THE ECONOMIC IMPACT OF AIR POLLUTION IN THE TOWNSHIPS OF MANGAUNG METRO MUNICIPALITY: A CASE STUDY OF PHAHAMENG AND ROCKLANDS

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DECLARATION

I, Sylvia Olawumi Israel-Akinbo hereby declare that this dissertation submitted for the degree of Master of Science in Agricultural Economics, at the University of the Free State, is my own independent work and has not previously been submitted by me to any other University. This project has not been previously published or submitted to any University for a degree. I further cede copyright of the dissertation in favour of the University of the Free State.

SYLVIA OLAWUMI ISRAEL-AKINBO

DEDICATION

In all humility and with a heart full of gratitude, I dedicate this work to the ALMIGHTY GOD, who has given me the health, opportunity and inspiration to undertake and complete this research study.

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ABSTRACT

Economic and domestic activities have been causing a profound deterioration of air quality in developed and developing countries. The health problems arising from air pollution, both indoor and outdoor, have become apparent which result in welfare losses in society such as increased workdays lost and high health cost. The empirical work on welfare losses as a result of air pollution in South Africa has focussed only on urban settlements, hence the need of this study. The main objective of this study was to explore the economic impact of air pollution in two townships of Mangaung metro municipality.

The study was conducted in Phahameng and Rocklands areas. The sampling technique used was the stratified random sampling technique. Data was collected through a Contingent Valuation (CV) questionnaire. The 26 questions in the questionnaire were compiled through interaction with knowledgeable individuals and completed via face-to-face interviews. A total sample of 300 households was surveyed with 111 questionnaires administered in Phahameng and 189 in Rocklands.

The mitigating cost and the number of workdays lost as a result of an episode of air pollution related illness was estimates from the survey. Mitigating cost is measured as the total cost incurred (include consultation fee, cost of medication, hospitalisation and transportation fees) as a result of treating the last episode (prior to interview) of air pollution related ailments. Workdays lost is measured as the number of days lost for the last episode (prior to interview) of ailment related to air pollution. For employed respondents, it is measured as number of days not able to go to place of work; for self-employed or unemployed respondents, it is measured as the number of days not able to perform daily routine or activities. For respondents that are studying, it is measured as days absent from school. The factors influencing these economic parameters (mitigating cost and workdays lost) were explored using Ordinary Least Square (OLS) Regression Model. The Contingent Valuation questions measured welfare losses by asking a hypothetical question regarding household willingness to pay for improved air quality.

Willingness to pay for improved air quality was determined through a double bounded iterative bidding. Based on the pilot survey and evaluation of previous studies, a starting bid of R100 was chosen. The mean willingness to pay per household was estimated from the upper and lower bound amount given by each household respondent. Three steps were taken to evaluate the respondents' willingness to pay for improved air quality. Firstly, the Cragg's Model was used to determine if the choice to pay and the amount that will be paid for improved air quality is one-decision or two-decisions. A Probit Model was fitted to evaluate the factors that influence the willingness to pay decision (whether or not to pay). Lastly, a Truncated Regression Model was fitted to determine the factors that determine the amount that will be paid for improved air quality as indicated by those who are willing to pay.

The empirical results revealed that the mean workdays lost and mitigating cost as a result of illness associated with air pollution in both study areas is 3.43days and R112.27 respectively. Health, duration of illness, age, district (Phahameng or Rocklands), mitigating cost and number of visits to see a doctor or to pharmacy for treatment were found to be the principal factor influencing workdays lost. High income level, duration of illness, district (Phahameng or Rocklands), ailment (episode of air pollution related ailment), workdays lost, treatment methods and unemployed were found to be the principal factors influencing mitigating cost. The mean willingness to pay per household for improved air quality on a monthly basis from both study areas is R110.59. The Cragg's Model showed that the choice to pay for improved air quality and the amount to be paid is two separate decisions and should thus be modelled as such. Results from the Probit Model shows that education and ailment (episode of air pollution related ailment) are the principal factors that influence the decision of whether or not to pay. The Truncated Regression Model indicated that the decision on how much to pay is determined by education and high income.

The conclusion from the study is that the impact of air pollution should be seen beyond the adverse health effect it poses. Air pollution can be reduced by creating environmental awareness not only in the study areas but in South Africa.

Keywords: Air pollution, Air quality, Workdays lost, Mitigating cost, Willingness to pay, Contingent Valuation, Cragg's Model

OPSOMMING

Ekonomiese en huishoudelike aktiwiteite het 'n geweldige agteruitgang in die gehalte van lug oral in ontwikkelde en ontwikkelende lande veroorsaak. Dit blyk dat gesondheidsprobleme as gevolg van lugbesoedeling, sowel binneshuis as buitenshuis, groot maatskaplike verliese veroorsaak, soos byvoorbeeld verhoogde aantal werksdae wat verlore gaan en hoë gesondheidsuitgawes. Tot dusver het die empiriese werk gedoen op maatskaplike verliese as gevolg van lugbesoedeling in Suid-Afrika slegs op stedelike gebiede gefokus, vandaar dan die noodsaaklikheid van hierdie studie. Die hoofdoelwit van die studie was navorsing oor die ekonomiese impak van lugbesoedeling in twee gebiede binne die Mangaung Metro Munisipaliteit.

Die studie is binne Phahameng en Rocklands-gebiede uitgevoer. Die proefnemingstegniek wat vir die studie gebruik is, was die stratigrafiese willekeurige proefnemingstegniek. Inligting is by wyse van 'n vraelys ingewin. Die 26 vrae vervat in die vraelys is deur middel van interaksie met kundige persone opgestel en met behulp van individuele onderhoude vervolmaak. 'n Totaal van 300 huishoudings is gedurende die proef bestudeer, met 111 vraelyste in Phahameng en 189 in Rocklands voltooi.

Die Versagtings koste ("mitigating cost") en die aantal werksdae wat verlore gaan as gevolg van lugbesoedeling-verwante siektetoestande was beramings