	€10	€7.5
4th Elementary Grade					
Mean (S.D.)	€37.42(69.4)	€37.14(58.81)	€47.85(62.19)	€21.85(30.43)	€45.02(71.71)
Median	€20	€20	€20	€10	€21.25
5fth Elementary Grade					
Mean (S.D.)	€22.5(19.6)	€84.42(87.91)	€85.38(73.27)	€41.92(35.07)	€44.01(44.24)
Median	€20	€20	€75	€50	€32.33
1rst Intermediate Grade					
Mean (S.D.)	€34.11(41.84)	€47.35(75.02)	€84.70(57.78)	€51.17 (72.09)	€42.01(31.72)
Median	€20	€10	€100	€50	€43
2-3 Intermediate Grade					
Mean (S.D.)	€259.87(237. 9)	€51.56(71.94)	€124.37(75.62)	€127.81(73.51)	€291.54(245.95)
Median	€150	€5	€100	€150	€200

S.D.: Standard Deviation

Table 4.9. Logistic Regression Results. Pocket Money, Money as Birthday and Festivity present.

Variable	***Pocket Money (Yes/ No)***	***Money as Birthday Present(Yes/No)***	***Money as Festivities present (Yes/No)***
	OR(S.E.)	***OR(S.E.)***	***OR(S.E.)***
Age			
8-9 vs. 6-7 years	3.83(2.49)*	2.06(1.52)	0.70(0.50)
10-11 vs. 6-7 years	5.32(3.39)**	3.56(2.59)*	2.39(1.79)
12-13 vs. 6-7 years	4.85(2.93)**	8.65(7.23)**	3.71(2.91)
Siblings	0.96(0.20)	0.51(0.12)**	0.50(0.12)**
Gender Female vs. Male	1.15(0.53)	1.64(0.95)	2.21(1.29)
Constant	0.56(0.47)	2.50(2.37)	2.64(2.46)
Log-Likelihood	-58.21	-43.52	-45.19
Pseudo R2	0.08	0.14	0.13

OR: Odds Ratio; S.E. Standard Error;*p<0, 05; **p<0, 01; ***p<0,001

Table 4.10. Logistic Regression. Saving, Borrowing and Lending money.

Variable	***Saving money (Yes/ No)***	***Borrowing money (Yes/No)***	***Lending money (Yes/No)***
	OR(S.E.)	***OR(S.E.)***	***OR(S.E.)***
Age			

8-9 vs. 6-7 years	0.85(0.63)	0.25(0.30)	0.21(0.05)**
10-11 vs. 6-7 years	2.71(2.47)	1.18(1.09)	0.05(0.03)**
12-13 vs. 6-7 years	0.50(0.34)	0.66(0.619)	2.24(1.28)
Siblings	1.10(0.23)	0.59(0.25)	0.97(0.22)
Gender Female vs. Male	0.60(0.32)	4.55(0.51)*	1.18(0.59)
Constant	6.58(6.11)*	0.03(0.04)**	0.62(0.53)
Log-Likelihood	-51.25	-29.14	-50.16
Pseudo R2	0.06	0.11	0.24

OR: Odds Ratio; S.E. Standard Error;*p<0.05; **p<0.01; ***p<0.001

Table 4.11. Tobit Regression Results. Monthly Pocket Money and Monthly Income

Variable	***Monthly Pocket Money***	***Monthly Income***
	Coefficient(S.E.)	***Coefficient(S.E.)***
Age		
6-7 vs. 8-9 years	98.47(51.73)	42.39(39.66)
6-7 vs. 10-11 years	96.44(50.02)	43.93(37.72)
6-7 vs. 12-13 years	213.54(47.63)***	158.88 (36.26)***
Siblings	9.90(14.59)	4.73(12.17)
Gender	32.27(32.82)	21.51(26.66)
Constant	-155.82(65.41)	-38.83(49.25)
Log-Likelihood	-470.39	-613.08
Pseudo R2	0.026	0.019

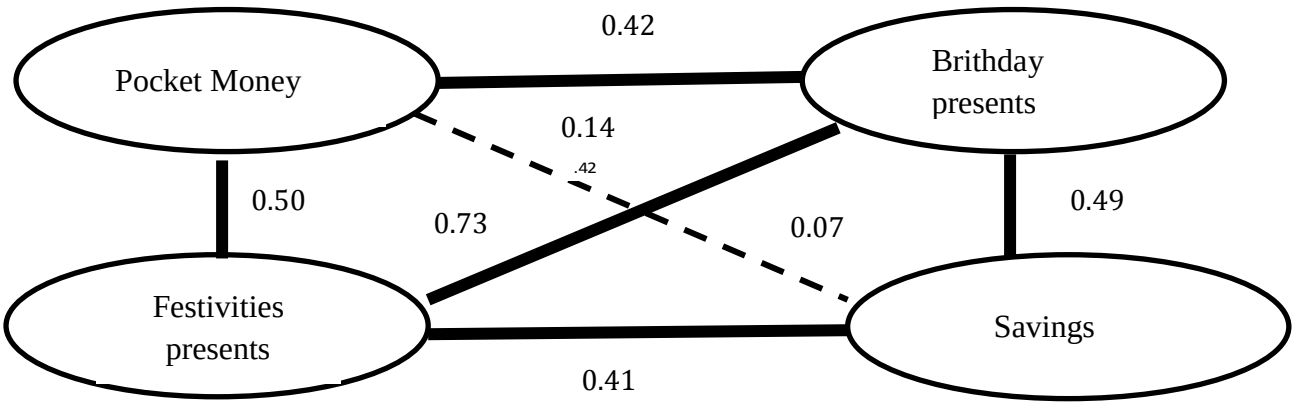
S.E. Standard Error ; *p<0.05; **p<0.01; ***p<0.001

Table 4.12. Tobit Regression Results. Savings, Frequency of Pocket Money and amount of pocket money.

Variable	***Amount of money saved***	***Frequency of pocket money***	***Amount received as pocket money***
	Coefficient(S.E.)	***Coefficient(S.E.)***	***Coefficient(S.E.)***
Age			
6-7 vs. 8-9 years	-8.42(26.29)	1.03(0.45)*	1.69(0.68)*
6-7 vs. 10-11 years	45.82(24.74)	1.07(0.43)*	2.04(0.65)**
6-7 vs. 12-13 years	-0.63(24.18)	0.84(0.41)*	2.05(0.62)***
Siblings	-13.06(8.04)	-0.01(0.13)	-0.06(0.19)
Gender	4.07(17.90)	0.10(0.29)	0.40(0.44)
Constant	49.26(32.85)***	0.22(0.56)	-0.72(0.85)
Log-Likelihood	-492.69	-155.11	-179.40
Pseudo R2	0.009	0.024	0.048

S.E. Standard Error ; *p<0.05; **p<0.01; ***p<0.001

Figure 4.2. Correlation measures the amount of money received from different sources and the amount of money saved. Heavy solid lines indicate a significant relationship with p<0.0000, continuous lines indicate a relationship with p< 0.05, dotted line indicate correlation that were not significant (p>0.05).



4.Discussion

The purpose of this study is to provide evidence regarding the use and understanding of money at younger ages. In the first experiment, the study investigated 6-13 year old children's understanding of money, finding that overall comprehension of money was high even at the younger ages . The results of the first experiment suggest that children were able to understand the relationship between objects and prices, and also to estimate the change resulting from transactions, independent of their age. The ability to perform other tasks, such as identifying the value of different denominations of money together with understanding budget constraints, improves significantly as children reach 8-9 years.

In this way, the study complements the exiting body of knowledge as set out in the longitudinal study of Berti and Bombi [19]. Compared with the Berti and Bombi study, the present study assesses the capabilities of children from a different age group, 6-13 (3-8 years in Berti and Bombi), and a different socio-economic class (lower vs. middle class in the previous study). Consistent with Berti and Bombi, the results of the study suggests that children's understanding of money improved with age. The study also failed to find any gender related differences in the overall ability to understand money. However, it found statistically significant gender differences in the ability to understand the value of money, in which girls performed better than boys, and independently of their age.

The second experiment investigated children's use of money. According to Webley, pocket money is uncommon in Italy [14]. Nevertheless the study results showed that the majority of children interviewed had a regular source of personal income, and that more than half received regular weekly allowances from parents . These results are consistent with previous studies regarding parental attitudes toward pocket money conducted in other countries[21, 24, 30]. According to both Furham, and Furnham and Kirkcaldy, the majority of parents are in favour of giving children a weekly allowance from the age of 6 [21, 31].

Consistent with the findings of earlier studies, it was found that age was associated with the increased likelihood of receiving pocket money (Yes vs. No) and also with the probability of receiving money as a birthday present [3, 5, 13]. Similarly, the amount of money received as an allowance and also the overall income, including festive and birthday presents, increased significantly with age.

Previous studies investigating parental attitudes to pocket money allowances suggest that parents treat females and males equally in relation to pocket money [13, 24, 31]. However, Furham and Walls also found that boys were more likely to receive more pocket money than girls in terms of birthday presents and payment for household chores [3, 32]. In the present study, it was likewise found that parents did not discriminate between males and females with respect to giving pocket money or the amount given for both birthdays and during festivities. As expected, results also show that the presence of siblings did reduce the probability of receiving money for festivities and birthday presents [31].

As with Furnham, results of the second experiment suggest that demographic factors (age and gender) did not influence levels of saving [3]. A majority reported that they saved money regularly. However, the amount saved varied significantly across children. Interestingly, the amount saved had little relation to the amount of money received as pocket allowance. Conversely, the proportion of children borrowing money was low. Consistent with previous studies on student attitudes towards debt , it was found that females were less likely to accumulate debts than males [33]. Age seems to

influence only the likelihood of lending money, which decreased from the younger to the older end of the age bracket, and increasing again when children turn 12 years old.

This study updates and expands previous knowledge regarding the degree of child and pre-adolescent understanding of money-related concepts. However, several caveats should be noted when interpreting the findings. First, the study is not longitudinal and did not assess the improved understanding of money-related concepts among the same subjects over time. The sample group was also homogenous, involving all children from lower class families. Consequently, it did not assess potential socio-economic differences involved in the understanding and use of money. Compared with the children of 'white collar workers' in the Berti and Bombi study, children involved in this study were associated with lower socio-economic groups, who may have lacked exposure to economic realities of adult life, and which was possibly one of the reasons why younger children score high in the first experiment. In addition, the study sample group may have also had different attitudes to saving habits than the children of more upwardly mobile parents. Indeed, Furnham and Thomas suggested that lower class children received more from their parents but saved less [13]. Other studies conducted with children aged 12-18 years have also shown that monetary attitudes such as saving are related to school performance and in particular mathematics achievements [34, 35]. Children that currently use money are more likely to face everyday situations in which they need to perform mathematical calculations such as paying for their own expenditures (buying clothes, food leisure goods etc.) The present study, however, did not gather such attitudinal measures of money understanding. And it did not collect information about individual mathematical achievement, which may influence children's understanding and use of money at younger ages. Further research is required to investigate how the use and understanding of money is related to school performance at younger ages.

5.Conclusions

As Dauphin et al. have suggested, a household collective model of family decision making involves some important limitations[7]. Firstly, it ignores household investments in secondary education. And

secondly, it also has the potential to produce incorrect analyses of intra-household welfare by failing to consider the role of children in contributing to family income and manufacturing household demands [7]. Consistent with the findings of Berti and Bombi, the results of this study suggest that the ability to understand money-related concepts increases with age. And by way of complementing their work, the present study found that children at even young ages, 6-7 years, scored high in all the different domains of money understanding [17,18]. Furthermore, consistent with earlier work in the field, the results of the second experiment described in this study show that the majority children aged 7 up to 13 received pocket money from their parents and that the amount of money received increase with age. For the future, researchers might consider investigating possible contributing factors such as mathematical performance at school and personal attitudes (e.g. risk aversion, altruism) to saving borrowing and lending. An understanding of money-related concepts, and in particular, budget constraint and the use of money at younger age, is a necessary but not sufficient condition for conducting willingness to pay studies with children. There are difficulties in establishing an a priori age threshold above which it becomes possible to obtain WTP estimates from children. Indeed, it has been shown that adult respondents do not consider budget constraints when answering WTP questions[36]. The main objective of the two experiments described in the present study is to provide evidence of an age gradient in the use and understanding of money. Both the experiments show that as children grow older, and in particular when they turn 9, they have both a higher ability to understand money related concepts and also display a higher degree of financial autonomy. In order to compare the use and understanding of money among wider age ranges, including also adolescents and adult individuals, additional research is necessary. For example, a study involving a larger sample and older age groups might provide further insights on the development of the use and understanding of money across different age groups.

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Section 3

The results of Section 2 suggest that children are able to understand environmental related health risks, and that even younger children (6-7 years old) are familiar with economic concepts such as the use of money in buying and selling, the value of bank notes and coins and the concept of a limited budget. The results of Chapter 4 also suggest that children receive money from their parents regularly, and that their monthly budget increases significantly as they get older.

Using the visual aid for health risk communication and information on age specific budget constraint tested in Chapter 3, this section of the thesis investigates child and parental WTP for reducing the risk of having an asthma attack.

The main objective of Chapter 5 is to provide preliminary responses to the following sub-questions: Do children show rational choice when answering contingent valuation (CV) questions? Which factors (e.g. age, gender) influence child and parental WTP for reductions in the risk of a child having an asthma attack? Does child WTP for their own risk reduction differ from parents' WTP?

Chapter 6 describes the results of a discrete choice experiment (DCE) conducted with a sample of children (within the same questionnaire). The main objective of the study described in Chapter 6 is to provide preliminary evidence on the ability of children to provide rational answers to DCE questions. Secondly, the objective of the study described in Chapter 6 is to estimate WTP from the DCE answers and to compare the estimates obtained with those elicited using the CV approach.

Research Paper 4. Willingness to pay for asthma health risk reductions. A comparison between children's and parents' preferences using the Contingent Valuation method.

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Contribution: CG led the conception of the research question, designed the experiments, carried out the data collection under the supervision of JC. The candidate also performed the data analysis under the supervision of JC. The candidate wrote the first draft. She managed each round of comments and suggestions from the co-authors. All the authors read and approved the final draft prior to inclusion in this thesis.

The candidate _____ The supervisor John Cairns

5.Chapter

1.Introduction

Children have been found to be the most vulnerable to the negative effects of environmental pollutants [1]. The environmental proportion of the global burden of disease ranges from 25 to 40%, but 43% of the total environmental burden of disease fall on children under 5 years [2, 3]. Because of the greater vulnerability of children to environmental hazards compared to adults recent executive and legislative decisions in US and in Europe have emphasized the importance of protecting children's health and including benefits to children in the cost-benefit analysis (CBA) of environmental interventions affecting children health [4-6].

A key input to account for children in CBA is the estimate of the monetary benefits of improving children's health. There is a wide range of approaches that can be used to assign monetary values to health benefit. Revealed preference techniques (e.g. hedonic wage methods), deriving values from the observed actions of individuals, have been suggested to provide the most reliable indicator of preferences because estimates are based on actual decisions rather than on individual choices under hypothetical scenarios [7]. In the absence of a market for the evaluated good, as in the case of environmental health-related risk reductions, stated preference techniques such as contingent valuation obtain willingness to pay (WTP) estimates by asking individuals how much they are willing to pay in order to reduce the risk of a given health outcome [7, 8].

Despite the high number of studies valuing health risk reductions for adults ,there is paucity of studies conducted to elicit monetary estimates specifically for children [6, 9]. The main reason for this is that estimating WTP values for children is challenging [10]. It is suggested that stated preference approaches cannot be used with children because they do not possess the cognitive skills and/or the financial resources to express the WTP for health risk reductions [11-13]. It is difficult to infer WTP

information from the market using revealed preference techniques, such as hedonic wage methods, because children are outside the workforce and are excluded from household consumption decisions [10]. Another possible hindrance in eliciting WTP estimates directly from children is that they may find the hypothetical scenario of CV study meaningless[14].

In order to address this gap, studies have used three approaches to elicit preferences directly: the adoption of a societal perspective which consists of consulting a representative sample of the population (parents and non-parents); the "adult as child perspective", in which adult respondents are asked to put themselves in the place of children; and finally, the parental perspective, in which parents are asked to value their children's health [10].

These approaches have two main weaknesses. First, according to welfare economic theory the children affected by the policy are the best judges of their own welfare. Any third person, e.g. parent, speaking on behalf of their child, may fail to express the child's preferences for their own health risk reductions [10]. The second main limitation of the three approaches arises as a result of difficulty distinguishing between different types of altruism (paternalistic and non-paternalistic[2]) that may have influenced the WTP estimates [6, 10].

Despite the common belief that children are not mature enough to speak for themselves recent findings suggest that it may be possible to elicit reliable WTP values for health risk reductions directly from children. Studies show that even at younger ages, children are able to make rational choice decisions, and to understand and use money in transactions within a budget constraint [15-17](See also Chapter 4). Moreover, it has also been shown that if appropriate visual aids are adopted, children as young as seven years old show a good understanding of health risk information (See Chapter 3).

[2] Paternalistic altruism refers to the situation in which the individual utility function depends on the consumption of other individuals of a particular merit good (e.g. size of the health risk reduction to the child). The non-paternalistic altruist's utility function depends instead on the others' welfare (e.g. child's utility level).

This study reports the results of a contingent valuation (CV) conducted with children aged 7-19 years, together with their parents, to estimate WTP for a reduction in the risk of asthma attack. In this way, the research provides preliminary evidence on an important and unexplored area. First, the research investigates the ability of children to provide reliable answers to WTP questions (children are able to make a trade-off between money and health risk reduction). Second using both parents' and children's answers, it investigates differences in WTP for the same health risk reduction (child's risk of having an asthma attack). Third, the study tests whether the WTP of parents and children is influenced by demographic, socio-economic and health characteristics (e.g. parents' and children's WTP changes according to the age of the child). Third, by asking respondents detailed questions about their attitudes and behaviours, the study examines which factors, such as altruism and risk aversion, influence WTP values and how these factors differ between children and their parents.

This study is organized as follows: the next part provides an overview of the previous studies conducted to elicit WTP estimates for reductions in children's health risk. Part 3 describes the questionnaires (parents' and children's) used to elicit WTP values for reducing the risk of asthma attack, and also the methodology for analysing questionnaires. Part 4 presents the main results of the study. The final section offers a discussion and some concluding remarks. In the Appendix 5 is also provided a brief description of the household decision making models for estimating WTP for children's health risk reductions.

2. Background: WTP for children's health risk reduction.

While the highest proportion of the environmental burden of disease falls on very young and very old individuals; it remains unclear whether WTP estimates should be adjusted for age. In the case of elderly, there has been much debate on whether using a lower value of a statistical life to reflect individuals' shorter life expectancy and higher morbidity [18]. For instance Rowe et al. results suggest that the value of a statistical life peaks at the age of 40 and then it decreases with age [19]. More

recently a contingent valuation study conducted by Krupnick et al. shows that WTP does not decrease until 70 years of age and that physical health status, with the exception of cancer, does not affect WTP for mortality risk reduction [20]. Accounting for the old age effect the DG environmental guidelines for cost-benefit analysis suggest adjusting WTP estimates (using a 0.7 correction factor) to account for the declining value of preventing fatality at older ages [21].

As with the elderly, there is still a debate in the case of children regarding whether to use adult or child-specific WTP estimates. According to a recent review of empirical studies parents are willing to pay more to reduce the risk to their children than to themselves [22]. In the case of mortality risk valuation, Hammitt and Haninger, for instance, estimated that parents' WTP estimates for mortality risk reduction for their children was 1.8 times higher than for themselves [23]. A more recent study conducted by Alberini and Scansy found that both the hazards (cancer, respiratory illness and traffic accidents) and type of programme (public vs. private) affect parents' WTP for their children and their own risk reductions [11]. For example, parents were willing to pay more for reducing their own risk of dying from cancer but a higher WTP for reducing the risk of their children dying from respiratory illness.

Studies examining the relationship between parents' WTP and children's age have led to conflicting findings. According to Dickie and Messman, Hammit and Haninger and Blomquist et al. the WTP for health risk reduction is inversely proportional to child age[23-25]. Dickie and Messman report, for example, that the WTP for avoiding illness in a 9 year old child is twice the value of parents avoiding illness, while after the age of 18 the difference is not statistically significant. Alberini and Scansy, on the other hand, found that WTP for mortality risk reduction increases with child age in the Czech Republic and is unrelated to child's age in Italy [11].

3. Methods

3.1The survey

The pilot study and the final survey were conducted between February and April 2013. The final survey was administered in class using a paper questionnaire offered to 370 children aged between 7 and 19 years living in Naples (Italy). The age range, 7-19 years, was adopted on the basis of previous studies (conducted with the younger sample of children involved in the present study) which suggest that children of 7 years and older are able to understand both health risk concepts (absolute risk and change in absolute risk) and also the use of monetary transactions taken in the context of a fixed budget constraint (See Chapter 3 and 4). Parents of children who agreed to participate to the study were given a brief questionnaire which they were asked to return within two weeks.

Children were recruited for the study from three different schools: an elementary school and an intermediate school, both of which located in the San Lorenzo district, one of the most polluted districts of Naples; and a high school located in the district of Chiaia which is a high income district with lower levels of environmental pressure.

Pre-tests and class discussions were conducted with younger children to ensure that they understood the questionnaire, and to improve the wording and format of the final version. Prior to the distribution of the final questionnaire, a brief class discussion was conducted during which information was given about the survey objectives and its intended uses. Then pupils who agreed to participate in the study completed Part 1 of the questionnaire and the CV questions (Part 2 of the questionnaire). The research received ethical approval from the CNR and the LSHTM. Informed written consent and informed assent was obtained from parents and children respectively.

3.1.1 Children's questionnaire

The children's questionnaire starts with the collection of basic demographic information, such as age, gender, and school year.

Belief in the relationship between environmental hazards and health. Children were asked to rate the relationship between environmental hazards and health based on a five point Likert scale. The aim of this question was to gather information regarding the relationship between ratings and the degree of belief in the possibility that environmental hazards influence child health.

Asthma health status. It has been shown that the health status of respondents affects the WTP for health risk reduction [6, 26]. In order to investigate whether the WTP of children and parents was influenced by the asthma experience of the child, pupils were asked if they experienced asthma attacks frequently, seldom, or if they had never before suffered from asthma.

Risk preferences influence risk reducing behavior and the WTP for health risk reduction [8]. In order to account for this factor the questionnaire collected information about children's attitudes and behaviours. Most of the questions were simple psychometric ones developed for adults and adapted to children.

Altruism. Altruism, i.e. devotion to welfare of others, includes non-use values such as benevolence towards friends and relatives, which may play a significant role in determining WTP estimates [8, 11, 27, 28]. Five different questions were used to ascertain the child's altruism towards others. The first question tests generic altruism: "If my classmate is in a difficult situation, I would try to help him". In order to test health/welfare related altruism, two questions were asked: "I feel sorry if my classmate cannot come to school because he/she is not feeling well"; and "If my classmate has nothing to eat during the break, I will share with him/her". Finally, non-paternalistic altruism was measured using: "I will lend money to my classmate if he/she needs money to buy something ".

Care for health. A five point Likert scale was used to measure children's concern for their own health. It was expected that children who cared more for their own health would be willing to pay more for small risk reductions.

Risk behaviours. Weber et al. developed a specific attitude scale to test risk behaviours in four different domains related to risk: health/safety, recreational, social and ethical domains [35]. Given

the difference between children and adults a shorter version of the attitude scale (including two of the four domains tested by Weber et al.) was developed and tested. The health and safety, and the recreational domains were considered relevant to children and thought to influence their WTP. In the analysis, each question was treated independently given that the content specificity of responses suggests that they should not be combined in a single score across and within content domains [29]. Risk attitude was measured with ten statements. Five of these explored risk preferences in the health and safety domains: "I always brush my teeth before going to bed";" I always use sunscreen to avoid sun burn"; "I always wash my hands before going to eat because I am afraid of germs"; "I always use the seatbelt when I am in a car" and "I always wear a helmet when riding the motorbike". The remaining five statements referred to preferences for recreational risk: "I would go to a safari in the jungle"; " I am scared when the motorbike goes fast" ; "I like going on holiday to places that I know are safer"; "I like to play dangerous sports (e.g. bungee jumping)" and "I pay careful attention when I cross the street". A detailed description of the attitudinal and behavioural variables collected in the children's questionnaire is reported in the Appendix 5 including a comparison of Weber et al. attitudinal scale with the questions used in the presents study.

3.1.2 Parents' questionnaire

The parental questionnaire is briefer than questionnaire given to children in order to encourage response. However, the parental questionnaire contained sufficient questions to facilitate comparison between child and parental attitudes. As with children, the parental questionnaire begins with questions about age, gender and occupation, and family income and family size. Following these preliminary questions, the questionnaire collects parental attitudes for the purpose of establishing any connections these might have in determining their/their children's WTP for health risk reductions. As in the child questionnaire, we investigated two risk behaviours domains: health/safety and the recreational domain. Where possible the same questions were used in both questionnaires. By this means, we avoided potential biases arising from the measurement of risk attitudes via different questions, while also facilitating measurement of behavioural patterns/risk attitudes. The questions

concerned with the relationship between WTP and relative degrees of belief in the potential effects of environmental hazards on child health and parental concern were the same on both questionnaires. In addition, we also included questions to investigate parental concern for their child's health.

Risk behaviours. Five statements or questions were used to measure parental aversion to health risk: "I use sunscreen to avoid sun burn", "I wash my hands before going to eat because I am afraid of germs", "Do you smoke?", "Do you exercise?". "I put a helmet on my child when riding the motorbike" is the only question used to measure child related health risk aversion. Five statements referred to the recreational domain: "I would go to a safari in the jungle", "I am scared when the motorbike goes fast", "I like going on holiday to places that I know because they are safer", "I like to play dangerous sports (e.g. bungee jumping)" and "I pay careful attention when I cross the street".

Care for health. Two generic questions were used to investigate parental concern for their own health and their attitude to their children's health using five point Likert scales. As with children a detailed description of the attitudinal and behavioural variables is reported in the Appendix 5.

3.2 The Scenario valued

The main objective of this study is to quantify the WTP for averting an asthma attack from both a child and a parental perspective. Given that children might have diverse levels of understanding of the hypothetical health scenario, an asthma attack was described using a graphic pathography before the questionnaire was distributed. The use of graphic pathographies - illness narratives in graphic form - to display the health condition being valued has two main advantages: first, in medical humanities, graphic medicine has been shown to be a useful way of providing detailed insights about the various aspects of a disease and also to reduce patient anxiety regarding their application [30]; secondly, by using the same picture to describe asthma effects in both parental and child questionnaires, it is possible to reduce the asymmetric information between children (those who have asthma and those have not) and also between children and parents.

The realism involved in the scenario was fundamental to the success of the study with children of different age groups and also with parents. The results of the study previously conducted with the younger children involved in this study (See Chapter 3), show that children are aware of environmental health risks, but are not necessarily alarmed by them. In order to increase the saliency of the hypothetical health scenario, conveners explained that people make decisions about reducing personal health risks (e.g. buying a bike helmet, buying a medicine, or paying for surgery) on a daily basis. However, in order to avoid the possibility that respondents might compound their WTP with other co-benefits, the conveners did not specify the nature of proposed policy for reducing risk of asthma attack [20, 31]. In the talk preceding the WTP questions, children were prompted to provide their true WTP, consistent with the recommendations of Brown et al.[32]. The problem of hypothetical bias was also explained (The conveners advised participants that failure to respond to questions in a realistic manner would decrease the scientific reliability of the study). As in Chapter 3, a fictitious character (Jack) was introduced into the experiment in order to alleviate any anxiety younger children might experience regarding health risk.

Children were presented with the following scenario*: "Imagine that you are Jack. Jack is a boy living in polluted city where 20 children in 100 have an asthma attack each month. Imagine that it is possible for Jack to pay a monthly amount to implement a policy intervention to reduce the risk of having an asthma attack. Remember Jack has a monthly budget constraint of €_____- (CV questions)"* Parents were directly asked to value reductions in risks to their child's health, omitting reference to Jack. Both parents and children's questionnaires are reported in Appendix 5.

3.3 Health risk reduction(s) communication.

In the present study, the baseline risk of asthma attack and the three risk reductions were communicated with the use of visual aids [6, 33]. As in Chapter 3 pictographs were used to display the health risk reduction to be valued. Visual Aids were also made available to assist children and parents in the interpretation of the change in health risk (See Appendix 5 for visual aids provided).

Each respondent was asked to value three health risk reductions: 19 in 100 (WTP1); 10 in 100(WTP2) and 4 in 100 (WTP3). The baseline risk reduction was 20 in 100, which was close to the average proportion of children experiencing asthma in the overall sample. Given that the order of the three questions might influence the responses, three different versions of the questionnaire were given in order to explore ordering bias (See Table 5.1).

Table 5.1. Order of questions in the three version of the questionnaire.

Version1	WTP1	WTP2	WTP3
Version2	WTP2	WTP3	WTP1
Version3	WTP3	WTP1	WTP2

3.4 The elicitation format.

Given that this is the first CV study conducted with children there is no existing evidence on which of these methods is the most appropriate to adopt with children. Before constructing the final questionnaire an open-ended CV questionnaire was piloted with a small sample (15) of children aged 7-10 years. The pilot questionnaire was administered in class and almost all the children (12 out of 15 children) asked further questions about how to answer the three open ended questions, with some making the comment that it was difficult to guess an exact value. Following this preliminary study, a second pilot study was conducted using a range of 15 payment card cells. In the second experiment pupils were asked to place a cross in the cell reporting their maximum WTP. All of the children agreed that the format was easier compared with the open ended elicitation.

As shown in the Chapter 4 children involved in the present study, even the younger ones, are able to understand how use money and receive a monthly allowance from their parents. However, given the differences in intra household income allocation it is not possible to compare in absolute terms whether children are willing to pay more or less than their parents for the same health risk reduction. In order to account for the different income distribution between age groups within the child sample

and between children and parents the WTP was estimated in terms of proportion of a pre-defined budget constraint.

For children aged between 7 and 13 years the median monthly budget available by class group was retrieved from the second experiment (see Chapter 4). For children aged 14 years and older a fixed budget constraint of € 200 (the same budget constraint observed in the oldest class group in Chapter 4). CV payment card sets (see Appendix 5) were created using budget constraint information.

In the parent questionnaire only one fixed monthly budget constraint was assumed. It was specified that this is the amount available for the household after paying for accommodation and food expenses. The median household expenditure in Campania is €1.661[34]. Of this amount, according to the Istituto Nazionale di Statistica (ISTAT), 26% is spent on food and 27% on accommodation[34]. However, given that parent sample considered included household coming from different socioeconomic classes a fixed budget constraint of €400 per month was used.

3.5 Debriefing questions

In the child questionnaire, respondents were asked if in principle they would be willing to pay a part of their pocket money to reduce the risk of having an asthma attack before the three risk reductions were presented. If respondents were willing to pay, they were asked the three payment cards questions. If they were unwilling to pay, they were asked about their reasons. A preliminary question regarding the WTP, in principle, for child health risk reduction was omitted in order to shorten the parental questionnaire. However, parents were asked to complete the debriefing questions following the three payment card questions.

Children and their parents were asked the same six debriefing questions to assess respondent motivations for being unwilling to pay for health risk reduction. The responses: “I do not care about health”, “the Mayor should deal with these problems” and “I need more information to answer to this question” tested for protest answers [8]. The remaining questions probed the reasons for not paying

for health risk reductions (e.g. financial reasons, or negligible risk reduction). Finally, children were asked how difficult they found the experiment and also their opinion about the wider research project.

3.6 Statistical Analyses

First descriptive statistics for the samples of children and parents are presented. Mean and standard deviation were estimated for each of the variables measuring parents and children attitudes and behaviours. A correlation analysis was also performed using Spearman correlation coefficients to investigate the relationship between individual characteristics, attitudinal and behavioural answers. Following this descriptive analysis a number of tests respondents' understanding were performed. In particular two tests were considered important to identify those respondents who did not understand, or did not pay enough attention, to the questions. Test 1 verifies whether individuals displayed a decreasing WTP for higher health risk reduction (WTP1<WTP2<WTP3). Test 2 combines results of two different tests: 1) testing that WTP is insensitive to health risk change WTP1=WTP2=WTP3 and 2) testing whether individuals are willing to give up their entire budget for reducing health risk (high protest bids)[8]. Failure of Test1 and 2 is assumed to indicate that either the respondent did not understand the question, or that they did not pay enough attention when completing the questionnaire. Logistic regression was performed to investigate whether children's and parents' characteristics influence the probability of scope sensitivity (WTP1>WTP2>WTP3).

Following this preliminary analysis to test understanding of the CV questions children's and parents' willingness/unwillingness to pay for asthma risk reductions were analysed. Logistic regression analysis was used to investigate whether children's and parents' characteristics, attitudes and behaviours influence the likelihood of agreeing to pay for health risk reductions. For both children and parents the model specification used is: Yes/No = f (characteristics, attitudes, behaviours) where Yes or No is a dichotomous response to the initial WTP question; characteristics, indicates all the demographic and socio-economic variables collected from respondents; attitudes and behaviours the attitudinal and behavioural variables.

Then the mean proportion of the budget that parents and children are willing to pay for the three risk reductions was calculated. The price bids selected by respondents were transformed from absolute numbers (e.g. €5) into proportions using the budget constraint assigned (e.g. if the budget constraint is €32, the amount selected, €5, corresponds to 16% of the budget). A generalized linear model (GLM) with logit link function in order to ensure linearity and binomial family distribution since the dependent variable is bounded between 0 and 1 [35-37]. Beta and a Zero Inflated Beta models were also tested but lead to poorer model estimation.

The objective of stated preference studies is to elicit a WTP value for a change in health risk independently from the respondents' characteristics. If the study involves an unbiased subset of the population the welfare estimates elicited using all sample responses and a constant only model will be representative of the larger population who will benefit from the policy intervention.

The willingness to pay per asthma attack averted was estimated using the following formula:

WTP per asthma attack = WTP/Δr

Where Δr is the size of the reduction in health (e.g. a reduction from 20 in 100 to 1 in 100).

After conducting a constant only model to estimate WTP values the internal validity of the WTP responses was tested by including independent variables in the model. The internal validity of the study is tested by including respondents' characteristics to investigate how they influence the WTP and if they conform to a priori expectations. The analysis was run for all respondents excluding protest answers, and separately for those who passed test 1 and 2 (Flag1 =0).

4. Results

4.1 Descriptive statistical analysis.

Table 5.2 provides descriptive statistics of the child and parental demographic characteristics. The number of children in each age group varied from 38 children (age 7-9 and 18-19) to 114 children in the 14-15 years age group. Overall, more females answered the questionnaire (56% females versus

44% males). The proportion of children who experienced seldom or frequently asthma attacks in the study sample is high, 29%, and does not vary by age groups (in the regression asthma status was dependent variable, and the age coefficient was not statistically significant: β=0.0053375; p= 0.825).

The average age of mothers was 45 years. For fathers, the mean age was higher (47 years). The majority of respondents to the parental questionnaire were females, of which 30% are unemployed, 49% employed in unskilled jobs and 31% employed in jobs requiring a university degree. According to the ISTAT the South of Italy has higher than average proportion of families with more than one child[34]. In the south, the proportion of families with 2 children is 48% versus a national average of 42%. In the sample, the average the family was composed by four individuals ranging from single parent and a child (only 2 cases in the overall sample) to 8 family members (only in 1 case). In the south of Italy, the average household income is €17.416 (42% lower than the average household income in the North) including accommodation expenditure[34]. However, compared to the rest of Italy, Campania has the lowest average income per capita (€16.400)[34]. 50% of the sample has a mean available income excluding food and accommodation expenditure equals to or higher than €600 per month. However, only 15% of the families spend more than €1200 per month. As expected monthly income and profession are highly correlated 47% (p=0.000).

Table .5.2. Children and parents' demographic characteristics

	Female	**Male**	**Total (%)**
Children			
Age			
7-9 years	22	16	38(10%)
10-11 years	41	28	69(19%)
12-13 years	11	30	41(11%)
14-15 years	69	45	114(31%)
16-17 years	45	25	70(19%)
18-19 years	19	19	38(10%)
Total	207	163	370
Asthma			
Frequently	25	16	41(11%)
Seldom	30	33	63(17%)
Never	147	112	259(71%)
Total	202	161	363
Parents			

Mean Age (SD)	45.41(7.49)	47.20(11.1)	
Jobtype			
Unemployed	52	8	60(35%)
Unskilled workers	14	21	35(20%)
Skilled workers	54	24	78(45%)
Total	120	53	173
Family Size	4.29(0.96)	4.28(0.98)	
Family monthly expenditure			
<€600	50	22	72(50%)
€600-€1200	35	15	50(35%)
€1200-€2000	8	4	12(8%)
>€2000	8	2	10(7%)
Total	101	44	144

Table 5.3. Descriptive statistics of children and parents' attitude variable

Variable	Description	Mean	S.D.	Min	Max
	Children				
Environmental-hazards-on-children's-health	Measures how children rate the relationship between environmental hazards and health. Low score indicates no effect of environmental hazards on health. High score indicates that the child believes that environmental hazards highly affect their health.	4.18	0.86	1	5
General-altruism	Dichotomous variable measuring general altruism.	0.96	0.19	0	1
Health-related-altruism	Dichotomous variable measuring health related altruism.	0.62	0.49	0	1
Welfare-related-altruism	Dichotomous variable measuring welfare related altruism.	0.72	0.45	0	1
Non-paternalistic-altruism	Dichotomous variable measuring non-paternalistic altruism	0.74	0.44	0	1
Care-of-children-for own-health	Measures the extent of care children have for their own health.	3.95	1.14	1	5
Health-risk-aversion-1	Dichotomous variable measuring health risk aversion.	0.85	0.31	0	1
Health-risk-aversion-2	Dichotomous variable measuring health risk aversion.	0.34	0.48	0	1
Health-risk-aversion-3	Dichotomous variable measuring health risk aversion.	0.78	0.41	0	1
Health-risk-aversion-4	Dichotomous variable measuring health risk aversion.	0.48	0.50	0	1
Health-risk-aversion-5	Dichotomous variable measuring health risk aversion.	0.81	0.39	0	1
Recreational-risk-aversion-1	Dichotomous variable measuring recreational risk aversion.	0.32	0.47	0	1
Recreational-risk-aversion-2	Dichotomous variable measuring recreational risk aversion.	0.28	0.45	0	1
Recreational-risk-aversion-3	Dichotomous variable measuring recreational risk aversion.	0.33	0.47	0	1
Recreational-risk-aversion-4	Dichotomous variable measuring recreational risk aversion.	0.47	0.50	0	1
Recreational-risk-aversion-5	Dichotomous variable measuring recreational risk aversion.	0.81	0.39	0	1

	Parents				
Environmental-hazards-on-children's-health-parents	Measures how parents rate the relationship between environmental hazards and health. Low score indicates no effect of environmental hazards on health. High score indicates that the parent believes that environmental hazards highly affect health.	4.65	0.64	1	5
Care-for-their-own-health-parents	Measures the extent of care parents have for their own health.	3.95	1.04	1	5
Care-for-children's-health-parents	Measures the extent of care parents have for their children's health.	4.80	0.48	1	5
Recreational-risk-aversion-2-parents	Dichotomous variable measuring recreational risk aversion.	1.36	0.73	0	1
Recreational-risk-aversion-3-parents	Dichotomous variable measuring recreational risk aversion.	1.16	0.73	0	1
Recreational-risk-aversion-5-parents	Dichotomous variable measuring recreational risk aversion.	1.80	0.48	0	1
Health-risk-aversion-5-parents	Dichotomous variable measuring health risk aversion.	1.40	0.77	0	1
Health-risk-aversion towards-children	Dichotomous variable measuring health risk aversion.	1.84	0.48	0	1

S.D. Standard Deviation

Table 5.3 provides a description of the variables used in the model along with their descriptive statistics for measuring attitudes and behaviours among children and their parents.

Table 5.4 investigates the relationship between child characteristics (age and gender) and attitudes in the different contexts. As evident in the second column, it appears that care for one's own health and health-related altruism is negatively associated with age. Non-paternalistic altruism increases with age together with the use of seatbelts in cars (used as proxy for health risk aversion). Gender does not seem to influence attitudes and beliefs. This is surprising given that previous studies have shown that boys tend to be more risk prone than girls at younger ages [38]. General altruism measure is positively correlated with third and fourth (non-paternalistic altruism) altruism measures; however, not with the second (health-related altruism). The second and third measures of altruism tests health and welfare related altruism. As expected, these are highly correlated. However, the correlation coefficient value indicates that the second measure explains only 15% of the variation of the third measure. Within the health risk and recreational risk measures, coefficients are positively correlated (correlation coefficient with a negative sign are not statistically significant) indicating a single underlying trait of risk aversion within the two contexts considered. Nevertheless, only some

coefficients are statistically significant. In particular, the second measure of health risk aversion: "I always use sunscreen when sunbathing" is positively and significantly correlated with all the recreational risk aversion indicators. Table 5.5 shows the results of the correlations for parental characteristics, attitudes and behaviours. As expected, the likelihood of smoking and the probability of practicing sport decreases with age, so too does risk aversion and trust in the relationship between environment and health. Confirming the findings of previous studies, men are more risk taking than women[39]. Gender also seems to be related with trust in the relationship between environmental hazards and health. Parents employed in skilled jobs are more likely to care for their health and to practice sport. Further, they are less likely to smoke and they are also more risk taking. The degree of trust in the relationship between environmental hazards and health is positively associated with risk aversion and care for one's own health. The two measures of risk aversion, recreational-risk-aversion-2 and recreational risk-aversion-3 , are strongly related. However, the likelihood of smoking decreases with risk aversion and health risk aversion. As expected, where parents are smokers, they are also less likely to engage in physical activity.

Table 5.4. Relationship between children's characteristics and attitudes and behaviours.

	Age	Gender	Environmnetal hazards on chidlren health	Care-of-children-for own-health	General-altruism	Health-related-altruism	Welfare-related-altruism	Non-paternalistic-altruism	Health-risk-aversion-1
Age	1								
Gender	-.029	1							
Environmental hazards on children health	.097	-.088	1						
Care-of-children-for own-health	.315***	.035	-.131*	1					
General-altruism	.032	-0.093	.092	-.007	1				
Health-related-altruism	-.327***	-.060	.009	.217***	.032	1			
Welfare-related-altruism	-.097	-.084	.074	.092	.118*	.155***	1		
Non-paternalistic-altruism	.238***	-.037	.006	-.070	.186***	-.001	.193***	1	
Health-risk-aversion-1	.115*	-.052	-.019	.072	.152***	-.051	.062	.0618	1
Health-risk-aversion-2	-.393***	-.041	.092	.115*	.034	.239***	.106*	-.0117*	-.047
Health-risk-aversion-3	-.084	-.085	.072	.207***	.059	.093	.198***	.0580	.142**
Health-risk-aversion-4	.120*	-.030	.076	.057	.059	.045	.030	.045	.063
Health-risk-aversion-5	.349***	-.079	.108	.002	.194**	-.069	-.001	.137**	.126*
Recreational-risk-aversion-1	-.333***	-.038	.004	.171**	.046	.154**	.126*	-.144**	.048
Recreational-risk-aversion-2	-.115	-.072	.029	.017	.099	.048	.015	-.023	-.153*
Recreational-risk-aversion-3	-.404***	.095	-.063	.229***	-.013	.167**	.084	-.032	.067
Recreational-risk-aversion-4	-.143**	-.129*	-.303	-.122	.044	.084	.126	.083	-.058
Recreational-risk-aversion-5	-.067	-.049	.087	.162**	-.248	.106*	.083	.021	-.002

Continues…

	Health-risk-aversion2	Health-risk-aversion3	Health-risk-aversion4	Health-risk-aversion5	Recreational-risk-aversion1	Recreational-risk-aversion2	Recreational-risk-aversion3	Recreational-risk-aversion4
Health-risk-aversion1								
Health-risk-aversion2	1							
Health-risk-aversion3	-.024	1						
Health-risk-aversion4	.022	-.024	1					
Health-risk-aversion5	.133*	-.017	.224**	1				
Recreational-risk-aversion1	**.181****	**.063**	**-.081**	**-.117**	**1**			
Recreational-risk-aversion2	**.212*****	**.037**	**.041**	**-.0118**	**-.032**	1		
Recreational-risk-aversion3	**.229*****	**.067**	**-.019**	**-.147**	**.344*****	.197**	1	
Recreational-risk-aversion4	**.180****	**.112***	**.005**	**-.094**	**.300*****	.016	.124*	**1**
Recreational-risk-aversion5	.105*	.119*	.069	.057	-.035	.030	.016	.124*

Table 5.5 Relationship between parents' characteristics and attitudes and behaviours.

	Parent Age	Parent Gender	Jobtype	Environmental-hazards-on-children's-health-parents	Care-for-their-own-health-parents	Care-for-children's-health-parents
Parent Age	1					
Parent Gender	.095	1				
Jobtype	.453***	.142	1			
Environmental-hazards-on-children's-health-parents	-.157*	-.226**	-.136	1		
Care-for-their-own-health-parents	-.068	.026	-.103	.228*	1	
Care-for-children's-health-parents	-.065	-.069	-.122	-.147	.218**	1
Recreational-risk-aversion-2-parents	-.058	-.224**	-.143	.197*	.004	.077
Recreational-risk-aversion-3-parents	-239**	.024	-.236**	.027	.147	-.007
Recreational-risk-aversion-5-parents	.056	-.051	.051	.070	.167*	.118
Health-risk-aversion-5-parents	.104	-.186*	.101	.148	.130	-.178*
Health-risk-aversion towards-children	.007	-.078	.102	.120	-.087	-.023
Smoking	-.166*	-.079	-.334***	.039	-.021	.122
Exercising	.164*	.016	.323***	.044	.050	-.129

Continues....

	Recreational-risk-aversion-2-parents	Recreational-risk-aversion-3-parents	Recreational-risk-aversion-5-parents	Health-risk-aversion-5-parents	Health-risk-aversion towards-children	Smoking
Parent Age						
Parent Gender						
Jobtype						
Environmental-hazards-on-children's-health-parents						
Care-for-their-own-health-parents						
Care-for-children's-health-parents						
Recreational-risk-aversion-2-parents	1					
Recreational-risk-aversion-3-parents	.204**	1				
Recreational-risk-aversion-5-parents	.145	.022	1			
Health-risk-aversion-5-parents	.148	-.129	-.022	1		
Health-risk-aversion towards-children	.077	-014	-.022	.163*	1	
Smoking	.027	.185*	-.189*	-.170*	-.146	1
Exercising	**-.125**	**-.133**	**0.000**	**.292*** **	**.113**	**-.205** **

4.2 Risk comprehension.

The main test used for assessing the validity of WTP estimates elicited with stated choice experiments is the scope test, in which WTP increases with the size of the health risk reduction. Among the different types of inconsistency with the scope test the one used in the present study - higher WTP for lower health risk reduction - clearly shows that respondents did not understand and/or did not pay attention to the three WTP questions posed. Other types of inconsistencies associated with the scope test were also conducted (See Table 3 and Table 4 in the Appendix 5). The proportion of children and parents failing to pass Test 1 (Test1=1 if WTP1<WTP2<WTP3) was low, 4% for both parents and children (12 children did not pass the test). Test 2 combines results of two different tests: first that WTP is insensitive to health risk change WTP1=WTP2=WTP3 and second those individuals are willing to give up their entire budget for reducing the health risk of asthma attack (WTP = budget constraint). The number of children failing to pass Test 2 (Test2=1) was low, 3 children on 370 (1% of the overall sample); for parents, this proportion was significantly higher (17 respondents; 10% of the overall sample). The overall number parents that did not pass both testes (Flag1=1) is 24 (14% of the sample) while for children the proportion of incorrect answers was considerably lower, 15, corresponding to 4% of the overall sample.

According to economic theory, WTP should be sensitive to the size of the health risk reduction (WTP1 > WTP2 > WTP3) [8]. In the child sample, almost 60% of children complied with the theory. For parents, however, a substantial proportion gave WTP values that were insensitive to the size of health risk reduction (32%).

The logistic regression reported in Table 5.6 explores possible factors influencing WTP scope sensitivity (WTP1>WTP2>WTP3). Age was a significant predictor of the probability of providing scope sensitive WTP estimates. For parents, type of job seemed to be important in determining the likelihood of providing risk sensitive estimates (See Table 5.7). In particular, it seems that those who are employed in a profession requiring a university degree are almost twice as likely to provide increasing WTP with increasing health risk reductions.

Table 5.6. Determinants of WTP1>WTP2 & WTP2>WTP3 in children. Logistic Regression results.

Variable	Odds Ratio (S.E.)
Age	
7-9 vs. 10-11	1.57(0.68)
7-9 vs. 12-13	2.75(1.32)*
7-9 vs. 14-15	3.02(1.22)**
7-9 vs. 16-17	4.66(2.04)***
7-9 vs. 18-19	3.44(1.67)**
Gender (Female vs. Male)	0.81(0.17)
Constant	0.44(0.16)*
Log Likelihood	-246.26

S.E. Standard Error; *p<0.05; **p<0.01; ***p<0.001

Table 5.7. Determinant of WTP1>WTP2 & WTP2>WTP3 in parents. Logistic Regression results.

Variable	Odds Ratio (S.E)
Age	1.00(0.02)
Jobtype	
Unemployed vs employed	1.29(0.65)
Unemployed vs. Highly skilled employee	2.33(1.00)*
Family size	1.04(0.18)
Gender (Female vs. Male)	0.90(0.34)
Constant	0.25(0.32)
Log Likelihood	-110.02

S.E. Standard Error; *p<0.05; **p<0.01; ***p<0.001

4.3 Willingness to pay for health risk reduction: Yes or No.

Table 5.8 shows the percentage of 'yes' answers to the initial question in the child questionnaire: "Are you willing to pay for health risk reduction of having an asthma attack?". Only 9% of children reported unwillingness to pay for health risk reduction. At the debriefing, the majority of the children who refused to pay for health risk reduction said that the "Mayor who should deal with this problem". The second most popular reason for not paying for health risk reduction was a commitment to other priorities. According to Bateman et al. those children who said yes to the questions: "I do not care about health" and/or "The Mayor should deal with these problems" and "I need more information to answer the question" were classified as protest answers and excluded from the analysis (number of children excluded 34) [40].

Table 5.9 shows the percentage of 'yes' answers for the three health risk reductions. According to economic theory, the percentage of zero answers to WTP questions increases with the decreasing size of the health risk reduction.

Table 5.8. Descriptive analysis of children's willingness to pay for health risk reductions.

	Children		**Parents**	
	Yes	**No**	**Yes**	**No**
Willingness to pay	336(91%)	34(9%)	NA	NA
WTP1	334(99%)	2(0.6%)	165(95%)	8(4.6%)
WTP2	334(99%)	2(0.6%)	162(93%)	11(7%)
WTP3	326(97%)	10(3%)	160(92)	13(8%)

NA: not available

Table 5.9. Descriptive analysis of children's answers to debriefing questions.

	Yes (%)	**No (%)**
I do not care about health	11(32%)	23(68%)
The Mayor should deal with these problems	29 (85%)	5(15%)
I do not have enough money to deal with this problem	15(44%)	19(15%)
I think there are other priorities	21(62%)	13(38%)
The change in health risk was too low	15(44%)	19(56%)
I needed more information to answer to the question	12(35%)	22(65%)

Of the 173 parents who returned the questionnaire, only 8 (4.6%) refused to pay for the highest health risk reduction (1 in 100). All those refusing to pay said that the Mayor should deal with the problem. As for children, the proportion willing to pay zero slightly increased with the size of the health risk reduction, and for all answer types the proportion was higher for parents compared with children. Table 5.10 shows the results of the logistic regression investigating possible factors influencing WTP (yes or no) in children. As seen, for children, the trust in the relationship between environmental

hazards and health was a strong predictor for deciding whether, in principle, they were willing to pay for a health risk reduction. In the case of parents, all the covariates were not statistically significant.

Table 5.10. Logistic Regression. Children Willing to pay (Yes or No).

Variables	**Model 1**	**Model 2**
Age	**Odds Ratio (S.E)**	**Odds Ratio (S.E)**
7-9 vs. 10-11	0.45(0.41)	0.84(0.94)
7-9 vs. 12-13	1.06(1.08)	2.32(3.02)
7-9 vs. 14-15	0.76(0.69)	0.89(1.11)
7-9 vs. 16-17	0.84(0.57)	0.50(0.64)
7-9 vs. 18-19	0.67(0.50)	0.32(0.44)
Asthma		
Frequently vs. Seldom	2.06(1.34)	2.06(1.51)
Frequently vs. Never	0.71(0.43)	0.99(0.81)
Gender	0.24(0.11)	0.38(0.20)
Ln(PocketMoney)	0.94(0.18)	0.91(0.20)
Environmental-hazards-on-children's-health		2.10(0.55)**
General-altruism		0.39(0.48)
Health-related-altruism		1.11(0.58)
Welfare-related-altruism		2.29(1.28)
Non-paternalistic-altruism		1.67(0.99)
Recreational-risk-aversion-1		0.99(0.62)
Recreational-risk-aversion-2		3.07(2.09)
Recreational-risk-aversion-3		0.52(0.31)
Recreational-risk-aversion-4		0.52 (0.28)
Recreational-risk-aversion-5		2.56(1.33)
Health-risk-aversion-1		1.03(0.94)
Health-risk-aversion-2		1.38(0.89)
Health-risk-aversion-3		0.77(0.45)
Health-risk-aversion-4		1.96(1.02)
Health-risk-aversion-5		1.54(1.01)
Care-of-children-for own-health		1.02(0.22)
Constant		0.59(1.24)
Log Likelihood	-86.30	-65.32

S.E. Standard Error ; *p<0.05; **p<0.01; ***p<0.001

4.4 Children's and parents' WTP as percentage of the available budget

Table 5.11 shows the results of GLM constant only model for the entire sample (excluding protest answers) and separately for those who failed the Test 1 and 2 (Flag1=0). As expected, the mean WTP is significantly larger for higher risk reduction than lower risk reductions for both parents and their children. Among children who satisfied the rationality test, the mean WTP ranged from 22% for the highest risk reduction (19 asthma attacks in 100 children risk reduction) to 11% (4-in-100 risk reduction)(Table 5.12). Among parents, the proportion of the budget they were willing to give up was significantly higher, ranging from 35% to 19% of the available budget. Parents WTP estimates (calculated by multiplying the parents' proportion of the budget by the budget constraint used in the experiment €400) for 19, 10 and 4 in 100 risk reduction are €140, €96 and €76 respectively (See the Appendix 6 for the description of the different theoretical models). For children, however, WTP depends on the theoretical model used. Where it is assumed that children faced parental budget constraints (€400), the WTP is €88 (19 in 100 risk reduction), €56 (10 in 100) and €44 (4 in 100 risk reduction).

Table 5.13, reports the ratios of WTP estimates for different health risk reductions.

As shown, both children and parental WTP estimates are sensitive to the size of the health risk reduction. Nevertheless, they do not exhibit proportionality in relation to the size of the health risk reduction. These findings hold even where the analysis is restricted to those who passed both Test 1 and Test 2. Parents' WTP per asthma attack averted is €7.3, €9.6 and €19 for 19 in 100, 10 in 100 and 4 in 100 health risk reduction respectively. As for the parents also for children the WTP is not proportional to the size of the health risk reduction. The corresponding WTP per asthma attack averted estimated using household budget and children's perspective is, depending on the size of the health risk reduction: €4.6, €5.6 and €11.

Table 5.14 compares the WTP estimates for parents, divided by child WTP, for the same health risk reduction. As shown, parental WTP estimates always exceed those of their children, however, the difference narrows for highest health risk reduction.

Table 5.11. Generalized linear model regression results (Constant Only Model)

Children	Total Sample		Flag1 =0	
	Coefficient	Robust Standard Error	Coefficient	Robust Standard Error
19-in-100 risk reduction				
Constant	-1.27***	0.06	-1.28***	0.06
Log-Likelihood	-130.6		-122.83	
N	336		321	
10-in-100 risk reduction				
Constant	-1.73***	0.06	-1.80***	0.05
Log-Likelihood	-106.13		-96.49	
N	336		321	
4-in-100 risk reduction				
Constant	-1.99***	0.05	-2.11***	0.08
Log-Likelihood	-96.37		-85.15	
N	336		321	
Parents				
19-in-100 risk reduction				
Constant	-0.35**	0.11	-0.63***	0.10
Log-Likelihood	-95.32		-79.40	
N	165		141	
10-in-100 risk reduction				
Constant	-0.76***	0.11	-1.35***	0.10
Log-Likelihood	-87.07		-65.50	
N	165		141	
4-in-100 risk reduction				
Constant	-0.97***	0.12	-1.42***	0.11
Log-Likelihood	**-84.52**		-59.87	
N	165		141	

Flag 1 =1: WTP answers failed to pass either Test1 or Test2. *p<0.05; **p<0.01; ***p<0.001

Table 5.12. Mean (95%CI) WTP as proportion of the available budget.

	WTP1		WTP2		WTP3	
	All observations	**Without Flag 1=1**	**All observations**	**Without Flag 1=1**	**All observations**	**Without Flag 1=1**
Children						
Mean	0.22 (0.20-0.24)	0.22 (0.20-0.24)	0.15 (0.14-0.17)	0.14 (0.13-0.15)	0.12 (0.10-0.13)	0.11 (0.06-0.12)
Parents						
Mean	0.41 (0.36-0.46)	0.35 (0.30-0.39)	0.31 (0.27-0.35)	0.24 (0.21-0.28)	0.27 (0.23-0.32)	0.19 (0.16-0.23)

Table 5.13. Internal scope test: is WTP proportional to the size of the health risk reduction?

	Ratio 19 in 100 to 10 in 100		Ratio 19 in 100 to 4 in 100		Ratio 10 in 100 to 4 in 100	
	All	**Without Flag 1=1**	**All**	**Without Flag 1=1**	**All**	**Without Flag 1=1**
Children						
Mean	1.46	1.57	1.83	2	1.25	1.27
Parents						
Mean	1.32	1.45	1.50	1.84	1.14	1.26

Table 5.14. Are the children's WTP values different from parents?

	WTP1 parents/WTP1 children		WTP2parents/WTP2 children		WTP3 parents/WTP3 children	
	All	**Without Flag 1=1**	**All**	**Without Flag 1=1**	**All**	**Without Flag 1=1**
Mean	1.86	1.59	2.06	1.71	2.25	1.72

4.5 The effect of children and parents socio-demographic characteristics on WTP

Table 5.15, presents the results of generalized linear regression model for those children who passed Test1 and Test2 (Flag1=0). Model 1 examines the effect of risk reduction size and socioeconomic characteristics such as age, gender and child asthma status on child and parental WTP for childhood asthma risk reductions by including covariates to the constant and the regression model. The WTP is highly related to the size of the risk reduction. As expected the higher the size of the health risk reduction the higher the WTP. However, the coefficient is lower than 1 indicating that, consistent with the results of previous studies, WTP is not proportional to the size of the health risk reduction.

In the case of children, the signs of the other coefficients are not known *a priori* for the reason that this is the first study to elicit WTP from their perspective. The statistically significant, negative coefficient of age indicates that children are willing to pay less for health risk reduction as they become older. The asthma coefficient is negative, indicating that the lower the frequency of asthma attack the lower the WTP for asthma health risk reduction. However, the coefficient is not statistically significant in Model 1. As for children, parental WTP is also significantly related to the size of the health risk reduction confirming the validity of the study. Surprisingly, the coefficient for parents is lower than for children, suggesting that child WTP is more proportional to the size of the health risk reductions. In Model 1, neither parental nor child age influence parental WTP for health risk reduction.

As seen in the correlation analysis, available household income (without accommodation and food expenses) is highly correlated with the parental job-types (Jobtype is 0= unemployed, 1= unskilled employee, 2= skilled employee). Thus, it is not surprising that there is a statistically significant increase in parents' WTP as job status increases.

In order to provide greater flexibility in the analysis of child responses, Model 2 includes the age, the size of the health risk reduction and the asthma status as dummies. Where the age coefficients are expressed as dummies, WTP is similar among those aged between 7 and 13 years and decreases significantly for those 14 years or older whose WTP amounts are on average 75% lower than those of younger respondents. Rather than including asthma as single indicator, it is possible to include it as a separate dummy accounting for frequency of asthma attack. As a result, those who experience frequent asthma attack have a higher (+25%) WTP compared with those who seldom suffer from asthma. However, no difference was detected between those who suffer from asthma frequently compared with those who have never suffered it.

For the analysis of the parental questionnaire under Model 2, the size of the health risk reductions as well as Job-type were included as dummies. Interestingly, the model finds that the age of the child is negatively related with parental WTP. Results of model 2 also shows that parents employed in a highly skilled job have a higher WTP compared with unemployed parents. Marginal effects are also reported in Table 5.17 and 5.18 for children and parents respectively. Marginal effects provide

information about the amount of change in WTP that will be produced by a 1-unit change in the independent variables. In the case of children, for instance, everything else equal, we would expect a 3% increase in WTP if the risk reduction offered by the policy changes from small to medium and a 10% increase if it changes from small to large risk reduction.

Table 5.15. Internal Validity of WTP estimates: children sample.

Variable	Model 1	Model 2	Model 3	Model 4
	Coeff.(S.E.)	Coeff.(S.E.)	Coeff.(S.E.)	Coeff.(S.E.)
Risk Reduction	0.41(0.00)***		-0.43(0.04)***	
Small risk reduction vs. medium risk reduction		0.30(0.06)***		0.31(0.07)***
Small risk reduction vs. large risk reduction		0.81(0.07)***		0.84(0.08)***
Child Age	-0.21(0.00)***		-0.16(0.06)**	
7-9 vs. 10-11		0.01(0.23)		0.22(0.22)
7-9 vs. 12-13		-0.13(0.28)		0.09(0.30)
7-9 vs. 14-15		-0.84(0.21)***		-0.72(0.25)**
7-9 vs. 16-17		-0.79(0.22)***		-0.67(0.25)**
7-9 vs. 18-19		-0.72(0.27)**		-0.62(0.33)
Asthma	-0.16(.09)		-0.18(0.10)*	
Frequently vs. Seldom		-0.25(0.12)*		-0.34(0.14)
Frequently vs. Never		-0.28(0.19)		-0.27(0.20)
Child Gender	0.11(0.13)	0.06(0.13)	0.28(0.13)*	0.23(0.12)*
Ln(PocketMoney)	-0.10(0.06)	0.10(0.06)	-0.13(0.56)*	-0.12(0.01)*
			0.18(.08)*	0.21(0.07)**
General-altruism			-0.39(0.31)	-0.37(0.35)
Health-related-altruism			0.14(0.13)	0.17(0.13)
Welfare-related-altruism			0.12(0.14)	-0.00(0.14)
Non-paternalistic-altruism			0.39(0.15)**	0.44(0.15)**
Recreational-risk-aversion-1			0.12(0.13)	0.02(0.14)
Recreational-risk-aversion-2			0.12(0.13)	0.14(0.13)
Recreational-risk-aversion-3			-0.17 (0.15)	-0.28(0.13)
Recreational-risk-aversion-4			-0.16 (0.13)	-0.12(0.12)
Recreational-risk-aversion-5			0.12(0.16)	0.08(0.17)
Health-risk-aversion-1			-0.18(0.25)	-0.15(0.23)

Health-risk-aversion-2			0.22(0.14)	0.17(0.13)
Health-risk-aversion-3			-0.05(0.16)	-0.10(0.16)
Health-risk-aversion-4			0.01(0.12)	0.03(0.12)
Health-risk-aversion-5			0.09(0.17)	0.16(0.18)
Care-of-children-for own-health			-0.13(0.07)	-0.11(0.07)
Constant	0.38(0.27)	-0.44(0.24)	-0.28(0.61)	-1.21(0.59)*
Log Likelihood	-266.79	-264.53	-249.06	-246.59
AIC	545.59	553.16	542.13	549.18
BIC	574.36	610.71	646.57	685.12

S.E. Standard Error; *p<0.05; **p<0.01; ***p<0.001; Individuals who did not pass Test 1 or Test 2 are not included in the analysis (Flag =1)

Table 5.16. Internal Validity of WTP estimates: parents sample.

Variable	**Model 1**	**Model 2**	**Model 3**	**Model 4**
	Coeff.(S.E.)	Coeff.(S.E.)	Coeff.(S.E.)	Coeff.(S.E.)
Risk Reduction	0.36(0.05)***		0.41(0.06)***	
Small risk reduction vs. medium risk reduction		0.24(0.06)***		0.28(0.04)***
Small risk reduction vs. large risk reduction		0.71(0.10)***		-0.82(0.11)***
Parent Age	-0.00(0.01)	-0.001(0.02)	-0.01(0.02)	-0.01(0.02)
Child Age	-0.11(0.06)	-0.12(0.06)*	-0.05(0.07)	-0.07(0.06)
Parent Gender	0.22(0.26)	0.29(0.27)	0.62(0.29)*	0.74(0.32)
Child Gender	-0.39(0.23)	-0.39(0.23)	-0.32(0.25)	-0.35(0.25)
Familysize	0.02(0.11)	0.02(0.12)	-0.08(0.13)	0.07(0.13)
Asthma Child	-0.17(0.19)	-0.17(0.19)	-0.39(0.20)	-0.39(0.19)*
Jobtype	0.41(0.21)*		0.48(0.22)*	
Unemployed vs. Employed		0.17(0.37)		0.09(0.36)
Unemployed vs. Highly skilled employee		0.88(0.41)*		1.01(0.43)*
Ln(Family budget)	0.19(0.10)	0.19(0.15)	0.12(0.16)	0.12(0.16)
Environmental-hazards-on-children's-health-parents			0.51(0.23)*	0.56(0.23)*
Health-risk-aversion-5-parents			0.45(0.17)**	0.45(0.17)**

Health-risk-aversion towards-children			0.20(0.21)	0.20(0.20)
Smoking			-0.11(0.13)	-0.08(0.13)
Exercising			-0.03(0.17)	-0.02(017)
Recreational-risk-aversion-2-parents			0.17(0.18)	0.14(0.18)
Recreational-risk-aversion-3-parents			0.04(0.15)	0.05(0.15)
Recreational-risk-aversion-5-parents			-0.40(0.27)	-0.35(0.28)
Care-for-their-own-health-parents			-0.44(0.12)***	-0.46(0.12)***
Care-for-children's-health-parents			0.67(0.34)*	0.61(0.34)
Constant	-0.33(1.07)	-0.01(1.11)	-0.66(2.87)	-4.19(2.84)
Log Likelihood	-199.34	-198.87	161.31	-160.55
AIC	418.69	421.74	362.63	365.10
BIC	458.58	469.60	440.35	450.60

S.E. Standard Error; *p<0.05; **p<0.01; ***p<0.001; Individuals who did not pass Test 1 or Test 2 are not included in the analysis (Flag =1)

Table 5.17. Internal Validity of WTP estimates marginal effects: cchildren sample.

Variable	**Model 1**	**Model 2**	**Model 3**	**Model 4**
	dy/dx(S.E.)	dy/dx(S.E.)	dy/dx(S.E.)	dy/dx(S.E.)
Risk Reduction	0.05(0.00)***		0.05(0.00)***	
Small risk reduction vs. medium risk reduction		0.03(0.01)***		0.03(0.01)***
Small risk reduction vs. large risk reduction		0.10(0.01)***		0.10(0.01)***
Child Age	-0.02(0.01)***		-0.02(0.01)**	
7-9 vs. 10-11		0.00(0.04)		0.03(0.03)
7-9 vs. 12-13		-0.02(0.04)		0.00(0.05)
7-9 vs. 14-15		-0.11(0.03)***		-0.11(0.04)**
7-9 vs. 16-17		-0.10(0.03)***		-0.10(0.03)**
7-9 vs. 18-19		-0.09(0.03)**		-0.10(0.04)
Asthma	-0.02(.01)		-0.02(0.01)*	
Frequently vs. Seldom		-0.03(0.01)*		-0.03(0.01)
Frequently vs. Never		-0.03(0.02)		-0.03(0.02)
Child Gender	0.01(0.01)	0.01(0.01)	0.03(0.01)*	0.02(0.01)*

Ln(PocketMoney)	-0.01(0.01)	0.01(0.01)	-0.01(0.01)*	-0.01(0.01)*
			0.03(.01)*	0.03(0.01)**
General-altruism			-0.05(0.03)	-0.05(0.03)
Health-related-altruism			0.02(0.02)	0.02(0.02)
Welfare-related-altruism			0.01(0.02)	-0.00(0.02)
Non-paternalistic-altruism			0.04(0.02)**	0.05(0.02)**
Recreational-risk-aversion-1			0.02(0.02)	0.00(0.02)
Recreational-risk-aversion-2			0.01(0.02)	0.02(0.02)
Recreational-risk-aversion-3			-0.01 (0.02)	-0.03(0.02)
Recreational-risk-aversion-4			-0.02 (0.01)	-0.01(0.02)
Recreational-risk-aversion-5			0.02(0.02)	0.01(0.02)
Health-risk-aversion-1			-0.02(0.03)	-0.01(0.03)
Health-risk-aversion-2			0.02(0.01)	0.02(0.01)
Health-risk-aversion-3			-0.00(0.01)	-0.00(0.01)
Health-risk-aversion-4			0.00(0.01)	0.00(0.01)
Health-risk-aversion-5			0.02(0.02)	0.02(0.02)
Care-of-children-for own-health			-0.00(0.01)	-0.00(0.01)

S.E. Standard Error; *p<0.05; **p<0.01; ***p<0.001; Individuals who did not pass Test 1 or Test 2 are not included in the analysis (Flag =1)

Table 5.18. Internal Validity of WTP estimates marginal effects: parents sample.

Variable	**Model 1**	**Model 2**	**Model 3**	**Model 4**
	dy/dx(S.E.)	dy/dx(S.E.)	dy/dx(S.E.)	dy/dx(S.E.)
Risk Reduction	0.08(0.01)***		0.08(0.01)***	
Small risk reduction vs. medium risk reduction		0.05(0.01)***		0.05(0.01)***
Small risk reduction vs. large risk reduction		0.15(0.02)***		0.16(0.02)***
Parent Age	-0.00(0.00)	-0.00(0.00)	-0.00(0.00)	-0.00(0.00)
Child Age	-0.02(0.01)	-0.02(0.01)*	-0.01(0.01)	-0.01(0.01)
Parent Gender	0.05(0.05)	0.06(0.06)	0.12(0.05)*	0.14(0.06)

Child Gender	-0.08(0.05)	-0.08(0.05)	-0.06(0.04)	-0.07(0.05)
Familysize	0.02(0.11)	0.00(0.02)	-0.02(0.03)	0.01(0.03)
Asthma Child	-0.04(0.04)	-0.04(0.04)	-0.07(0.04)	-0.08(0.04)*
Jobtype	0.08(0.04)*		0.09(0.04)*	
Unemployed vs Employed		0.03(0.07)		0.06(0.02)
Unemployed vs. Highly skilled employee		0.19(0.08)*		0.20(0.08)*
Ln(Family budget)	0.04(0.03)	0.04(0.03)	0.02(0.03)	0.02(0.03)
Environmental-hazards-on-children's-health-parents			0.10(0.04)*	0.10(0.04)*
Health-risk-aversion-5-parents			0.09(0.03)**	0.09(0.03)**
Health-risk-aversion towards-children			0.04(0.04)	0.04(0.04)
Smoking			-0.02(0.03)	-0.02(0.01)
Exercising			-0.00(0.03)	-0.00(0.03)
Recreational-risk-aversion-2-parents			0.03(0.03)	0.03(0.03)
Recreational-risk-aversion-3-parents			0.01(0.02)	0.01(0.03)
Recreational-risk-aversion-5-parents			-0.08(0.05)	-0.07(0.05)
Care-for-their-own-health-parents			-0.09(0.02)***	-0.09(0.02)***
Care-for-children's-health-parents			0.13(0.06)*	0.12(0.06)

S.E. Standard Error; *p<0.05; **p<0.01; ***p<0.001 Individuals who did not pass Test 1 or Test 2 are not included in the analysis (Flag =1)

4.6 Mean WTP by Children Age group

In Table 5.19-5.20 the mean WTP was estimated for two broad age groups (7-13 years and 14-19 years) of children found to have different WTP in the previous analysis. As before WTP was estimated as the mean proportion of the budget by fitting a constant only generalized linear model for each

subsample. Consistent with previous findings, despite the absolute budget available increasing with the age of the child, WTP, estimated as proportion of the budget, decreases for older children. In the youngest age group, the mean proportion of the budget that children are willing to give up for reducing the risk of having an asthma attack ranges, according to the size of the risk reduction, between 17% and 29%. For the oldest age group the proportion is considerably lower ranging between 8% and 18%.

Age-specific children WTP mean values adjusted for parents' budget constraint (€400) range between €68 and €116 for the youngest age groups and between €32 and €72 for the oldest children (Table 5.21). Assuming a household budget, the WTP per asthma attack averted are €6.1 (19 in 100), €8 (10 in 100) and €17 (4 in 100) for the youngest age group and €3.78 (19 in 100), €4.4 (10 in 100) and €8 for the oldest age group(4 in 100) .

Table 5.22 reports children's WTP estimates based on -specific budget constraints for those children who passed both Test 1 and Test 2 (Flag1=0). As seen, despite younger children being willing to pay more, given their budget their WTP is low even for the highest risk reduction. The WTP per asthma attack varies according to both the budget and the risk size. For example, for the youngest age group it ranges between €0.11 and €0.32 while for the oldest age group is €1.89 for the highest health risk reduction and €4 for the 4 in 100 health risk reduction.

Table 5.19. Generalized linear model regression results (Constant Only Model) by children age groups

	WTP1		**WTP2**		**WTP3**	
Children (7-13 years) All Observations						
	Coefficient	S.E.	Coefficient	S.E.	Coefficient	S.E.
Constant	-0.844366***	0.0921	-1.2818***	0.09123	-1.4574***	0.1097
L-L	-59.98		-51.23		-48.93	
N	137		137		137	
Children (14-19 years)						
	Coefficient	S.E.	Coefficient	S.E.	Coefficient	S.E.
Constant	-1.5268***	0.0696	-1.9864***	0.0727	-2.311***	0.1075
L-L	-82.87		-66.43		-57.19	
N	199		199		199	
Children (7-13 years) Without Flag 1=1						
	Coefficient	S.E.	Coefficient	S.E.	Coefficient	S.E.
Constant	-0.8721***	0.0860	-1.39527***	0.0762	-1.6069***	0.1061
L-L	-53.88		-43.968		-41.56	
N	129		129		129	

Children (14-19 years) Without Flag 1=1						
	Coefficient	S.E.	Coefficient	S.E.	Coefficient	S.E.
Constant	-1.5216***	0.0673	-2.0139***	0.0681	-2.4531***	0.0971
L-L	-79.01		-62.02		-49.30	
N	193		193		193	

S.E. Standard Error *p<0.05; **p<0.01; ***p<0.001; L-L = Log-Likelihood

Table 5.20. Mean WTP values by age group and size of the health risk reduction

Variable	Mean WTP1 (95%CI)	Mean WTP2 (95%CI)	Mean WTP3 (95%CI)
Children (7-13 years) All	0.30(0.26-0.34)	0.22(0.19-0.25)	0.19(0.16-0.22)
Children (14-19 years) All	0.18(0.16-0.20)	0.12(0.10-0.14)	0.09(0.07-0.11)
Children (7-13 years)Without Flag 1=1	0.29(0.26-0.33)	0.20(0.17-0.22)	0.17(0.14-0.19)
Children (14-19 years) Without Flag 1=1	0.18(0.16-0.20)	0.11(0.10-0.13)	0.08(0.07-0.09)

Table 5.21. Mean WTP values adjusted for parents' budget constraint

Variable	Mean WTP1	Mean WTP2	Mean WTP3
Children (7-13 years)	€116 (104-132)	€80 (68-88)	€68 (56-76)
Children (14-19 years)	€72 (64-80)	€44 (40-52)	€32 (28-36)

Table 5.22. Mean WTP values adjusted for differences in preferences between age groups and for class-specific budget constraint (€2013)

Budget group	Mean WTP1	Mean WTP2	Mean WTP3
€7.5 (Age 7-8)	€2.17 (1.95-2.48)	€1.5 (1.28-1.65)	€1.28 (1.05-1.42)
€21 (Age 8-9)	€6.09 (5.46-6.93)	€4.2 (3.57-4.62)	€3.57 (2.94-3.99)
€32 (Age 10-11)	€9.28 (8.32-10.56)	€6.4 (5.44-7.04)	€5.44 (4.48-6.08)
€43 (Age 12-13)	€12.47 (11.18-14.19)	€8.6 (7.31-9.46)	€7.31 (6.02-8.17)
€200 (Age 14-19)	€36 (32-40)	€22 (20-26)	€16 (14-18)

4.7 The effect of children's and parents' attitudes and behaviours on WTP

Model 3 of Table 5.15 re-runs the regression to examine the effect of child attitudes and beliefs on their WTP. Once children's attitudes are controlled for, monthly pocket money becomes, all else being equal, negatively related to the WTP. A possible explanation for this is that the amount of the personal

allowance indicates the degree of the child's autonomy, the more children receive from their parents the more they are responsible for buying things that they need.

As evidenced in Model 3, once all four dummies measuring the different types of altruism are included in the model, only non-paternalistic altruism increases the WTP for health risk reduction. As expected, the majority of the coefficients used to measure risk aversion show a positive sign, indicating that more risk adverse individuals have a higher WTP. However, none of the risk aversions measures are statistically significant. Surprisingly, care for health was negatively related with WTP. Yet, the effect of this variable was not significant at the conventional levels. But, as expected, those who believe that the environmental hazards seriously affect child health have a higher WTP for health risk reduction.

Model 3 in Table 5.16 shows the effect of parental attitudes and beliefs on their WTP for childhood health risk reduction. As found with children, the stronger the parental belief that environmental hazards can affect child health, the more they are willing to pay for health risk reduction. In the case of parents, one measure of health risk aversion, 'using sunscreen when sunbathing' was significantly associated with higher WTP for child health risk reduction. As expected, the frequency with which parents smoke is negatively associated with WTP. However, smoking was not significant at a conventional level. Surprisingly, the frequency with which parents practice sport is negatively related with WTP for child health risk reduction however as for smoking the coefficient is not significant. An interesting finding of Model 4 is the contrasting sign of the two coefficients: care for own health and care for child health. The negative sign of care for one's own health indicates that the less parents care for their own health, the more they are willing to pay (sacrifice part of their budget, given a fixed budget constraint) for reducing child asthma.

5. Discussion

This paper reports the result of a contingent valuation study conducted with children and their parents to elicit their WTP to reduce the risk of the child having an asthma attack. Since previous studies suggest that children do not possess the ability or the financial resources to make decisions

about reducing their health risk, the first objective of the study was to test the hypothesis that children can provide meaningful answers to WTP questions regarding their health risk reductions [9, 10, 12, 13, 41].

While understanding of health risk information is essential in order to obtain reliable WTP estimates, information on the ability of children to understand health risks is limited. Previous research, conducted with the younger age group of children involved in this study, tested their understanding of health risk information. As children get older their ability to interpret risk information increases (see Chapter 3). Confirming these results the current study shows that children's WTP estimates are highly sensitive to the size of the health risk reduction and that age was a significant predictor of the likelihood of passing the scope sensitivity test (WTP1>WTP2>WTP3). Interestingly, it was found that the proportion of children failing to pass the scope sensitivity test together with the number of children failing to consider the assigned budget constraint in the WTP questions was lower compared to the proportion of parents.

Central to the validity of contingent valuation studies is the saliency of the hypothetical scenario. A further hindrance in studies conducted with children is that they may be unable to cope with information presented in the scenario given their limited knowledge about health risk. However, the results of the present study suggest that a high proportion of children suffer from and thus understand asthma attacks. Confirming these findings, only a small proportion of children refused to pay for the intervention reducing the risk of asthma and justified it with protest answers. Only thirty-four children did not provide genuine answers to the WTP questions replying with a zero value instead. Only three children replied with high protest bids (unrealistically high WTP equal to the budget constraint). These results confirm previous studies suggesting that children, even at younger ages, consider their budget constraint when using money [16, 42-45](see Chapter 4).

The second objective of this study was to investigate differences in WTP between parents and children for the same health risk reduction. It was estimated that on average children are willing to give 22%

of their budget to decrease their risk of having an asthma attack from a baseline risk of 20 in 100 to a final risk of 1 in 100. For a lower health risk reduction (50% decrease from baseline risk) children are willing to pay 14% of their budget, while for the lowest health risk reduction they are willing to give up 11% of their budget. Analysis of the parents' answers shows that on average parents are willing to give up 35% of their budget for the highest health risk reduction. This proportion decreases to 19% for the lowest health risk reduction.

Previous valuation studies investigating parents' WTP to reduce child health risk suggest that WTP is higher for children than for adults with an adult to child ratio ranging between 1.5 to 2.6 [25]. Possible explanations provided for the "child premium" other than pure parental altruism towards their children, are the opportunity cost of parental time and that parents feel responsible for protecting children against risks that their children cannot control/understand[6, 22]. As Dockins et al. suggest, in general, society is more risk averse when risks are experienced by children compared with adults [10]. This is reflected, for example, in the more stringent regulation of those pollutants that affect children's health.

Using both parents' and children's responses this study estimated the ratio of parents' to children's WTP as a percentage of available budget. Findings suggest that parents are willing to pay a significantly higher percentage of their budget to reduce their child's risk of having an asthma attack, independently from the size of the health risk reduction. If confirmed in future studies these results suggest that parents' preferences expressed on behalf of their children are different from those of the children themselves. Another interesting finding is that the parent to child WTP ratio changes for different sizes of health risk reduction ranging from 1.59, for the highest health risk reduction, to 1.72 for the lowest health risk reduction. The narrower difference between parents' and children's WTP for higher risk reduction and wider for lower may be due to age differences in risk perception. Harbaugh et al. found that while adults underweight high risks and overweight low risks children tend to overweight high risks and underweight low risks [46].

The third question that this study tries to answer is whether the WTP of children and their parents varies with the child's characteristics. Children's WTP for their own health risk reduction decreases significantly with age. Differences in attitudes and behaviours at different ages may explain the decrease in WTP for asthma health risk. The analysis of the attitudinal and behavioural measures collected from children found mixed findings. While younger children scored higher in health-related altruism and in measures of recreational health risk, older children were found to care more for their own health, were more likely to show paternalistic altruism and scored higher on health risk aversion measures.

Previous studies investigating the relationship between a child's age and parents' WTP suggest that parents are willing to pay less as children get older. For example, Bloomquist et al. using a parental perspective estimated that the WTP for asthma control ranges between €4000 annually for four year olds to approximately €2000 for seventeen year olds [25]. Consistent with previous studies, also in this study it was found that parents' WTP for risk reduction decreases as the child's age increases. It has been suggested that parents feel less responsible for protecting children from involuntary health risk as the child ages [6, 25, 47].

Unlike Liu et al. who found that Taiwanese mothers were willing to pay more for their sons, this study found that Italian parents show no favouritism between sons and daughters [48]. However, the results suggest that both boys and fathers are willing to pay significantly more compared to girls and mothers. It was not possible to establish why boys are willing to pay more than girls. There were no significant differences in attitudes and behaviours between boys and girls. Similarly the descriptive statistics suggest that the differences in WTP between parents are not due to differences in attitudes and behaviours. In the correlation analysis, men were found to be less likely to believe that environmental hazards can affect children's health and were less risk averse (with respect to both health risk and recreational risk). Alberini and Scansy suggest that a possible explanation for this difference between spouses is that women are more reluctant to spend family income without the approval of their spouse [11].

Previous studies adopting a parental perceptive only showed that the health status of the child, e.g. whether or not the child suffers from asthma, does influence parents' WTP for their own and their children risk reductions[24]. A high prevalence of childhood asthma was found in the sample of interviewed children. In children answers analysis asthma status per se was not found to affect WTP. However, when frequency of asthma attack is taken into account children who experience asthma frequently show a higher WTP compared to those who have asthma attack only seldom. A similar finding was also observed in parents' WTP once accounted for parents' behaviours and attitudes. Apart from asthma other individual characteristics affecting WTP were parents' job type and children pocket allowance. Highly skilled employees were found to be willing to pay more for their children health risk reductions compared to those that are unemployed. In the children sample it was found that children WTP decreases as their pocket allowance increases. Surprisingly the family budget was not found to influence parents' WTP. A possible explanation for this is that family budget and job type have been found to be highly correlated. Previous studies investigating quantity-quality trade off within household found that parents' WTP per child health risk reduction decreases as the number of children within the household increases [24]. For example Dickie & Messnam results show that the mean parents WTP to avoid a child symptom day decreases significantly as the number of children increases. However in this study the family size did not affect parents' WTP.

Using psychometric measures, the study investigated whether health and recreational risk aversion was directly associated with parents and children WTP for health risk reduction. The analysis of children sample found no evidence of a causal relationship between risk measures and WTP while for parents a measure of health risk aversion "using sunscreen when sunbathing" was consistently related with increased WTP. Interestingly it was found that the children's' degree of trust in the relationship between environmental hazards and health does affect both: the likelihood of agreeing to pay for health risk reduction and the amount paid. A similar result has also been found among parents.

In the analysis of parents' results, parents 'care for their own and their child's health were found to be related to WTP. In particular, results suggest that the less parents care for their own health the more

they are willing to pay for their children. This finding supports evidence from previous studies that found that parents' marginal WTP for a unit reduction in their children risk is higher than their WTP to reduce the same risk to themselves[24].

According to Johansson, benevolence towards friends and relatives accounts for from 50% up to 75% of the overall WTP for an environmental project [49]. In this study it was tested whether it is possible to infer a causal relationship between different measures of altruism (general, health/welfare related and non-paternalistic) and children's WTP. The study findings show that, as suggested by Hoffman, Krupnick and Adamovicz, "children's concern for their own health includes also altruistic concerns about other children"[50]. In particular, the results of this study suggest that non-paternalistic altruism is associated with higher WTP. This is a very important point that needs to be confirmed or otherwise in future research as it shows that children (even the younger ones) have altruistic predispositions towards other children affected by environmental health hazards. According to Dockins et al. paternalistic altruism can be included in WTP values without the risk of double counting, whereas non-paternalistic altruism (preference respecting), on the other hand, can only be accounted for if the altruistic individual is willing to pay for the good (health risk reduction) and offer it free of charge to other individuals[10].

CV methods have often been criticised with respect to the validity and reliability of the results. Following NOAA panel guidelines and subsequent recommendations for CV study design this study accounts for the most common potential problems associated with stated preference studies [51].

Consistently with the "burden of proof" when testing the reliability of the study results it was found a low proportion of non-responses among parents that returned the questionnaire. All the children in this study were very eager to participate. The children's questionnaire was pre-tested to ensure that children understood the questions. Overall 3% of children rated the questionnaire as "very difficult" while 73% considered it "very easy".

Nevertheless several limitations should be considered when interpreting the findings. The understanding of health risk by children aged 7-13 years was investigated before conducting the CV experiment (see Chapter 3). However, this study did not collect any information about parents' understanding of risk, or that of older children. To account for this potential source of bias, the analysis was repeated excluding children and parents that had provided inconsistent answers.

According to NOAA guidelines reminding respondents about the budget constraint is important to receive meaningful answers [51]. One of the main problems when eliciting values using stated preference questionnaires is that respondents provide WTP estimates without considering their budget constraint. To account for this problem Ortiz, Markandya and Hunt, for example, bounded the respondents' income between zero and the annual income divided by two [52]. They assumed that individual disposable income (after taxation and living expenses) was equal to the half of the annual income.

It was expected that the inclusion of a budget constraint in the CV survey encourages respondents to consider their budget constraint when answering the questions. However, in this study a hypothetical budget constraint was imposed to compare children's' and parents' WTP estimates. As a consequence, the estimated WTP was not genuine, based on the actual disposable income of the respondent, but influenced by the assigned budget constraint.

A class-specific budget constraint (given that the questionnaire was administered in class, class was used as proxy of age) was used for the younger children since information was available regarding median budget, whereas in the case of older children (14-19 years) a budget constraint was assumed which turned out to be higher than the median reported subsequently by respondents, which may have inflated the WTP estimates among older children. A constant family budget constraint (excluding accommodation and food expenses) of €400 per month was used for parents. The descriptive analysis suggests that the budget constraint for parents was similar to the one assumed in the study. Half of the parent sample reported having a disposable family income (excluding accommodation and food cost) lower than €600. Future studies using pre-defined budget constraints

in CV questions may wish to consider using individual specific budget constraints to elicit WTP. This would produce more realistic choice situations and genuine answers despite the hypothetical context [53].

Another limitation of the study is that it compared children's WTP in terms of proportion of their own budget versus parents' WTP in terms of proportion of household budget excluding accommodation and food related expenditures. This study did not ask to the children their WTP given the household budget because children may not be able to consider family expenditures when making a trade-off between money and their own risk reductions. Further research is needed to investigate whether children are able to consider household budget, as this would allow a better comparison between parents' and children's WTP estimates.

Independently from the perspective adopted to elicit the preferences (children's perspective, parents', adults as children's perspective and societal perspective), WTP estimates for children's health risk reduction are not elicited in an individual context but within an household context. The objectives of this chapter were to investigate whether preferences can be elicited for reductions in health risk directly from children and to compare the WTP estimates of children with those of their parents. Future studies are needed to investigate whether or not children preferences for their own risk reduction are/should be considered and which factors influence children decision power on household decisions.

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Research Paper 5. Children's willingness to pay for environmental health risk reductions. Discrete Choice experiment versus Contingent Valuation Approach.

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The candidate _____ The supervisor _____

6.Chapter

1. Introduction

Asthma is the most common chronic disease among children. Latest findings from the International Study of Asthma and Allergies in Childhood (ISAAC) suggest that the prevalence of asthma in children is increasing, ranging from less than 5% in Albania to more than 20% in United Kingdom(UK)[1]. Because of the high prevalence among children there is also a significant healthcare cost associated with asthma care. In the UK, it is estimated that the cost to the National Health System of providing services for asthma is approximately £1 billion a year [2]. Epidemiological studies have shown that at younger ages, environmental hazards and traffic-related air pollution in particular, play a prominent role in exacerbating asthma[3].

The valuation of children's health has received increasing attention from national and international governmental bodies because of the greater vulnerability of children to environmental hazards [4, 5]. Reliable welfare estimates for the reduction of the environmental risk of asthma attack in children are required in order to assess the cost-effectiveness of environmental health interventions aimed at protecting this vulnerable population group[5]. The Organisation for Economic Co-operation and Development (OECD) argues that it may be more cost effective to invest in environmental interventions (ex ante) rather than spending money to cure environmental associated health outcomes (ex post)[5]. In evaluating child health risk reductions, there are a number of issues that need to be considered. Epidemiological studies show that children have different exposure and susceptibility to environmental hazards compared with adults. However, as OECD suggests, differences between adults and children may also exists when it comes to valuing health risk reductions[5]. Given the difficulties in eliciting willingness to pay (WTP) estimates directly from children, previous studies valuing morbidity and mortality risk reduction have used a parental perspective[6, 7]. These studies show that parents have a higher willingness to pay for risk reductions

for their children than for themselves. Dickie and Messman estimated the WTP of parents to reduce health symptoms to themselves and to their children[6]. According to their results parents WTP for their children health risk reductions is twice the size of their WTP for their own health risk reductions[6].

Bloomquist et al. assessed the effect of a child's age on parents' WTP for improving fatality risk and control of asthma symptoms[8]. They found that the annual value of symptom control ranged from €4000 to €2000, for aged between 4 and 17 years[8]. Dickie and Messman and Hammitt and Haninger also found parental WTP for reduction of child illness symptoms was influenced by the age of the child[6, 9]. According to Dickie and Messman results the parents' WTP (in 2000 prices) was $271 for a child aged 3 years, $196 for a child aged 6 years, $160 for a child aged 9 years, $141 for a child aged 12 years and $120 for a child aged 17 years. All of the studies conducted so far have used a parental perspective. No study has evaluated WTP for reducing the risk to the child's health using children's preferences. According to OECD a parental perspective facilitates the WTP evaluation and is justified by the fact that parents are affected in many ways from increased health risks in children[10]. However, using a third party perspective violates the principle of autonomy of the decision maker and may result in double counting (when the WTP includes also parents' non-paternalistic altruism) [5, 7, 11, 12]. Despite the assumption that children are not able to speak for themselves (because they have no defined preferences for their own risk reductions) when it comes to assessing the value of health risk reduction no stated preference study has been conducted so far to test this assumption and verify whether to some extent/from a certainty age children start having defined preferences for their own health risk reductions[5].

Stated preference techniques such as contingent valuation(CV) and discrete choice experiments (DCE) have been increasingly used to assign a monetary value to non-marketed goods and services [13, 14]. Unlike CV studies, which directly ask respondents how much they are willing to pay for a specific change (e.g. in health risk), DCEs present respondents with a number of choice sets, in which alternatives, described as a set of attributes, are mutually exclusive [15]. The alternatives presented in

each choice set vary in one or more attribute levels to infer information indirectly on individual preferences regarding the relevant parameters. Compared with CV technique, DCE have the capacity to describe a choice situation with a range of attributes that reflect the different characteristics of the good being valued[15]. When a cost attribute is included, marginal utility estimates for changes in the level of each attribute can be converted into WTP estimates [14, 16]. Given these several advantages, DCEs have become popular in transportation economics [17, 18]. Only in the last decade, however, DCE become the subject of increased use in estimating WTP for environmental health risk reductions [18, 19]. There is paucity of stated choice experiments conducted with children[20]. It may be that a DCE design with only two attributes; cost and risk reduction, is less cognitively demanding and hence more effective in eliciting children's preferences compared a with CV questionnaire.

The aim of this study is to investigate whether children have defined preferences for their own health risk reductions. In particular the study objectives are: (1) using a DCE, to investigate whether children are capable of providing reliable estimates of WTP for asthma health risk reduction, (2) to investigate how WTP for asthma health risk reduction varies according to children's characteristics such as age, gender and asthma status, and (3) using data collected in the same questionnaire, this study also aims to compare the DCE results with those of a CV study.

2. Discrete Choice Experiment Design

The DCE reported in this chapter is a part of a larger questionnaire that collects information in the classroom on child demographics and health related characteristics and also presents CV questions. For further details on the overall structure of the questionnaire and the preliminary discussion in class please see Chapter 5.

The DCE begins with a hypothetical scenario, which introduces Jack, a person living in a polluted city where the risk of asthma attack is 20 in 100 children each month. The children are next asked to complete a questionnaire imagining that they are Jack, and that they can make decisions on his behalf within a monthly budget bearing in mind that each choice set presented is independent from other

choice sets. The scenario introduces a generic public intervention designed to reduce pollution and thus Jack's risk of asthma attack. The type proposed intervention is left unspecified so that the WTP does not reflect any benefits other than the reduction of the risk of asthma attack. The scenario makes clear that payments are due each month. Given that the experiment was designed to estimate the tradeoffs children were willing to make between health risk reduction and their income (allowance or pocket money), the policy question comprised only two attributes: (i) the size of the health risk reduction and (ii) the cost of the policy. The risk reduction was presented in terms of risk of asthma attack per 100 children after the policy. As seen in Table 6.1, both the size of the risk reduction and the price proxy take four possible levels (attribute levels). For each alternative in the choice set, the final risk after the policy was presented. The four risk reduction levels were the same for all the respondents, namely: 19, 10, 4, and 1 in 100 children each month. For instance, a risk reduction of 19 asthma attacks in 100 children corresponds to a final absolute health risk of 1 asthma attack in 100 children. Given the baseline risk of asthma of 20%, a final risk of 1 in 100 also corresponds to a 95% risk reduction. In order to enhance risk understanding, health risks were displayed using graphic pictographs with human figures (see Chapter 3).

For each age group, the median monthly budget was used to estimate the price proxy values for children involved in the study. Estimates of the median monthly budget by class are fully reported in Chapter 4. The price levels used in the experiment are estimated as 4%, 7%, 15% and 30% of the available monthly budget. For example, given a monthly budget constraint of €32, the cost attribute took four possible values: €1, €2, €5 and €10. A status quo alternative was included to allow respondents the option of maintaining the risk of asthma attack at the current level (20 in 100 children) at zero cost. An example of the choice set is reproduced in Figure 6.1. According to NOOA guidelines, there is a reminder about the budget constraint in each choice set [21] (See Figure 6.1).

Table 6.1. Attributes and attribute levels used in the discrete choice experiment

Attributes	Levels
Health Risk Reduction (Health Risk after the intervention)	19 in 100 (1 in 100) 10 in 100 (10 in 100) 4 in 100 (16 in 100) 1 in 100 (19 in 100)
Cost to respondent (€)	€1,€2€5 and €10

Figure 6.1. Example of a choice set.

1 **Ricorda che ogni mese Jack ha a disposizione € 32**

Alternativa	A	B	c
Rischio per la salute senza nessun intervento ambientale	*20 su 100* ragazzi soffrono di asma	*16 ragazzi su 100* Soffrono di asma	*1 ragazzo su 100* Soffre di asma
Quanto paga Jack per l'intervento di disinquinamento	**€0**	**€1**	**€2**
Domande			
Dovendo scegliere fra le tre alternative quale sceglieresti?	○	○	○
Dovendo scegliere fra le alternative B e C, quale sceglieresti?		○	○

The attributes and the attribute levels selected for the experiment resulted in 16 (4^2) possible profiles and 120 pair wise choices ((16*15)/2). Both the pilot survey and the final design of the DCE were generated with Ngene in accordance with the principle of D-efficiency. The principle of D-efficiency is to provide the maximum amount of information and the smallest variance from a given number of choice sets presented to each respondent. A pilot study was conducted with 29 respondents aged from 7 to 10 years to check that the questionnaire was easily understood and that there were no problems with face validity. The risk and cost coefficients estimated from the pilot data were used to design of the main survey in order to ensure statistical efficiency and a design more robust to model misspecification. Overall children had to answer to seven choice sets. The last one was a dominant choice set which has been included to test for rationality. The main questionnaire collected additional information, such as the child's age, gender, asthma status and individual monthly allowance. The DCE was analyzed using STATA. For further details about the survey questionnaire and descriptive statistics of the sample, please see Chapter 5.

3. Discrete Choice model estimation

The results of the DCE are used to assess individual preferences within the random utility maximization (RUM) framework proposed by Thurstone in 1927 and further developed by McFadden in 1974 [22-25]. According to RUM individual choice is determined by some construct of indirect utilities for choice alternatives. Given that the researchers cannot directly observe all the individual factors affecting their utility, individual choice behaviour is broken-down into two additive and separable parts: one, a systematic (observable) component determined by the characteristics of the alternatives $V(X_{in},\beta)$, and a second random (unexplained) component ε_{in}. ε_{in} which represents the variation in respondent choices influenced by individual characteristics, such as heterogeneity in tastes, measurement errors and functional specification[26].

The latent utility function of alternative *i* faced by individual n including the explainable and unexplainable components is represented in the following formula[24, 26]:

1. $U_{in} = V(X_{in}, \beta) + \varepsilon_{in}$

Given a choice set C_n, the main assumption of the RUM is that each individual will choose the alternative *i* if *i* maximizes their utility amongst all the alternatives (j) included in the choice set[24].

2. $y_{in} = f(U_{in}) = \begin{cases} 1 \; if \; U_{in} = \max\{U_{ij}\} \\ 0 \; otherwise \end{cases} \forall j \neq i \in C_n$

Y_{in} is the choice indicator which is equal to 1 if the alternative i is chosen and 0 otherwise. The probability that respondent *n* chooses alternative *i* is equal to the probability of difference between the random utility of any alternative *j* and the random utility of the chosen alternative *i* being lower than the difference between the utility of the systematic component of alternative *i*, and, the systematic utility levels of any alternative *j*[26]:

3. $P_{in} = Pr(\varepsilon_{jn} - \varepsilon_{in} < V_{in} - V_{jn}) \forall j \neq i \in C_n$

Assuming that disturbances ε_{in} are independent, identically distributed (i.d.d.) and follow an extreme value type I (Gumbel) distribution, the probability of individual *i* choosing alternative *n* is given by the following formula:

4. $P_{in} = \frac{\exp(\mu V_{in})}{\sum_{j \in C} \exp(\mu V_{in})}$

Thus, if we assume that the systematic component of the utility function $V(X_{in}, \beta)$ is linear in parameters and that error variance is constant ($\mu \equiv 1$), then the conditional logit model (CL) allows identifying those values of β that maximize the log-likelihood function:

5. $lnL = \sum_{n=1}^{N} \quad \sum_{i \in Cn} y_{in} \, (ln(P\_in)) = \sum_{n=1}^{N} \sum_{i \in Cn} y_{in} \left(\beta' X_{in} \quad - ln \sum_{j \in Cn} \exp(\beta' X_{jn}) \right)$

For instance, the basic utility model in this study (attributes only model) is:

6. $U_{in} = \beta_R(R_j) + \beta_p(P_j) + \varepsilon_{ij}$

In this equation, P_j is the price proxy for the risk reduction. β_p is the coefficient of the price proxy. R_j is the risk reduction and β_R is the coefficient on the risk reduction proxy.

The base model specification of this study does not account for the characteristics of individuals. However the willingness to pay for reducing the risk of asthma attack may vary according to age, gender, health condition (being asthmatic or not) and available income. Taste variations was investigated using standard CL models by including interaction terms between the attributes of the alternatives and individual characteristics such as age, gender and asthma status. An example of the model used to account for heterogeneity in tastes (for health risk reduction) between age groups is detailed in the following formula:

7. $U_{in} = \beta_R(R_j \times Age_c) + \beta_p(P_j) + \varepsilon_{ij}$

In this equation, Age_c is a dummy variable indicating whether or not the child belongs to the *c* age group (e.g. 8-10 years)

The starting point for most analyses of DCE data is the CL model. The popularity of CL is associated with a number of properties which make it easily computable. However, the assumptions underlying the CL model are also restrictive. For example, one of these assumptions relates to the independent and identical distribution of the error term. The validity of this assumption depends on the data and also on the underling theoretical model. As noted in earlier studies, an important limitation of the CL model is its failure to account for random taste variation between respondents; or in others words, that individuals attach different levels of importance to alternatives within the choice set based on their attitudes and tastes[23]. To account for potential heterogeneity between respondents' tastes, a mixed logit model with random coefficients was also used to further analyse the data. In the model, the observed variables are no longer assumed fixed, but considered to vary according to a predefined distribution (usually normal and lognormal), which offers a representation of the heterogeneity

between respondent's tastes. In the mixed logit, the choice probability is given by the following formula[19]:

8. $$P_{in} = \int \frac{\exp(x'_{ni}\beta)}{\sum_{j=1}^{J} \exp(x'_{ni}\beta)} f(\beta|\theta)\, d\beta$$

In this equation, $f(\beta|\theta)$is the density function of β.

4.Willingness to pay from discrete choice experiment

In DCEs, the willingness to pay for a health risk reduction is equal to the Hicksian consumers' surplus attached to the equivalent price change[27]. The WTP value for a given attribute is estimated by calculating the ratio of the attribute coefficient to the price coefficient [27].

9. $$MWTP = -\frac{\beta_R}{\beta_p}$$

From the above equation, the marginal willingness to pay (MWTP) for a 1% decrease in risk of having an asthma attack is defined as the marginal rate of substitution between the price proxy and the coefficient for risk reduction.

If it is assumed that the utility function is linear in parameters, then the general formula for estimating the mean aggregate WTP for a specified change in a number of attribute levels is as follows[27]:

10. $$WTP = -\frac{1}{\beta_P}\{\ln(\sum_j exp^{U_I^*}) - \ln(\sum_j exp^{U_I^0})\}$$

In this equation, U* is the utility level with the health risk reduction and U^0 is the utility level of the status quo.

The most common approaches used to estimate 95% confidence interval(CI) of WTP estimates are: Krinsky and Robb method, Fieller's method, the delta Wald-type method and more recently the 'bootstrapping method'[28]. In 2006, Hole demonstrated that three of these methods - the delta Wald type method, Krinsky and Robb method and the bootstrapping method - yield similar results in the

majority of cases and are also associated with a high degree of accuracy[28]. Unlike other methods for computing confidence intervals, which rely on simulations, the Delta method is an analytic approach using first derivatives of the ratio function. According to Daly, the Delta method provides a more precise estimate of the WTP standard error[29]. More recently, Bliemer and Rose showed that the Delta method is preferable to other models for computing WTP confidence intervals from mixed logit models because it requires less simulation[30].

5. Results

The DCE questionnaire was administered to a total of 370 children. Of these 367 replied to all the seven choice sets in the experiment. Those who did not reply, or provided incomplete answers, were removed from the analysis. The female proportion of respondents was higher (56%) than the male one. Respondents were uniformly distributed across the six age groups with the exception of the 14-15 years age group, which alone accounted for 31 % of the sample. The estimated mean and median monthly budget for the overall sample was € 119.84 (sd: 119.25) and €96 respectively. A high proportion of children suffered from asthma, (29%). Further descriptive analyses of the sample are reported in Chapter 5. The internal validity of the choice experiment was assessed by examining the percentage of respondents answering the consistency question (choice set with dominant alternative) and by analysing the sign and size of the attribute coefficients. In total, 55 (15% of the sample) children failed to pass the dominant question. Logistic regressions on age and class year suggest that the probability of answering correctly to the dominant question does not depend on these variables (Odds Ratio for the age coefficient = 0.97 p=0.569; Odds Ratio for the class coefficient = 0.96 p=0.471).

5.1Basic Model

The results for the attributes only model (Equation 1) are reported in Table 6.2. Results are reported excluding those that failed the 7th choice set (the choice set presenting the dominant alternative). Results including all respondents are reported in the Appendix 6. The magnitude and the signs of the

coefficients are in line with the expectations and support the theoretical validity of the model. The price coefficient is negative and statistically significant, suggesting that, other things equal, respondents prefer lower prices and also show a strong preference for higher risk reduction. Using results from Table 6.2, the average WTP for a 1% risk reduction is equal to €3.74 (95%CI: €3.28-€4.19).

Table 6.2 Conditional logit model

Model Parameters	Coefficient (S.E.)
Health Risk	0.119(0.004)***
Cost	-0.321(0.002)***
No. individuals	312
No. observations	6552
R^2	0.214
X^2(df)	1026.47(2)
Log-Likelihood	-1885.81

S.E. Standard Error , *p<0.05; **p<0.01; ***p<0.001

5.1.1Model with children characteristics

Table 6.3 reports the results of the models in which the health risk coefficient is interacted with the age, the gender and the asthma status of the respondents. Interaction terms between risk reduction and age group indicator are all statistically significant and suggest a decreasing marginal utility of risk reduction with increasing age. Wald tests suggest that there is a statistically significant difference between children aged 7-13 and children aged 14-19 years (Wald statistics between the third and fourth age group 9.12, p = 0.002). Gender (being male) is associated with an increase in the marginal utility of the risk reduction. While not being asthmatic (non-asthmatic = 1) is not associated with a higher marginal utility from risk reduction.

Table 6.3. Conditional Logit model with children characteristics

Model Parameters	Coefficient (S.E.)
Risk Reduction	
Age 7-8	0.185(0.027)***
Age 9-10	0.131(0.011)***
Age 11-13	0.123(0.013)***
Age 14-15	0.081(0.007)***
Age 16-17	0.092(0.008)***
Age 18-19	0.082(0.007)***
Gender	0.017(0.007)*
Asthma	-0.004(0.008)
Cost	-0.027(0.002)***
No. individuals	312
No. observations	6552
R^2	0.172
$X^2(df)$	1008.00(9)
Log-Likelihood	-2317.23

S.E.: Standard Error ;*p<0.05; **p<0.01; ***p<0.001

According to economic theory, individuals with a higher income have a lower marginal utility of income and have higher WTP. Information about the monthly income (pocket allowance from parents) was available for the majority of the children included in the study, 318 children, (86% of the sample) of these, 10, failed to reply correctly to the dominate question and were excluded from this analysis. The median monthly allowance across all children was €96. In order to investigate the relationship between personal income (pocket allowance) and WTP at younger age, two dummy variables for the monthly income (above and below €96) were created and interacted with the cost coefficient. Results presented in Table 6.4 show that both interaction terms are highly significant, indicating that the WTP estimated from the model is a function of personal allowance. The size of the two interaction terms suggests children have a diminishing marginal utility of income (children with lower monthly pocket allowance have a higher marginal utility of income and pay more attention to the cost of the intervention). However, the Wald statistics test results indicates that the interaction parameters are not statistically different (Wald statistics 0.75 p=0.387).

Table 6.4 Conditional Logit model with children' monthly income.

Model Parameters	Coefficient (S.E.)
Risk Reduction	0.120(0.004)***
Cost	
Cost x (<€96)	-0.034(0.003)***
Cost x (≥€96)	-0.030(0.002)***
No. individuals	308
No. observations	6468
R^2	0.215
$X^2(df)$	1032.29(3)
Log-Likelihood	-1881.029

S.E.: Standard Error ;*p<0.05; **p<0.01; ***p<0.001

The main problem with Equation 7 is that it imposes a restrictive form of the utility function, which assumes that the marginal utility of health risk reduction is linear. To address the potential bias associated with this assumption, the continuous health risk variable was replaced by four dummy variables corresponding to the four risk reduction sizes associated with the policy intervention (19, 10, 4, 1 in 100). Results of the analysis are reported in Table 6.5. As expected, the children have greater appreciation for the value of higher health risk reduction. Wald tests indicate a statistically significant difference between the four coefficients in the conditional logit model. The last two columns of Table 6.6 show results from the mixed logit models accounting for different size of the risk reductions. 2000 Halton draws were used to estimate risk reduction random coefficients, which were also assumed to follow a normal distribution. Previous studies suggest that the difficulties surrounding a random price coefficient necessitate the assumption that this is fixed across respondents, and even in the event that the assumption implies that the marginal disutility of income is the same for all interviewed children [31]. As shown by the Log-likelihood value, random parameters fit data better. The mean coefficients and the standard deviations are significant for all random parameters. Examining the size of the standard deviations with respect to the mean value, the results suggest that the highest heterogeneity in child marginal utility is observed for the two highest risk reductions (10 in 100 followed by 19 in 100). Wald tests on both conditional logit and mixed logit coefficients confirm that coefficients are all statistically different at a convenience level. (Wald test for mixed logit coefficients: risk1=risk2: 17.24 p=0.000; risk2=risk3:13.14 p=0.003; risk3=risk4: 39.05 p=0.000)

Table 6.5. Conditional Logit and Mixed Logit results accounting for different risk reduction size.

	Conditional Logit	Mixed Logit	
Model Parameters	**Coefficient (S.E.)**	**Coefficient (S.E.)**	**S.D. (S.E.)**
Risk Reduction			
19 in 100	2.687(0.090)***	4.010(0.254)***	2.482(0.272)***
10 in 100	2.175(0.121)***	2.782(0.237)***	2.374(0.327)***
4 in 100	1.562 (0.080)***	2.021(0.121)***	-0.454(0.213)*
1 in 100	1.071 (0.071)***	1.244(0.119)***	1.272(0.140)***
Cost	- 0.047(0.002)***	-0 .065(0.003)***	
No. individuals	312	312	
No. observations	6552	6552	
R^2	0.253	NA	
$X^2(df)$	1431.47(5)	225.84(5)	
Log-Likelihood	-2105.5017	-1655.64	

S.D.: Standard Deviation; S.E.: Standard Error ;*p<0.05; **p<0.01; ***p<0.001

To account for the differences in the marginal utility of health risk reduction and budget constraints within the sample of interviewed children, the sample was segmented in two age groups (7-13 and 14-19 years). The results of both conditional logit model and mixed logit model are shown in Table 6.6 and 6.7. As expected, using the mixed logit model the goodness of fit of the model increases (lower Log Likelihood)in both the age groups considered. In the youngest age group the standard deviations show substantial heterogeneity in the preferences for the highest health risk reductions. Wald tests between coefficients show that the differences between the first two coefficients (19 in 100 vs. 10 in 100) is statistically significant (Wald statistic: 8.75; p-value=0.003). The difference between the second and third, and third and fourth coefficients is not significant at conventional level.

Results for the older age group show higher heterogeneity in preferences for all the health risk reduction size. The difference between the marginal utility of the health risk reduction size is statistically significant between the first and the second (Wald statistic: 7.05; p value=0.008) and between the third and the fourth (Wald statistic: 22.74; p value=0.000).

Table 6.6. Conditional and Mixed Logit results age group 7-13 years

	Conditional Logit	**Mixed Logit**	
Model Parameters	**Coefficient (SE)**	**Coefficient (SE)**	**S.D. (SE)**
Risk Reduction			
19 in 100	1.196 (0.071)***	4.566 (0.132)***	6.240(1.80)**
10 in 100	0.630(0.024)***	1.496(0.324)***	-1.144(0.462)*
4 in 100	0.621(0.164)***	1.494(0.200)***	0.016(0.357)
1 in 100	0.591(0.142)***	1.325(0.175)***	-0.345(0.345)
Cost	- 0.054(0.024)*	- 0.125(0.033)***	
No. individuals	127	127	
No. observations	2667	2667	
R^2	0.136	NA	
X^2(df)	155.81(5)	198.40(4)	
Log-Likelihood	-491.17	-391.7	

S.D.: Standard Deviation; S.E.: Standard Error ;*p<0.05; **p<0.01; ***p<0.001

Table 6.7. Conditional and Mixed Logit results for age group 14-19 years

	Conditional Logit	**Mixed Logit**	
Model Parameters	**Coefficient (S.E.)**	**Coefficient (S.E.)**	**S.D. (S.E.)**
Risk Reduction			
19 in 100	2.177(0.110)***	3.424 (0.292)***	2.66(0.329)***
10 in 100	1.193(0.177)***	2.211(0.411)***	3.652(0.573)***
4 in 100	1.277(0.103)***	2.009(0.173)***	1.010(0.192)***
1 in 100	0.833(0.087)***	1.1019(0.159)***	1.557(0.181)***
Cost	-0 .045(0.003)***	- 0.0693(0.004)***	
No. individuals	185	185	
No. observations	3885	3885	
R^2	0.1976	NA	
X^2(df)	619.66(5)	198.40(4)	
Log-Likelihood	-1257.89	-391.7	

S.D.: Standard Deviation;, S.E.: Standard Error ;*p<0.05; **p<0.01; ***p<0.001

Table 6.8 presents the mean WTP estimates calculated from mixed logit models along with their 95% confidence intervals. The random coefficient mean values and confidence intervals were estimated by applying the Delta method procedure to WTP estimates from the random coefficient model. As seen in

Table 6.8, the WTP values increase with the size of the health risk reduction. If preference differences between age groups are not taken into account, the WTP for asthma health risk reduction ranges between €58 and €23. If age differences are considered, older children (14-19 years) are willing to give up €49 per month to reduce their risk of asthma attack to 19 in 100 children, and only €16 for a 1 in 100 risk reduction. For younger children, the WTP for the highest health risk reduction is equal to €36 decreasing to €11 for the lowest health risk reduction.

Table 6.8. WTP estimates by risk-size and age group. (All values are from the mixed Logit coefficients)

	19 in 100	**10 in 100**	**4 in 100**	**1 in 100**
All Ages				
Model 1	€57.82 (€49.88-€67.55)	€46.27 (€40.1-€52.44)	€33.24 (€29.14-€37.34)	€22.92 (€19.17-€26.66)
Age 7-13 years				
	€36.52 (€13.27-€68.37)	€11.99 (€6.36-€17.61)	€11.97 (€6.49-€17.45)	€10.62 (€4.87-€16.32)
Age 14-19 years				
Model 1	€49.38 (€41.17-€57.59)	€28.98 (€24.94-€33.03)	€30.56 (€26.06-€35.79)	€15.88 (€11.53-€20.22)

The usual approach in analyzing results from DCE is to test for the non-linearity of the marginal utility in risk reduction [32]. As the WTP for public goods is usually only a small percentage of individuals' budgets previous studies conducted with adults assume a linear marginal utility of income. However, given that this is the first study estimating welfare estimates directly from children non-linearity in preferences for costs was tested. Analysis of non-linearity in preferences for cost could be undertaken by age group since different age groups face different budget constraints and price bids. However, this approach would have reduced the sample size significantly (especially in the case of the younger age groups). For this reason the non-linearity in costs was tested using the proportion of budget model and the full sample. Results of the analysis are reported in Table 6.9.

As expected the coefficient of the different cost bids have negative signs (the marginal disutility increases as the price bid increases). The difference between the coefficients is also statistically

significant indicating that as the size of the price bid increases there is a statistically significant increase in the marginal disutility.

Interestingly, the coefficient for a change from 2% of the budget to 7% of the budget is almost half the size of the coefficient from 2% to 15% suggesting linearity in the marginal disutility of cost. However, as we move to a significant proportion of the budget (30%) the decrease in marginal utility is more than double (-0.417*2 = 0.824) vs. -1.258. This result suggests that the assumption of linearity with respect to income does not hold if the policy costs a significant proportion of the respondents' available budget.

Table 6.9. Testing linearity in preferences for costs.

	Conditional Logit
Model Parameters	**Coefficient (S.E.)**
Risk Reduction	**0.112(0.006)*** **
Cost	
7% of the budget vs. 2% of the budget	-0.195(0.090)*
15% of the budget vs. 2% of the budget	-0.417(0.110)***
30% of the budget vs. 2% of the budget	-1.258(0.094)***
No. individuals	312
No. observations	6552
R^2	0.196
X^2(df)	943.90(4)
Log-Likelihood	-1925.105

5.1.2 Comparing welfare estimates from DCE vs. CV study.

The third objective of the study was to compare the WTP estimates from the DCE and the CV. The studies were not designed with the intention of comparing WTP values. However, given that DCE and CV were conducted consecutively on the same subjects within the same questionnaire, a comparison of the two techniques provides some interesting insights.

The CV study estimated WTP in terms of the proportion of their budget that children were willing to give up for a given health risk reduction. The advantage of this approach is that it provides an

understanding of how WTP varies, assuming that all children face the same budget constraint. To compare the results of the two studies, the budget-specific price bids in the DCE dataset were replaced by the proportions of budget bids (4%, 7%, 15%, and 30%). Using this modified dataset, every child faces a unitary budget constraint. On this basis, children are asked about the percentage of the unitary budget they are willing to give up, independently of their age. This modified dataset was analysed using both a conditional logit and a mixed logit model. Results are reported in Table 6.10. Consistent with previous results, the estimated coefficients show that the marginal utility of the health risk reduction is higher for higher risk reductions. Wald tests indicate that the coefficients of the health risk reductions are statistically different for both models.

Table 6.10. Proportion of the budget. Conditional and Mixed Logit Model results.

	Conditional Logit	**Mixed Logit**	
Model Parameters	**Coefficient (S.E.)**	**Coefficient (S.E.)**	**S.D. (S.E.)**
Risk Reduction			
19 in 100	2.572(0.087)***	4.122(0.276)***	2.772(0.307)***
10 in 100	2.080(0.125)***	2.891(0.278)***	3.040(0.397)***
4 in 100	1.454(0.079)***	2.137(0.135)***	0.746(0.160)**
1 in 100	1.020(0.070)***	1.862(0.121)***	1.331(0.144)***
Cost	-5.912(0.387)***	-9.576(0.661)***	
No. individuals	312	312	
No. observations	6552	6552	
R^2	0.224	NA	
$X^2(df)$	1264.53(5)	256.35(5)	
Log-Likelihood	-2188.97	-1710.75	

S.E.: Standard Error; S.D.: Standard Deviation; S.E.: Standard Error ;*p<0.05; **p<0.01; ***p<0.001

Table 6.11 reports WTP estimates from the DCE and the CV. The contingent valuation study using the payment card method of elicitation, estimated the WTP for three (19 in 100, 10 in 100 and 4 in 100) of the four asthma risk reductions. Independent of the size of the health risk reduction, the mean estimates from CV study are consistently lower than those from the DCE data. The last row of the Table 6.11 also reports the ratio of DCE to CV WTP estimates, suggesting that on average DCE WTP estimates are twice the size of CV ones.

Table 6.11. Comparison between CV vs. DCE WTP estimates.

Stated preference method	1 in 100	10 in 100	4 in 100
DCE	0.43 (0.37-0.49)	0.30 (0.25-0.35)	0.22 (0.20-0.25)
CV	0.22 (0.20-0.24)	0.14 (0.13-0.15)	0.11 (0.06-0.12)
DCE/CV ratio	1.95 (1.85-2.04)	2.14 (1.92-2.33)	2.00 (3.33-2.08)

DCE: Discrete choice experiment; CV: contingent valuation study, WTP: willingness to pay.

6.Discussion

Using a DCE, the present investigated the trade-off children were willing to make between their income (monthly allowance) and the risk of an asthma attack. The results suggest that children as young as seven years old can provide reliable/rational answers to DCE questions. Few children asked for extra explanation during the experiment. Overall, they found both the experiment and the choice sets straightforward and easy to understand. Only a low proportion of children failed to respond correctly to the dominant choice set. The sign of the coefficients of risk reduction and the costs were as expected. The results of this study suggest that on average children are willing to pay €4 for a 1% risk reduction of asthma attack. As with studies conducted with adults, it was found that the WTP for health risk reduction is sensitive, but not proportional to, the size of the health risk reduction. On average, children aged 7-19 years were willing to pay €58, €46, €33 and €23 for a 19, 10, 4 and 1 in 100 risk reductions respectively.

The second objective of the study was to assess the effect of children's characteristics (particularly their age) on their WTP for asthma risk reduction. The study results suggest that older children have a

lower marginal utility of risk reduction. On average, it was estimated that children aged 7-13 years were willing to pay €36 for the highest risk reduction and €11 for the lowest health risk reduction. The mean WTP for the older age group was €49 and €16 for the highest and lowest health risk reductions respectively. The results also suggest that, all else being equal, boys have a higher marginal utility of risk than girls and, as a consequence, a higher WTP for risk reduction. Asthma status was not significantly associated with marginal utility.

The third objective of this study was to compare DCE results with the result of the WTP estimates elicited via CV method within the same questionnaire. Theoretical validity was fund in the results of both, CV and DCE, studies. In both, WTP is significantly higher for larger risk reductions. Examining the further convergent validity of the two approaches, they also seem to yield to similar conclusions. As the contingent valuation study and the DCE, WTP for the asthma health risk reductions decreases with age. In particular, there is a significant decrease when children turn 14 years old. In both the approaches, boys, compared with girls, were willing to pay more for health risk reduction. Nevertheless, when comparing the estimates from the two methods, the DCE leads consistently to higher WTP estimates compared with the CV study. The mean WTP estimates from the payment card CV study in terms of proportion of the budget were 22%, 14% and 11% for the 19 in 100, 10 in 100 and 4 in 100 risk reductions respectively. In the DCE the average percentage of budget across the sample was on average twice the size estimated with CV, 43% and 22% for the highest and lowest risk reductions respectively.

This result is consistent with the previous studies findings which show that the valuation leads consistently to smaller welfare estimates where more choices are available to respondents (more open ended elicitation formats) [14, 27, 33-35]. For instance, Ryan and Watson who compared WTP estimates for Chlamydia screening using both the payment card method and DCE method, found that the mean WTP estimate from DCE method was significantly larger than that estimated with the payment card (£38.18 vs. £23.71). More recently, Van der Pol et al. reported mean WTP estimates from a DCE almost twice the size of mean estimates from an open ended CV[13].

The large difference between the two approaches is a cause for concern when using WTP estimates for populating cost-benefit analyses. Using one of the two approaches may, depending on the individuals' true preferences, undervalue or overvalue the real benefits achieved by the policy [13]. The best strategy for assessing the reliability of WTP estimates from stated preferences method would be to compare the stated values with the actual WTP estimates. In the fields of transportation and health care sector, studies have shown that DCE results are reliable in predicting actual choice of consumer (e.g. for mode of transportation). For example, Ryan and Watson compared stated screening intentions with actual behaviour. In the payment card CV study, 77% of respondents acted in ways that were consistent with the stated choice. In the DCE, however, 80% of respondents answered the same way when faced with the actual choice as compared with the hypothetical choice. Furthermore, Mark and Swait found that DCE results conformed to actual choice behaviour in the case of physicians' prescribing decisions for alcoholism medications [14]. Nevertheless, the criterion validity of welfare estimates from DCE and CV studies is still an open issue [26]. In developed countries, health and environmental health interventions are usually publicly funded. Ideal market conditions do not apply making the testing of the validity of WTP estimates problematic. Nevertheless, given the potentially wide application of DCEs and CV studies in both the health and environmental health sectors, testing the criterion validity of welfare estimates might become a priority in the future.

A number of limitations must be considered when interpreting these study findings. First, the objective of this study is to investigate whether children have defined preferences for their own health risk reduction using a DCE. To investigate whether children preferences are/should be accounted for within the household context is beyond the aim of the study.

The salience of the price bids is essential to the success of the DCE [18]. In the case of children, this becomes even more important. Previous studies show that at younger ages the amount of pocket money/budget constraint increases significantly with age (see Chapter 4). For example, it is not realistic to ask an 8 year old child, who has a monthly budget of 20 Euros, if he/she is willing to pay 60 Euros for reducing the risk of an asthma attack. In order to account for the age gradient of the budget

constraint among children, the study uses age specific choice sets designed on the basis of information regarding money availability among the interviewed sample (See Chapter 4). In order to compare CV study results with DCE results, actual WTP values have been translated in relation to the proportion of the budget. By using WTP values expressed as a proportion of the budget, the study is able to compare WTP values across age groups (who face different budget constraint). However, a disadvantage is that respondents were not directly asked about their proportion of the budget. As such, this alteration has potentially biased their responses (if respondents were presented with WTP questions expressed in terms of proportion of the budget, they might have given different values). Future studies may consider directly asking respondents about the proportion of the budget they are willing to give up. While this approach may be more challenging for respondents, it will require less manipulation of data during the analysis.Another potential limitation is the failure to consider the potential ordering bias. Given that the questionnaire was presented to the class in unison (making sure that each pupil replies autonomously), it was not possible to assign a random order to the different parts of the questionnaire. As a result, the answers provided to the DCE could have been influenced by those of the CV study. To account for this potential problem, there was a 30 minute break between the two parts of the questionnaire. Researchers might in future consider randomly allocating the order of the experiments (CV and DCE) within the same questionnaire in order to test whether this affects both the responses and the welfare estimates.

The mixed logit model was performed to account for heterogeneity of the study sample. The mixed logit appeared to fit the data better than the conditional logit. However, a major problem in using mixed logit models is that they may produce a highly skewed WTP distribution. As in previous studies, to deal with this potential issue in the model it was assumed a fixed price coefficient. This has the disadvantage that it assumes that all children have the same preferences for cost [36, 37]. Further research is required to assess whether a mixed logit model in WTP space, rather than in preference space, can solve this problem. A mixed logit model in WTP space allows to make a priori assumptions regarding the WTP distribution rather than on the coefficients for estimating WTP [31, 38].

Another potential approach to accounting for sample heterogeneity would involve integrating latent variables (children's attitude and behaviour variables collected in the questionnaire) in the discrete choice model [39]. The advantage of this approach compared with traditional conditional and mixed logit models is its capacity to provide realistic explanations of the psychological factors influencing the respondent choices [40, 41].

Finally, another possible limitation in the comparison of CV and DCE data is that differences between WTP estimates may be due to the different statistical methods used to analyse the data. A possible solution would involve creating a simulated dichotomous choice dataset from payment card data. Under this solution, estimates would be derived from the simulated data using the RUT framework, as for the DCE [35, 42]. Nevertheless, an earlier study conducted by Ryan and Watson which followed this approach found that the DCE welfare estimates remained higher than the mean WTP estimated under the simulated DC dataset [27].

7. Conclusion

Given the increasing the evidence of environmental factors on childhood burden of disease, it is essential to assess the effectiveness and the cost effectiveness of environmental policies targeting young generations. WTP measures provides information about how much people value non marketable goods and services. Such estimates are useful in assigning prices to these goods for the purpose of populating cost benefit analysis studies of environmental health interventions [42]. For the first time, this study uses a DCE to elicit children's preferences for asthma risk reductions. The study shows promising results. The children understood the DCE questions and were able to provide valid answers (in line with expectations). These results suggest that children have an increasing marginal utility for higher health risk reduction and a diminishing utility for increase of cost. As for parents, it was found that the WTP for asthma health risk reduction decreases with the age of the children, but possibly for different reasons. In comparing the results of DCE studies with those of the CV within the same questionnaire, it was found that DCE welfare estimates are significantly higher

than those of the CV. This study provides preliminary evidence on the potential for including children's preferences in the welfare evaluation of their own health risk reduction. Future research needs to be conducted to assess the theoretical and external validity of children's WTP estimates and the household decision making process.

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Section 4

In section 2, the thesis investigated whether or not children are able to understand health risks and money-related concepts. Given the positive results of both the studies described in section 2, section 3 estimated WTP for reducing the risk of an asthma exacerbation from the child and parental perspectives. The results of the CV and a DCE experiments reported in Chapter 5 and 6 are promising. Both stated choice experiments suggest that children are able to understand WTP questions and also to express, for a given budget constraint, their own WTP for health risk reductions. The results of both studies consistently suggest that child WTP for health risk reductions decreases as the children grow older. The other main finding of section 3 is that child WTP expressed in terms of proportion of the budget available, is significantly lower than parental WTP independently of the size of the health risk reduction considered.

Using the WTP estimates from parents and their children estimated in section 3, together with the methodological framework for CBA described in Chapter 1, this section provides a practical application of CBA of EHIs targeting child health. Chapter 7 will present the results of an analysis estimating the potential monetary benefits of reducing traffic-related indoor air pollution in London primary schools. The study will use primary environmental and health data collected by the SINPHONIE study from London primary schools located in urban and suburban areas to quantify the number of asthma exacerbations potentially averted by decreasing NO_2 exposure in primary school children.

Research Paper 6. The monetary benefits of reducing traffic-related indoor air pollution in London primary schools

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Contribution: CG conceived the research question, designed the analysis and drafted the manuscript. LE contributed to writing the manuscript and interpreting the study results. JC provided methodological guidance in the design of the study and contributed to the interpretation of the study results. DM oversaw the conception of the methodology, the analysis and drafting of the manuscript. All authors read and approved the final manuscript.

The candidate _____ The supervisor John Cairns

7.Chapter

1.Introduction

Over the past few decades, research evidence regarding the effects of traffic related air pollution on human health has been mounting.[1]. Previous economic evaluations conducted on the potential human health benefits of reducing traffic related air pollution showed that there is a strong economic incentive to improve air quality. Using annual average PM_{10} concentrations, Zhang et al. estimated that the health cost of air pollution in 111 major Chinese cities was approximately US$ 29,178.7 million [2]. The bulk of this was associated with premature death, which alone accounted for 88% of the total cost. Another study conducted by Kunzli et al. quantified the health costs associated with traffic-related air pollution in three European countries: Austria, France and Switzerland. It showed that air pollution related costs of all three countries amounted to some €49,400 million and that road traffic alone was responsible for €26,400 million [3].

Given the high vulnerability of children to environmental hazards, previous economic evaluations assessing environmental health interventions targeting youth health showed that the economic incentive is even higher in children compared with adults [4]. Previous economic evaluations estimating the burden of childhood asthma associated with exposure to traffic pollution in Southern California (USA) suggest that the annual potential monetary benefit of reducing air pollution are high: US$2,765,520 and US$6,110,400 in Riverside and Long Beach respectively[5]. A more recent study conducted in 10 European cities showed that the potential monetary benefit of reducing traffic-related pollution is even higher because of the higher traffic densities and proportion of urban dwellers living in proximity to busy roads compared to US urban areas [6]. On average, Perez et al. estimated that up to 14% of all asthma episodes are attributable to exposure to traffic-related pollution [6].

Outside home, children spend most of their time at school. Previous epidemiological studies have shown that children exposed to traffic related nitrogen dioxide (NO_2) while at school have an increased risk of asthma prevalence[7]. Despite the importance of providing healthy environments for children in school, there are no economic evaluations of interventions to reduce traffic-related air pollution close to primary schools.

This objective of this study is twofold: (1) using indoor and outdoor pollution data collected in London primary schools by the SINPHONIE project, it estimates the burden of preventable childhood asthma under reduced exposure to indoor NO_2; (2) using willingness to pay values from both a parent and a child perspective, it quantifies the potential monetary benefit of preventing traffic-related childhood asthma exacerbations in primary schools.

The study is organized as follows: a brief description of the database is presented, followed by an outline of the methodology and the data used to populate the analysis. The results of the baseline analysis together with the results of sensitivity analyses (deterministic and probabilistic) are presented in section 4 while section 5 offers concluding observations outlining the limits of the study and the opportunity for further research.

2.The UK database of the SINPHONIE project

Overall, 38 environmental and health institutions from 25 countries participated in the SINPHONIE study. The study adopted a multidisciplinary approach creating an integrated database of (a) physical, chemical and microbial levels in classrooms, (b) building characteristics, meteorological parameters and the microenvironment and (c) health responses collected with a standardised field survey matched with non-invasive clinical tests. The UK database of SINPHONIE project was used as the basis for the health-based monetary evaluation of reducing air pollution in UK schools presented in the study.

2.1 Case Studies

Consistent with the harmonised SINPHONIE methodology, a detailed investigation was conducted in five primary schools in Greater London from October 2011 to January 2012. The sample comprised three schools built in the 19th century (Victorian) in central London, and two contemporary schools in suburban areas. The schools (S1-S5,see Table 7.1) varied considerably in terms of their construction characteristics and proximity to likely external pollution sources. The Victorian urban schools are high thermal mass buildings with un-insulated walls, while the suburban schools are contemporary buildings with a mixture of insulated walls of high and low thermal mass. S2 was designed as a low-carbon building, with high air-tightness and good thermal performance. Urban school S3 was located close to a main street with high traffic intensity, while urban S4 and S5 were surrounded by pedestrian streets and vegetation. Traffic in S2 was related to the operation of the school, and coincided with the start and the end of the occupied period. A detailed description of the case studies, methodology used for monitoring of the pollutants and main results are presented in [8] and[9].

Table 7.1. Construction characteristics of the investigated schools

School	Area	Investigation period	Construction Year	Free School Meals	Ventilation Strategy
S1*	Suburban	9 January 2012-13 Jan 2012	2000	37%	NV cross-ventilation with windows on high level
S2	Suburban	14 Nov 2011-18 Nov 2011	2010	22%	MM NV Assisted with Mechanical Exhaust
S3	Urban in immediate proximity to main traffic artery	21 Nov 2011-25 Nov 2011	1896	53%	NV single sided
S4	Urban background	28 Nov 2011-2 Dec 2011	1870	13%	NV single sided
S5	Urban background in proximity to a carpentry industry	5 Dec 2011-9 Dec 2011	1866	95%	NV single sided Restricted windows in winter

NV: Natural Ventilation ;MV: Mechanical Ventilation;*S1 in this paper corresponds to S6 in papers [8] and [9]

Monitoring was performed over five typical consecutive teaching days in three classrooms and one outdoor site in each school. Selected classrooms had comparable occupancy densities and schedules, and were occupied by older children (9-11 years old). Socioeconomic information collected included percentage of students eligible for Free School Meals (FSM), which is a crude financial indicator long used as the main indicator of deprivation in official estimates, together with UK educational research reports [10]. FSM differed significantly between schools, ranging from 13% to 95%.

2.2 Environmental parameters

Outdoor NO_2 concentrations are significantly higher during the winter season due to complex meteorological and photochemical phenomena [11]; therefore sampling was performed from November to January (Table 7.1). Readings from a nearby central station ranged from 58.0 to 62.8 μg/m^3, and were in good agreement with concentrations sampled in urban school premises that ranged from 40.2 to 49.4 μg/m3 (Table 7.2). These exceeded World Health Organization(WHO) 2010 annual guidelines values [12]. Since sampling was performed across a total of four typical weeks in the heating season, it is likely that concentrations in urban schools exceeded guidelines during the whole winter period. The higher values recorded in the central station may be related to the location of the station on a high intensity traffic street compared with schools located in urban background locations. Among the urban schools, the highest concentrations were recorded in S3, which was located in immediate proximity to a high traffic intensity street. The strong spatial variation of outdoor NO_2 concentrations was also reflected in the two-fold higher concentrations recorded in urban school premises compared with suburban schools which ranged from 28.0 to 30.2 μg/m^3 (mean: 29.1 μg/m^3, σ: 1.1), and the difference was statistically significant ($p>0.001$).

Table 7.2. indoor and outdoor NO_2 concentrations (μg/m^3) in the study schools during the heating season

	Indoor mean (σ)	**min-max**	**Outdoor (σ)**	**Outdoor Central Station**	**I/O ratio**
S1*	21.6 (0.9)	20.4 - 22.5	30.2		0.7
S2	10.9 (2.2)	9.1 - 13.6	28.0		0.3 - 0.5
Suburban	**14.9 (5.6)**	**9.1 - 22.5**	**29.1 (1.1)**		**0.5 (0.2)**
S3	37.9 (2.4)	35.6 - 41.2	49.4	58.0	0.7 - 0.8
S4	27.6 (1.9)	25.5 - 30.0	40.2	61.0	0.6 - 0.8
S5	28.0 (2.8)	26.0 - 31.9	41.5	62.8	0.6 - 0.8
Urban	**31.2 (5.3)**	**25.5 - 41.2**	**43.7 (4.1)**	**60.6 (2.0)**	**0.7 (0.1)**
Total	25.2 (9.1)	9.1 - 41.2	37.9 (7.8)	.	0.6 (0.2)

σ: standard deviation, *S1 in this paper corresponds to S6 in papers [8] and [9]

In the absence of indoor sources, indoor NO_2 is strongly influenced by outdoor levels, and is usually below ambient levels due to chemical reactions and deposition on internal surfaces. Indoor concentrations in the suburban schools were in the range from 9.1 to 22.5 μg/m^3 (mean: 14.9 μg/m^3,

σ: 5.6), half (p>0.001) the indoor levels in urban schools which ranged from 25.5 to 41.2 μg/m^3 (mean: 31.2 μg/m^3, σ: 5.3).

The simplest screening method for calculating long term indoor concentrations from outdoor sources is the indoor to outdoor (I/O) ratio, which is widely used in epidemiological studies. Currently, there is limited evidence on the effect of envelope air-tightness on penetration ability of NO_2; however, results indicated that air-tight S2 had lower I/O ratios ranging from 0.3 to 0.5 compared with I/O ratios calculated in the rest of the schools (0.6 to 0.8). Previous investigations in school buildings reported higher I/O ratios 0.8<I/O<1.2[13-15].

2.3 Asthma prevalence in relation to NO_2 exposure in London

Information on prevalence of asthma in children in the school environment was collected through an on-site questionnaire survey distributed to 376 children aged 9 to 11 attending the 15 investigated classrooms (Response Rate=86%). Asthma prevalence in suburban schools was 1.54% and was almost seven times lower than the 10.16% in urban schools (range: 7.89% to 12.50%). The highest number of asthmatic children in the school environment was recorded in S3 which was close to a busy street with the highest NO_2 levels. Findings were consistent with The International Study on Asthma and Allergies in Childhood (ISAAC) results, which show that the prevalence of asthma among children in primary schools in UK is 7.18%, which is the highest among European Countries (Table 7.3).

Table 7.3. Prevalence of asthma in the SINPHONIE study

	Total number	**Children reporting asthmatic symptoms in the school**	**Prevalence (%)**
S1*	67	1	1.49
S2	63	1	1.59
SINPHONIE: Suburban	**130**	**2**	**1.54**
S3	88	11	12.50
S4	76	6	7.89
S5	82	8	9.76
SINPHONIE: Urban	**246**	**25**	**10.16**
SINPHONIE: Total	**376**	**27**	**7.18**

Among all investigated pollutants, multilevel analysis (at classroom and pupil level) controlling for gender, age and exposure to environmental tobacco smoke, revealed that only exposure to outdoor concentrations of NO_2 (and thus indoor NO_2 concentrations) were significantly related to asthma prevalence in the school environment. The Odds Ratio is a measure of effect size, and describes the strength of association between two data values. The OR was estimated using a multilevel (classroom and student level) logistic (logit) regression model based on data from the SINPHONIE. The binary outcome (1: asthma attack experienced at school in the last year, 0: never experienced asthma attack at school in the last year) was associated with a continuous predictor (NO_2 levels). Exposure to indoor NO_2 (OR: 1.11, 95% CI: 1.04-1.19) in the school environment was positively associated with childhood asthma prevalence. Important to notice the OR does not change in relation to the range of the exposure. Indeed, the strength of the association remains the same. As a result, even if data on asthma was collected by SINPHONIE in the non-heating season, exactly the same prevalence (there being no new incidence cases) would have been obtained at lower NO_2 concentration.

A meta-analysis of 19 studies found an association between exposure to NO_2 with prevalence of asthma (meta-OR: 1.05, 95% CI: 1.00–1.11) which falls within the range estimated in the UK component of the SINPHONIE study.

3.Methods

A damage function analytical framework was used to value the health impact of reducing NO_2 exposure in pupils attending primary school in London. The framework combined environmental, health and economic data to quantify the potential monetary benefits of reducing NO_2 exposure in schools.

The analysis consisted of four steps; firstly to quantify the number of asthma exacerbations attributable to traffic-related air pollution in London primary schools. The second step was to assign a monetary value to the burden of childhood asthma that can be prevented by reducing indoor concentrations of NO_2. The economic value of a policy intervention depends on how long the policy is assumed to display its effect. The third step was to estimate the present value of the future monetary benefits arising from reduction in traffic-related air pollution.

In order to account for the high degree of uncertainty associated with the input parameters used in the study, the fourth component of the study involved an extensive sensitivity analysis (deterministic and probabilistic using Monte Carlo simulation) performed to assess how variation in the parameters affects model results.

3.1 Health Benefits analysis: asthma exacerbations associated with traffic air pollution.

The yearly number of asthma exacerbations per school that can be prevented by reducing outdoor NO_2 concentrations was estimated in three consecutive steps:

The first step consisted of calculating the probability of having an asthma related symptoms for a decrease in 10 μg/m³ of NO_2 using the following formula[16]:

1. $$P_{10} = \frac{\left(\frac{P_0}{1-P_0} * OR\right)}{\left[1 + \left(\frac{P_0}{1-P_0} * OR\right)\right]} - P_0$$

Where P_0 is the relevant background rate among children in primary school age and OR is the Odds Ratio of having experienced asthma related symptoms per 10 mg/m^3 NO_2. The background rate (P_0) used in the baseline analysis is the average prevalence of asthmatic children in the urban school. While the OR comes from the SINPHONIE study (OR: 1.12 95%CI:1.0-1.2).

The second step was to estimate the average indoor NO_2 concentration (Xc) given the observed outdoor NO_2 concentration (X_0) and the fraction of NO_2 indoor related to outdoor traffic air pollution (I/O).

2. $$Xc = XO * I/O$$

The choice of the baseline concentrations of NO_2 is crucial in assessing the potential benefits for child health arising from lower outdoor traffic-related air pollution. The outdoor NO_2 concentration assumed in the baseline was the average NO_2 level observed in the winter season in urban schools. The I/O ratio in the baseline was equal to the mean I/O ratio in urban schools.

The number of asthma exacerbations per year in each school (Dc) is estimated by the following formula[16]:

3. $$D_c = N * P_{10} * G_d * T_e \left[\frac{(Xc - B)}{10}\right]$$

The above equation quantifies the annual number of additional asthma exacerbations (D_c) per N children subjected to category *c* of exposure. In this case, we assumed N to be equal to the average number of pupils of those schools included in the UK SINPHONIE sample (416 pupils SD: 83.31). G_d is the daily prevalence of asthma exacerbations among those who are asthmatic. Using data from the Clean Air for Europe study, G_d is assumed to be 10%, which is the mean daily prevalence of bronchodilator use by school children who reported having asthma symptoms in school environments during the winter season[17]. T_e is the time of exposure, which in our case is the number of days each year in which children are exposed to *c* levels of NO_2. In one year, there are at least 190 school days.

The number of heating days, together with the patterns of ventilation, depends on both the school's location and internal policy.

Indoor and outdoor temperatures collected during the academic year were analysed in order to calculate the heating days based on the temperature difference. It was found that heating was on in 78% of days (on average heating started in October and ended at the end of April), thus there are assumed to be 147 days of exposure per year. Xc is the average NO_2 indoor concentrations in schools in areas with high traffic volumes. B is the baseline indoor NO_2 exposure level in suburban schools in the winter season (14.9μg/m3).

The final step is to quantify the number of additional asthma exacerbations attributable to indoor NO_2 concentration per primary school. This involves assessing the lower and upper estimates for Dc using the 95%CI for the adjusted OR.

3.2 Monetary valuation of the asthma exacerbations averted.

There are two main approaches to assigning economic values to health outcomes in the cost-benefit analysis of environmental health interventions: the human capital approach and the willingness to pay (WTP) approach[18]. The human capital approach quantifies the overall tangible cost to the society associated with a given disease. Despite the advantage of being straightforward and easy to compute, the human capital approach underestimates the real costs associated with diseases by not including intangible costs in the evaluation, such as the pain and the suffering associated with individuals' loss of well-being.

As the name suggests, the WTP approach involves eliciting how much individuals are willing to pay for a change in a health related risk (e.g. how much they are willing to pay for a 10% reduction in the risk of an asthma exacerbation). Since eliciting WTP directly from children is difficult, the majority of the WTP studies with respect to children's health have estimated the WTP using the "parental perspective"[19]. The parental perspective attempts to quantify how much parents are willing to pay to reduce the health risk faced by their children. According to Viscusi et al. and Alberini et al. the

parental perspective offers are reliable source of WTP estimates because parents have defined preferences for their children's health and because parents are the persons who actually pay for their children's health risk reduction [20, 21].

Nevertheless, the adoption of a parental perspective violates the decision maker autonomy; according to the principle of consumer sovereignty individuals who benefit for the health risk reductions are also the best judges to assign them an economic value[22]. Also if a parental perspective is adopted the WTP estimate is not based on children's preferences, and both parental altruism and parents' risk perception may bias WTP estimates [19].

Only one study has elicited WTP for health risk reduction from both parents and children (see Chapter 5). The CV study described in Chapter 5 estimated the monthly WTP for reductions in the risk of asthma exacerbation from 370 children and their parents. The main findings were that, according to economic theory, children's WTP decreases for lower health risk reductions. The study results also suggest that parental WTP values for risk reductions were significantly higher than the ones provided by children themselves. The study also found that children's WTP decreases as children grow older.

As Pearce et al. suggest, the valuation of children's health risk depends on the household context and, in particular, on the distribution of the decision power within the household members[23]. The results of the study described in Chapter 5 suggest that children have defined preferences for their own health risk reductions and that they are able to trade off money for risk. However, the study did not explore whether or not/to what extent children's preferences for their own risk reduction are taken into account within the household. To account for the lack of information about the context of household decision making, this study uses three different WTP values to estimate the potential benefit of reducing indoor NO_2 exposure in primary schools: children's WTP adjusted for household budget, parents' WTP estimates and children's WTP based on children's pocket money (children willingness to pay given their monthly income). An aggregate household perspective (children plus parents WTP according to their personal budgets) was not adopted because of potential double counting.

The WTP values estimated in Chapter 5 were adjusted to be used in the present study in two consecutive steps. Firstly it was estimated the annual value of an asthma episode (VSCA) by dividing the monthly WTP estimate by twelve and then by the size of the risk reduction, Δr, associated with the policy (e.g. from 20 in 100 to 10 in 100 children have an asthma exacerbation)[23]:

4. $$VSCA = \frac{WTP/12}{\Delta r}$$

As in previous studies, and also with the CV study described in Chapter 5, parental and child WTP estimates, and as result the VSCAs, are not proportional to the size of the health risk reduction, i.e., the WTP for 10 in 100 risk reduction is not twice the size of the WTP for 5 in 100 risk reduction . VSCA was estimated using WTP estimate for 50% risk reduction as it is closer to the estimated size of health risk reduction in the present study. The second step consists in adjusting the VSCA for the different context in which environmental policy is taking place. Since the WTP estimates for asthma risk reduction were estimated in Naples (Italy), they were translated into London values (2013 prices) using unit value transfer with income adjustment procedure. The OECD recommends this method of benefit transfer because it is simple, transparent and generally yields reliable WTP estimates[18, 24]. The formula used to translate the WTP for an asthma health risk reduction in the study site (Naples) to policy site (London) values is the following [18, 24]:

5. $$WTP_J = WTP_i \left(\frac{y_j}{yi}\right)^e$$

Where WTP_i is the WTP estimate from the revealed preference study site, Y_i and Y_j are the income per capita in Naples and London respectively[25, 26]. *e* is the income elasticity which measures the proportional change in WTP for the environmental health risk reduction in response to a proportional change in real income.

An income elasticity of 0.8 was assumed in the baseline analysis, as recommended by the OECD[24]. Changes in the benefit estimates for different elasticity values were explored in one-way and in

probabilistic sensitivity analyses. Yj and Yi and WTP values were converted to 2013 £ value using purchasing power parity adjusted exchange rate [27]. Given that the CV study was conducted in 2013, WTP values year adjustment was not necessary (see Chapter 5).

The resulting WTP per asthma exacerbation estimates were: £78, £93 and £4 assuming a child perspective adjusted for family budget, a parental perspective and a children's willingness to pay respectively[19]. The first and last WTP values were adjusted for the age of child (younger children have a higher WTP compared to adolescents). Child WTP is the estimate of how much children are willing to pay each month using their pocket money to reduce their own risk of an asthma attack (children willingness to pay given their monthly income) (see Chapter 5).

3.3 Time adjustment

The present value of the potential benefit (PVB) of reducing NO2 indoor exposure in schools is estimated using the present value of an annuity formula [28]:

6. Present Value = $Dc*\lambda*((1-1/(1+d)^t)/d)$

Where: Dc is the number of asthma episodes that can be averted by reducing indoor NO_2 concentration in schools, t is the number of years over which the benefits accrue, d is the discount rate and λ is the willingness to pay for averting an asthma exacerbation [28].

The time horizon considered in the baseline analysis is 10 years. One way sensitivity analyses have also been conducted for the purpose of assessing how a shorter (5 years) and a longer time frame (20 years) would affect the benefit estimates. The monetary value of future health benefits are discounted using a 3.5 % discount rate as recommended by the UK Treasury Green Book guidelines for economic evaluation [29].

3.4 Sensitivity Analysis

Sensitivity analyses were conducted in order to assess how the baseline estimates of the potential monetary benefits of reducing traffic-related asthma exacerbations changed according to changes in

input parameters. Tornado diagrams were used to display the results of one way sensitivity analyses graphically for each of the three WTP perspectives.

The sensitivity analyses explored how the estimated benefits varied assuming a counterfactual concentration ranging from 40.2 mg/m^3, the lowest observed value observed in an urban school in the SINPHONIE study, and 49.4 mg/m^3 the highest value observed in the urban school located near a main traffic artery. According to Hammitt and Robinson, results of benefit transfers are sensitive to the value of income elasticity assumed in the model[29]. To assess how overall benefit estimates would change assuming different income elasticity values, it was used the same range as the US Environmental Protection Agency: 0.04 to 1.00[30, 31] . This range also includes 0.4 which is the value suggested in the meta analysis by Lindhjem et al. which only included studies that satisfied the scope test (increasing WTP for higher risk reductions) [32, 33].

Univariate sensitivity analysis was also performed in order to assess how the prevalence of asthma and the I/O ratio affected the potential monetary benefits for reducing indoor NO_2 exposure in schools. The lowest estimate of asthma prevalence was 7.89%, which is the lowest prevalence found in the urban school children while the highest estimate, 12.50% was the prevalence of asthma among children in the urban school most exposed to traffic air pollution.

The estimate of the mean prevalence of asthma exacerbations among children with asthma assumed in the baseline analysis 10%, was retrieved from the Clean Air For Europe study and was assumed to be the same as the mean daily prevalence of bronchodilator usage among asthmatic children. One way sensitivity analysis was conducted in order to assess how the change in this parameter affects the estimates of the monetary benefits estimate of 2%, which is the prevalence of bronchodilator use among children living in Paris during the winter season and 13% which is the mean percentage using bronchodilators on any given day among asthmatic children living in Kubio (Finland) [34, 35]. As per the UK Treasury Green Book recommendation, a 3.5% discount factor was adopted for the main

analysis. However, in order to assess how the study results are influenced by the adopted discount factor, the study performed a sensitivity analysis.

The sensitivity analysis considered discount rates of 2% and 7%, the former being the rate recommended by the European Commission for cost benefit analyses, and the latter being the rate used by Alberini et al. [36,37]. It is difficult to establish the duration of the health benefit arising from pollution control interventions a priori. In the baseline analysis, the reduction of NO_2 indoor exposure was assumed to last for 10 years. To assess how potential benefits might increase/decrease according to different time frames, we performed a one way sensitivity analysis assuming a time horizon of 2 years and of 20 years.

A Monte Carlo simulation with 1,000 iterations was also performed to assess how parameter uncertainty affects the model results. Probability distributions were assigned to the main parameters in the analysis according to standard guidelines for economic evaluation of health care intervention[38]. A Gamma distribution was assigned to willingness to pay estimates, Beta distribution was adopted for probability estimates (e.g. Baseline asthma prevalence, daily probability of bronchodilator use) and a uniform distribution was assigned to outdoor NO_2 measures and number of days per year in which pupils are exposed to high indoor NO_2 concentrations.

4.Results

Reducing indoor NO_2 exposure in a London primary school would result in a reduction of 94 asthma exacerbations each year (32-155 asthma exacerbation per year). Table 7.5 reports the potential monetary benefit per school associated with indoor NO_2 exposure at school assuming a 10 year time horizon for the pollutant reduction and 3.5% discount rate. According to the different WTP estimates adopted for the analysis, the total monetary benefit ranges between: £3k per school if a child perspective (considering child's budget) is used up to £68k if the parents' perspective is adopted. The last row of Table 7.6 also reports the benefit per pupil which has been estimated by dividing the overall monetary benefit by the average number of students in the SINPHONIE sample.

Results of the sensitivity analyses are reported in the tornado diagrams in Figure 7.1-7.3. The uncertainty is expressed as the change from baseline estimates (black vertical line) of the monetary benefit of reducing NO_2 exposure.

Assumption about the duration of the benefits and the daily probability of having an asthma exacerbation have the greatest impact on the monetary benefit associated with the reduction of NO_2 exposure. If the daily probability of having an asthma exacerbation is 2% the potential benefit assuming a parents' perspective is £14K while if the daily probability is 13% the potential benefit is almost £88K pounds.

The third most influential source of uncertainty is the I/O ratio. Assuming a I/O ratio of 0.6 the potential benefit from a children perspective adjusted for household budget is £41k. Alternatively, if the I/O ratio is equal to 0.8, then the potential benefit increases to approximately £73K. As expected, by holding the other parameters constant, the potential benefit achievable by reducing indoor NO_2 concentration was also found to be sensitive to the I/O ration and to the baseline asthma prevalence.

Results of 1,000 iterations of Monte Carlo simulation suggest that the average monetary benefits is £44,304 (95%CI: 1,736-182,727), £53,135 (95%CI: 2,089- 206,999) and £2,196 (95%CI: 195-9,203) assuming a children perspective adjusted for household budget, a parent perspective and children WTP estimate respectively.

Table 7.4. Annual Asthma Exacerbations associated with high indoor NO2 exposure per school.

Overall number of asthma exacerbations OR (95%CI)	**Asthma Exacerbations per pupil OR (95%CI)**
94 (32-155)	0.2 (0.1-0.4)

OR: Odds Ratio; CI: Confidence Interval

Table 7.5. Monetary Benefits of reducing NO2 exposure per school assuming 10 year horizon.

	Children's preferences adjusted for family budget	Parents' preferences	Children's preferences
Overall Monetary benefit	£56,818 (£19,093-£93,942)	£68,181 (£22,911-£112,730)	£2,836 (£952-£4,689)
Benefit per pupil[a]	£137 (£46-£226)	£164 (£55-£278)	£7 (£2-£11)

a: Overall Monetary Benefits divided by mean number of pupils in the primary school

Figure 7.1. Tornado Diagram showing sensitivity analysis results: Children's perspective adjusted for family budget (values in thousand £).

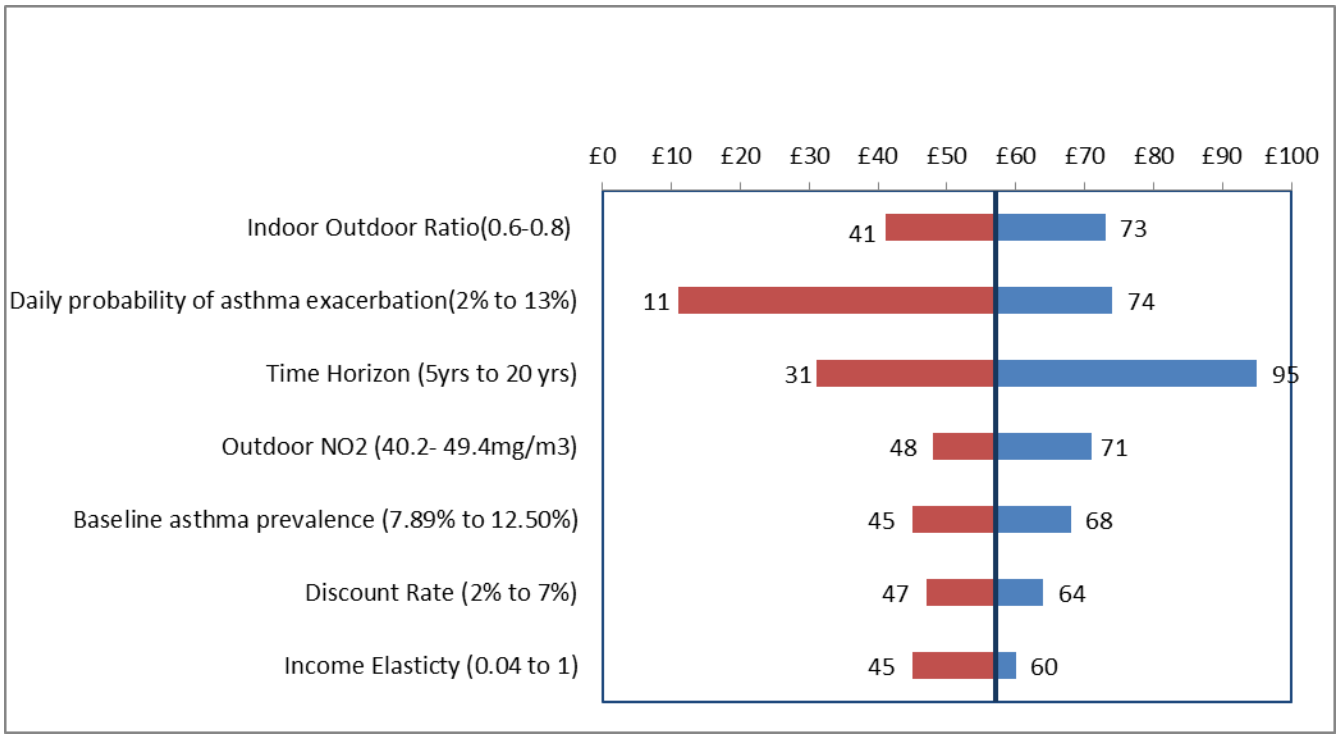


Figure 7.2. Tornado Diagram showing sensitivity analysis results: Parents' perspective (values in thousand £).

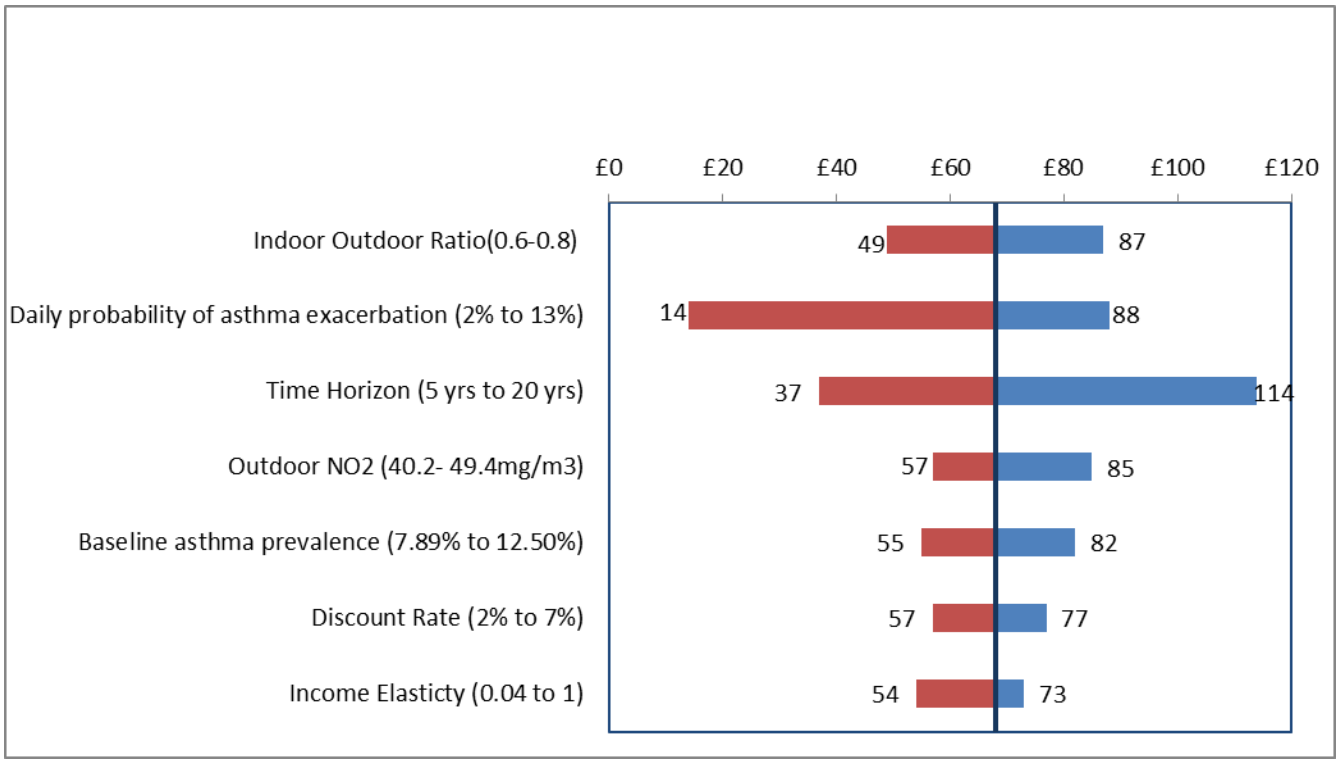
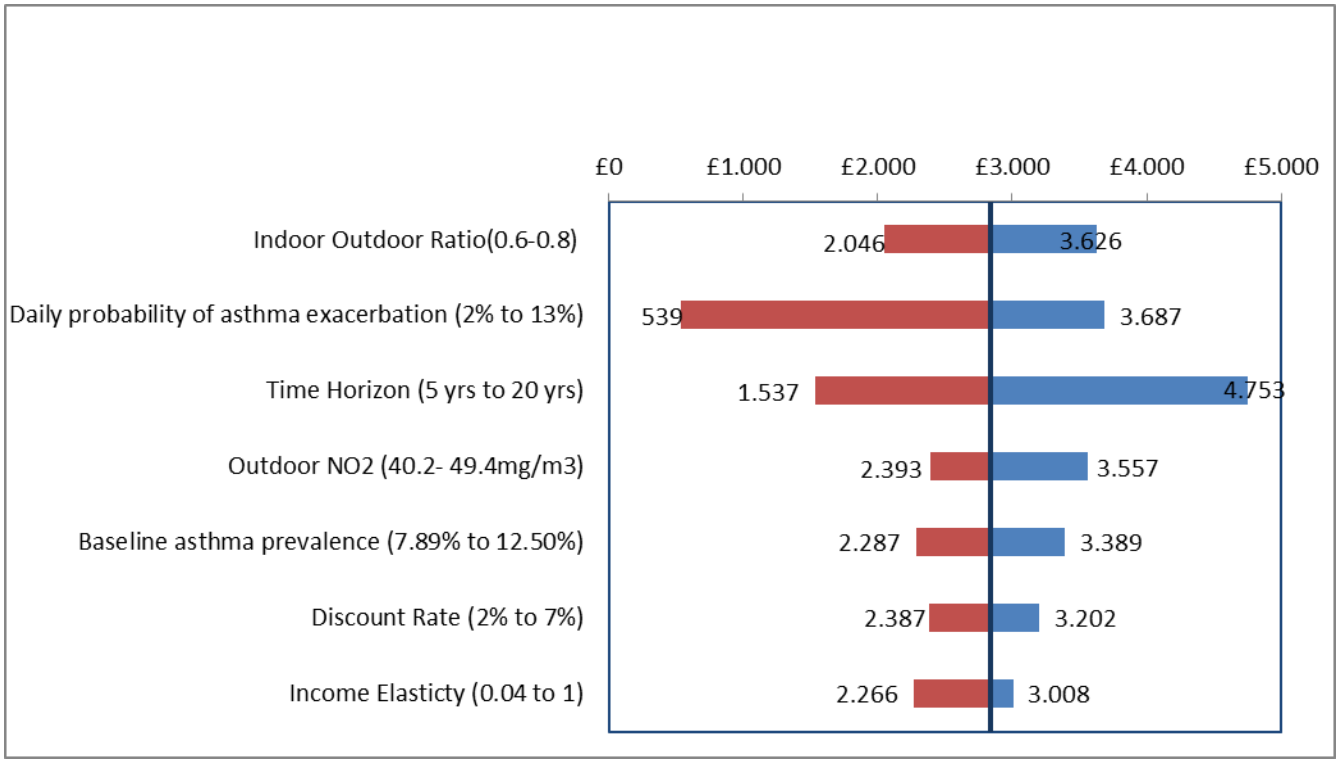


Figure 7.3. Tornado Diagram showing sensitivity analysis results: Children's perspective (values in £).



5.Discussion

This study is the first to quantify the potential benefit of preventing traffic-related childhood asthma exacerbations in children attending primary schools using indoor air quality data. The results suggest that there are approximately 90 asthma exacerbations that can be prevented by reducing outdoor NO_2 concentrations each year in a primary school located in proximity to busy roads. The associated potential monetary benefit of reducing indoor NO_2 exposure during school time, depending on the perspective adopted for the analysis, would range between £3k and £68k per school. The results of the deterministic sensitivity analysis suggest that the duration of the benefits and the daily probability of having an asthma exacerbation are the most influential parameters in the analysis.

According to the latest estimates provided by Transport for London, there are 1,148 schools within 150 metres and 2,270 schools within 400 metres of roads in London carrying over 10,000 vehicles per day [39]. Assuming that 60% of these schools are primary schools, there are 128,028 asthma exacerbations due to NO_2 exposure that can be prevented in children at primary schools in London each year. Given this figure, the neglected potential monetary benefit of reducing indoor NO_2 exposure assuming a 10 year time horizon would be ranging between £4M and £77M.

Improving indoor air quality often depends on several factors, such as: building design, time of exposure and traffic volume. Two main strategies can be adopted in order to mitigate indoor pollution levels in school classrooms: (a) filtration of outdoor air or (b) reduction of the source. The results of the SINPHONIE study suggest that mechanical ventilation and envelope air-tightness affect the penetrability of NO_2. Indicative results of the monitoring investigation suggested that increased air tightness of building envelope and ventilation strategies may reduce permeability of NO_2 and protect occupants from this harmful pollutant. Although, more research is necessary, if the building envelope can filter outdoor NO_2, there would be an even greater incentive to build low carbon emission buildings as these would both reduce greenhouse-gas emissions and reduce NO_2 indoor

exposure. Nevertheless filtration strategies have also many disadvantages including increased energy consumption of the school building stock, reduced efficiency of removal, and more importantly, in cases of poor maintenance of the mechanical systems, further deterioration of indoor air quality[40]. Reduction of outdoor sources seems therefore preferred and may include greening of urban spaces and introduction of traffic-free zones around schools [41]. It is difficult to identify a priori cost-effective strategies to reduce traffic pollution in the London area. According to Tonne et al., the congestion charge scheme, which, implemented in February 2003, is one of the world's most ambitious traffic congestion schemes, had only a modest effect on NO_2 concentrations and its effects were mainly localised in the congestion charge zones[42]. Mediavilla Sahgun et al. estimated the effect of different interventions to reduce traffic-related emission. For example, they suggest that the adoption of low emission fuels for vehicles or the use of electric buses for public transportation may substantially decrease air pollution in London in the next few years [43]. The study conducted Woodcock et al. estimated that the benefits arising from a decreased use of motor vehicles in London through the promotion of walking and cycling would be associated with higher health benefits (7332 disability adjusted years of life in one year) than those arising from an increased use of lower emissions vehicles (160 disability adjusted years of life in one year)[44].

When interpreting the study findings, several limitations also need to be considered. The generalizability of this study is limited, as the sample size and the age group considered is small. The analysis was conducted using the OR estimated in the SINPHONIE study among children aged 9 to 11 years also for younger children attending primary school. Future studies are necessary to determine whether there is an effect of NO_2 for younger children (below 9 years). Additional epidemiological studies are also needed to estimate the relationship between air traffic pollution exposure at school and asthma exacerbation (and possible asthma onset) characterized by high NO_2 outdoor concentrations and high childhood asthma prevalence in areas such as London. Separating school exposure from other exposures is challenging, as children attending urban schools may be living in

proximity to the school, and therefore be exposed to high levels of traffic-related pollutants at home. NO_2 is an indicator of traffic intensity; but other pollutants may be causing the observed health outcomes. Because there was a significant difference between indications of deprivation in the investigated schools, exposure to NO_2 may reflect a broader picture of inequalities in health, as children from poorer households tend to have worse health outcomes[45]. Previous studies quantifying the health impact of PM_{10} on asthma exacerbation in children suggest that the bronchodilator usage among those that are asthmatic is a reliable measure of the exacerbations of asthma[16, 46]. However, bronchodilator usage may overestimate the number of asthma exacerbations it is difficult to identify which factors trigger the use of bronchodilator in children. It may be possible that for example those children not having an asthma exacerbation but just coughing and feeling wheezy use their bronchodilator. On the other hand, the study estimate of the potential benefit achievable by reducing indoor NO_2 exposure in primary school children in London considered only asthma exacerbations and not their potential consequences. The consequence of a asthma exacerbation for children may have a severe and long-lasting impact on children quality of life, parents' life and health care resource use [5]. In addition, there is mounting evidence that traffic-related exposure is also associated with childhood neurodevelopmental outcomes[47]. Consequently, the study may significantly undervalue the potential burden of other health outcomes that can be prevented by improving indoor air quality in classrooms. Most cost-benefit analyses value the health benefits to children using cost of illness values or adults' WTP estimates [48]. This study estimates the potential benefit of reducing NO_2 exposure using for the first time both parental and child perspectives. Despite the advantage of taking into account child preferences for health risk reduction, one possible limitation of the study is that the WTP estimates came from a study conducted in Italy and translated to London values using the benefit transfer procedure.

Potential transfer error due to differences in real prices and incomes between countries, and differences in the attributes of the users, and in cultural and context characteristics may have influenced the study results [3]. Indeed, several other studies examining the validity of the benefit transfer approach found that the methods used (e.g. currency conversion only, income adjustment and value function approach) to translate WTP values between sites may significantly affect the transfer error [49]. A previous study assessed the transfer error rates for adults' and children's' (using parental perspective) VSL between the Czech Republic and the UK [33] . It showed that the different adjusting procedures significantly affect the transfer error values. Simple transfer without purchasing power parities adjustment was associated with a transfer error between 50% and 240%. This value decreases significantly with the adjustment for income differences between countries (transfer error between 3% and 50%). However, even if adjustment for income differences is performed, cultural differences still affect VSL, especially where a monetary value is assigned to child health risk reductions in different countries. According to Alberini et al., the transfer error between the UK and the Czech Republic is low in terms of parental values of a statistical life (transfer error using an income adjustment procedure equals 7%) For children, however, the values for the Czech Republic are 50% lower than the UK estimates.

The present study has minimised the potential for transfer error by using purchasing power parities and by accounting for income differences between the study and the policy sites. The study has also adjusted the WTP values to account for population characteristics (age of children who would benefit from NO2 reduction)[3]. For the future, additional WTP studies need to be carried out in the UK, and possibly in different regions, to assess how much English school children and their parents are willing to pay to reduce asthma related risk. Future studies may also wish to investigate whether children have same preferences for health risk reduction independently from the place in which they were born

This study focuses only on a small part (childhood asthma) of the potential burden of disease avoidable by reducing traffic exposure pollution among school children. Nevertheless, this study suggests that there is a strong economic incentive for providing a healthier indoor class environment by reducing the traffic pollution close to schools.

Given the increasing demand for primary school places, the UK Government announced £1.6 billion of funding for new school places last year, with London receiving more than a third of this funding, £576 million. This study suggests that given the relationship between asthma exacerbations in children and traffic exposure locating new schools at least 400 metres from busy roads may also be a very cost-effective intervention.

In conclusion, increasing active transport and reducing motor vehicles related emissions can have important implications for health and climate change[50].

Further research is needed to investigate the relationship between NO_2 exposure at school and asthma (exacerbation and onset) and potential environmental intervention to reduce the penetrability of NO_2 in new and existing school buildings.

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Concluding Chapter

1. Key Findings

This section brings together the main findings from each chapter reflecting the broader aims of the thesis. The objective of the first chapter was to describe the main steps necessary to conduct a complete and informative CBA. The methodological framework described in Chapter 1 was applied to two practical cases: the economic evaluation of remediating the two industrial sites of Gela and Priolo (Chapter 2) and the potential monetary benefits of reducing NO_2 exposure of primary school children in London (Chapter 7).

Chapter 2 describes the results of the CBA conducted in Gela and Priolo. The study estimated that 47 cases of premature death, 281 cases of cancer and 2,702 non-cancer hospital admissions could be averted each year in the two industrial areas. The potential monetary benefits of remediating the two areas, considering only health benefits to the adult population, were €6,639 million in Gela and €3,592 million in Priolo. These estimates were considerably higher than the estimated cost of remediating the two sites: €127.4 million in Gela and €774.5 million in Priolo. The results of the study suggest there is a strong economic case for remediation of the two industrial sites.

The second objective of this thesis is to provide preliminary evidence on the ability of children aged 6-13 years to understand questions about willingness to pay (WTP) for health risk reductions. To achieve this objective, the thesis investigated whether or not children could understand health risks and money-related concepts.

Chapter 3 describes the results of two experiments conducted with children, aged 7-13 years, to test their ability to understand health risks. The results of the first experiment, which tested two different visual aids (comic and abstract), specifically designed for communicating risk to children, suggest that the percentage of correct answers was high even for the younger age group (66% correct answers in 7-9 year olds), independently of the visual aid used. Both descriptive analysis and logistic regression

results suggest that children who were asked to respond to the question with the abstract visual aid were more likely to provide correct answers. The results of the second experiment exploring children's understanding of absolute health risk and change in absolute risk reveals that even the younger children understand health risk and that their ability to do so improves with age.

Chapter 4 presents the results of two experiments conducted to investigate children's understanding and use of money. The first experiment found that the ability of children to understand economic concepts improves with age. In particular, the study showed that the ability to understand some monetary concepts, such as budget constraint and ordering cash and coins by their value, increases significantly when children are 8-9 years compared with the younger age group (6-7 years).

The second experiment investigated children's use of money. The results showed that the majority of children receive money from their parents as a regular pocket money allowance (76%) and that the amount children receive as pocket money, for birthday and festivity presents, increases significantly as children get older. The results of the studies conducted to investigate the ability of children to understand both health risk and money related concepts suggests that even the youngest children may be able to understand WTP questions, and that their ability improves as they get older. The results of the questionnaire investigating children's use of money, shows that the majority of children receive money as pocket allowance and that their financial resources increase as they get older ,which confirms previous studies conducted in countries other than Italy[1, 2].

Building on these findings, the third objective of the thesis is to elicit, from children and their parents, their WTP to reduce the child's risk of having an asthma attack.

Chapter 5 reports the results of the first contingent valuation (CV) study conducted with children aged 7-19 and their parents. The first finding of the CV study is that the majority of children's answers are sensitive to scope: their WTP for health risk reductions increases with the size of the health risk reduction. Confirming the results of the study investigating children's understanding of health risk,

this chapter finds that the proportion of children that pass the scope test increases with age. Overall, only 34 children refused to pay for health risk reductions. Only two children replied with high protest bids, meaning that they offered to pay their entire budget for the health risk reduction independently of its size. This result suggests that children consider budget constraints when trading off between money and risk reductions, confirming earlier findings from the thesis (see Chapter 4). As with children, parental WTP is also scope-sensitive. However, a considerably higher proportion of parents offered to pay their entire budget.

The second main objective of the CV study was to estimate and compare parents' and children's WTP for different health risk reductions in terms of proportion of available budget. The average proportion of the available budget children are willing to pay ranges between 22% and 11% for a 19-in-100 and 4-in-100 risk reduction respectively. Parents are willing to pay a higher proportion of their budget compared with children independently of the size of the health risk reduction (range: 35% to 19% of the available budget). The ratio between parents' and children's WTP estimates ranges from 1.59 for the highest risk reduction to 1.72 for the lowest one.

Chapter 5 also investigates whether children's characteristics influence WTP for asthma risk reduction. Children's WTP for a reduction in their health risk decreases significantly as they get older despite the increase in available budget. Other factors found to affect children's WTP are: boys are willing to pay more than girls, and also trust in the relationship between environment and health, and asthma status. The amount of pocket money is negatively correlated with a child's WTP while being altruistic and, in particular, being willing to give money to those who need it, is positively associated with WTP. In the analysis of the parent sample, it was found that the job of parents is a predictor of increased WTP for risk reduction to children. Considering attitudinal and behavioural variables, as with children, parental trust in the relationship between environment and health is a predictor of WTP. Parental care for their own health is inversely related to their WTP for health risk reductions for their children.

Chapter 6 reports the results of a discrete choice experiment (DCE) conducted within the same questionnaire as the CV study. The results of the DCE experiment suggest that the children understood the DCE questionnaire. The coefficients for marginal utility of risk reduction and marginal utility of income have the expected signs, and are both highly significant. Only a small number of children (10 children) failed to select the dominant alternative. The average estimated WTP for reducing the risk of an asthma attack are €58 and €23 for a 19 in 100 and 1 in 100 risk reduction respectively. The second objective of the DCE study was to assess the effect of children's characteristics on their WTP. Age is negatively associated with the WTP for health risk reductions. On average children aged 7-13 years are willing to pay €36 and €11 for a 19 in 100 and 1 in 100 risk reduction respectively, while for older children WTP is €49 and €16. The third objective of the DCE experiment was to compare children's WTP estimates in terms of proportion of the budget, obtained with CV and DCE methods. Both approaches suggest that children's WTP decreases consistently with the size of the health risk reduction, but not proportionately. Both methods also suggest that child's WTP decreases as children get older and that boys have a higher WTP than girls.

The key finding in the comparison of the studies is that the WTP from DCE is twice the size of the one obtained with the CV approach. This is consistent with previous studies which compared welfare estimates obtained from adults using payment cards and a DCE [3, 4].

The last key finding of this thesis comes from the evaluation of the potential benefit of reducing traffic-related asthma exacerbations in children attending primary schools in London. Approximately 90 asthma exacerbations can be prevented each year by reducing indoor NO_2 concentrations in schools located close to a busy road. Given uncertainty about the appropriate way in which to value health benefits to children, three different perspectives were explored in the economic evaluation: parental perspectives (parents share identical preferences, children are bystanders), children's perspective adjusted for household budget (in which children decide alone about their own risk reduction and their WTP is adjusted for the overall household budget), and the children's perspective (where the

child's WTP is what they can pay based on their individual financial resources). The estimated potential monetary benefit per school (assuming a ten year time horizon) is £3k for the child's perspective, £57k for the child's perspective adjusted for family budget, and £68k taking the parents' perspective.

2.Contribution to Knowledge

The research presented in this study makes several contributions to knowledge. Its findings should be interpreted as a first attempt to provide answers to some important questions rather than as providing conclusive evidence. The objective of this section is to briefly summarise how the findings of the thesis can contribute to and expanding existing knowledge.

In contexts where there are limited resources available to remediate contaminated sites, and also where the environmental remediation is at a preliminary stage, CBA can provide a transparent and important source of evidence for policy makers [5, 6]. Nevertheless, CBA has rarely been used to prioritise contaminated sites and select clean-up interventions [5, 6]. Remediating industrial sites is costly, especially if, as in Gela and Priolo, the industrial activity has compromised the quality of the air, the soil, the groundwater and the food chain. In the Italian context, the limited funding for remediation of the polluted sites included in the national priority list has served as a justification for political inactivity for decades [7]. Currently, there are 39 sites included in the national priority list, the first sites having been identified for clean-up in 1998. However, since that date, little has been done to remove the environmental hazards in the contaminated areas [7].

Despite the high compliance cost necessary to clean-up of the areas of Gela and Priolo, the CBA described in the first chapter shows that remediating the two industrial sites is a worthwhile investment in which the estimated benefits greatly outweigh the costs.

If information about the potential benefits and costs becomes available for other national priority list sites, decision makers will be able to prioritise sites based on the results of the economic evaluations, and also to decide which intervention and implement strategies are most appropriate (e.g. capping vs. excavation). A previous study conducted to estimate the potential monetary benefits of remediating other such areas in the Italian National Priority list also show similar results [8]. By remediating illegally created toxic wastes sites in the provinces of Naples and Caserta, 848 cases of premature mortality and 403 cases of fatal cancer would be prevented each year [8]. The potential monetary

benefits of remediating the polluted areas in Campania, assuming a 10 year time horizon, is €5.4 billion[8]. Studies like the one described in this thesis, and the one conducted in Campania, provide essential information for policy makers because as long as the true benefits of clean-up interventions are unknown, it will be impossible to allocate the limited available funds efficiently [7].

Excluding the potential benefits to children from any evaluation, underestimates the potential benefits of EHIs given children's greater vulnerability to environmental hazards [9, 10]. Nevertheless the lack of available values for children's environmental health outcomes precludes the evaluation of the efficiency of new and existing EHIs affecting children's health.

Previous authors have suggested that children are unable to speak for themselves because they do not understand health risk, do not understand money-related concepts such as, budget constraints and also because children do not have financial resources [11]. However as Hoffman, Krupnick and Adamovicz suggest, "The central problem is neither whether children's preferences should be counted, nor whether the answer should be assumed. But, more precisely, the questions reveal uncertainty about when children's preferences should be counted" [12]. This thesis tried to provide a preliminary answer to this important question in Sections 2 and 3.

Children's understanding of health risk, and their understanding and use of money was investigated in Section 2. Communication of health risks to children is important because children make decisions about their health autonomously, and need to understand that their decisions can have important consequences for their health [10, 13, 14]. The study detailed in Chapter 3 was the first to investigate understanding of health risk among children aged 7-13 years. The results are promising, suggesting that even younger children can understand both absolute health risk and change in absolute risk when appropriate visual aids are employed. However, the study should be interpreted as a point of departure for further research given that communication of health risks to children is a complex and under researched area [15-19].

The results of the two experiments conducted to investigate children's use and understanding of money contribute to existing knowledge by showing that children are not "bystanders" as generally considered in the majority of models of household behaviour. Instead, they are autonomous economic agents in "their own economic world" [2, 20-23].

The results of the two chapters in Section 2 provide preliminary evidence on the ability of children to understand questions eliciting WTP for health risk reductions, and suggest that their ability to trade-off money for reduced health risk increases with age. Based on this finding, the objective of Section 3 was to elicit and analyse WTP estimates for asthma health risk reductions from children and their parents. While there is paucity of studies where health risk reduction is valued by children, there are several studies where adults value health benefits to children [9, 14]. The thesis contributes to the existing research by eliciting WTP estimates directly from children and comparing them with estimates from parents. Chapter 5 and 6 provide preliminary findings on the ability of children aged 7-19 years to understand both CV questions and DCE. In both studies, children's WTP varies according to the size of the health risk reduction, and children take into account the available budget when trading-off money for health risk reduction. Analysis of the children's responses to both CV and DCE questions suggests that the WTP for reducing asthma health risk reduces with age, and that boys are willing to pay more for health risk reductions compared to girls. As in previous studies, it was found that parental WTP is influenced by the age of the child, but not by their gender [24]. The comparison between parental and child WTP, in terms of proportion of the available budget, shows that parents are willing to pay almost twice the amount of children.

Using parents' and children's WTP estimates from the CV study, the final chapter of the thesis provides evidence on the potential benefits of reducing nitrogen dioxide (NO_2) exposure to children attending primary schools in London. The study contributes to the literature in two ways: (1) using pollution data collected simultaneously indoors and outdoors in London schools by the SINPHONIE project, it estimates number of asthma exacerbations that can be prevented by reducing children's exposure to

indoor NO_2 at school; and (2) using parents' and children's preferences, the study quantifies the potential monetary benefit of preventing traffic-related childhood asthma exacerbations in primary schools.

3.Limitations

The main limitations of the studies are discussed in each of the seven chapters of the thesis. This section brings together the main elements discussed in the previous chapters, offering a summary of the limitations of the thesis.

The CBA presented in the second chapter is the first attempt to estimate ex ante the potential benefits of removing pollutant contamination from industrial areas. However, the analysis does not include health-related benefits to children and some non-health benefits, given both the absence of WTP estimates for use in the valuation of children's health benefits and the lack of values to assign to non-health benefits, such as improvement in air quality, and expected increases of tourism in the area.

Chapters 3 to 6 describe the results of the *Respiriamolacitta* project, conducted with children aged 6 to 19 years in Naples (Italy).

The *Respiriamolacitta* studies were limited by restrictions in the funding available for meeting the cost of questionnaires and interviewer assistance. Also due to limited funding, the sample sizes are small, ranging from approximately 100 children, in the studies investigating children's understanding of money and of health risk, to 370 children in the stated choice studies.

In addition to these general limitations, each study methodology could be improved. For instance, the study in Chapter 3 tested only two visual aids specifically designed for children: a comic visual aid and an abstract visual aid. Also, the study investigating use of money by children did not collect specific pieces of information, such as what children buy with their money.

The studies eliciting WTP directly from children present several limitations that need to be addressed in future studies. For instance, before delivering the final questionnaire, two elicitation formats were tested: open ended and payment card. However, children's ability to understand the referendum format was not tested, and this is currently the most commonly used format for adults, and recommended by the NOAA panel for eliciting WTP estimates [25].

Both the CV and DCE questionnaires used specific budget constraints estimated on the basis of the data collected in the study investigating children's understanding and use of money (Chapter 4). According to NOAA guidelines, reminding respondents about the budget constraint is critical to receipt of meaningful answers [25]. The payment card values in the children's CV study and the cost attribute levels in the DCE were designed using real budget information rather than a priori assumptions on the individual's budget. Nevertheless, the information about a budget constraints was available only for younger children. In the case of older children (14-19 years), the study assumed the budget constraint to be equal to the one of the older age group involved in the experiment testing children's use of money. Similarly, a fixed budget constraint was used with parents without considering potential variations in the household budget across the parents interviewed. Use of a higher/lower pre-assigned budget constraint might have changed the WTP estimates. The stated choice studies collected information about important variables such as family size, children's and parents' age, gender and children's asthma status. However, they did not account for other factors that may have influenced WTP such as household structure (e.g. divorce, age structure of the overall family, presence of the father/mother) and also other information on how decisions are made within the family (e.g. who makes decision about the children's health)[9, 26].

The study described in Chapter 7 is the first quantifying the health effects of preventing children NO_2 exposure using both outdoor and indoor data, and estimating the potential monetary benefits of preventing asthma exacerbations in primary schools from both the children's and the parents' perspective. Nevertheless, there are several limitations to this final study: the data on indoor and outdoor NO_2 concentrations were collected in a small sample of schools. Similarly, the odds ratio estimated from the UK sample of the SINPHONIE, which consisted of a small sample of children aged 9-11 years, has been applied in the economic evaluation to younger children attending primary school. The study quantifies the burden of asthma exacerbations without considering the degree of severity of asthma. An asthma exacerbation can be mild, such as a temporary shortness of breath, or can be so severe as to require hospitalisation of the child [27]. Similarly, the WTP estimates used in the CBA

were elicited from children and their parents for an asthma attack in general without taking into account the different levels of asthma severity. Another limitation of the study is the use of WTP estimates elicited in a different site (Naples) translated to London via the benefit transfer procedure. To explore these limitations/assumptions, extensive deterministic and probabilistic sensitivity analyses were performed. The results of these analyses will help policy makers gauge the cost effectiveness of future interventions taking into account the uncertainty in the benefits estimates.

4. Future Research

The several pieces of work comprising this thesis provide a preliminary finding which tackles new areas that have not been adequately explored. The evidence of previous CBAs of EHIs, and the two studies presented in this thesis (Chapters 2 and 7), show that it may be more efficient to invest resources for the reduction of environmental hazards (ex ante intervention) than to spend money to cure the health outcomes generated by environmental problems (ex post intervention)[9]. The number of cost effectiveness studies of EHIs in previously neglected areas, e.g. the reduction of greenhouse gases, is increasing [28-31]. However, given the paucity of studies, providing further evidence on the cost-effectiveness of EHIs remains a research priority because the lack of information about the potential benefits of EHIs may discourage the adoption of cost-effective interventions. Despite the higher vulnerability of children to environmental hazards, few resources are invested to prevent child exposure to these hazards [32]. Possible reasons for this are the lack of epidemiological and economic data, and the methodological issues associated with eliciting WTP estimates to value children's health benefits [14, 32].

Consistent with the principles of welfare economics, children from certain age groups may be the best judges of the value to them of their own health risk reductions. As a result, the child perspective may offer the best point of departure for estimating WTP values for child health benefits [9]. Previous studies valuing reductions in risks to child health assumed that children are not rational decision makers and therefore used adults' valuations [9]. The results reported in this thesis provide preliminary evidence on the ability of children to make trade-offs between money and health risk reductions.

The study reported in Chapter 3 of this thesis is the first exploring child understanding of health risk. Given the importance of this topic, future research is needed both to confirm these results and also to

further investigate the best methods (e.g. numbers, pie charts, histograms etc.) for communicating health risk information to children [33-36].

The studies described in Chapter 5 and 6 are among the few stated preference studies ever conducted with children. The results of both studies suggest that children may have defined preferences for current health risk reductions and that there are factors, such as age, that influence their preferences. Further research is needed to confirm this hypothesis. Further research is also needed to investigate the external validity of adults' and children's WTP estimates obtained from DCE and with CV elicitation methods [3, 4].

Context of valuation is another key factor in estimating children's health benefits. Context evaluation involves considerations of, for example: whether children's preferences are considered in the household decision-making; which factors (e.g. age, whether the child works, cultural factors, household structure) influence children's decision power? The majority of previous theoretical models used in family economics did not include a child utility function [10, 37, 38]. Nonetheless, some studies show that children influence household choices, such as choice of holiday destinations and products to buy [23, 39-41]. To investigate the decision making process within households and how decisions can be influenced by both household structure and the child's characteristics (e.g. age) is beyond the scope of this thesis but constitutes material for further research.

This research provides preliminary evidence on child preferences for current health risk reductions. However, if children are found able to express their preferences for future health benefits, research also needs to be undertaken to determine which factors influence their inter-temporal choices [42, 43].

Finally, this thesis focused only on the evaluation of health benefits arising from EHIs. As the latest report of the intergovernmental panel on climate change suggests, the economic exploitation of the natural environment, the alteration of ecosystem and its consequences are the greatest challenges that humanity has to face [44]. Under-pricing or ignoring of goods and services offered by the natural ecosystem has led to their exploitation and degradation [45, 46]. According to the Millennium

Ecosystem Assessment survey, two thirds of the services and goods provided by nature are in rapid decline [47]. Economic evaluation can play a fundamental role in placing a price on ecological goods and services, and their benefits to human welfare [45]. Given the pace of economic development, preserving and restoring the natural capital and halting the climate change are the biggest challenges for the future. Assigning a value to biodiversity and ecosystem services is complex and remains a major methodological issue to address. Given the promising results of this thesis, perhaps a further question is whether younger generations should be asked to value the natural capital. After all, children will inherit the planet. Whether or not they have preferences for non-health benefits arising from EHIs is still an open question.

5. Conclusion

CBA can play an important role in guiding decision-making as it offers a transparent source of evidence on the potential benefits, costs and the associated uncertainty of environmental interventions affecting human health [48, 49].

When EHI affects children's health the availability of child-specific monetary values is essential to assess the cost-effectiveness of the intervention/policy. This thesis provides preliminary evidence on the ability of children as young as seven years to understand health risks and money-related concepts. Consistently with these findings the contingent valuation study and the discrete choice experiment suggest that children understand WTP questions, that they have defined preferences for their own health risk reductions, and that their preferences differ from those of their parents. As shown in the last chapter of this thesis the perspective (children's vs. parents') used for estimating the monetary benefit arising from interventions targeting children's health influences the policy's cost-effectiveness. Whether or not children's preferences are and should be taken into account in the household decision model for estimating WTP for children's health risk reduction is a priority for future research.

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Appendices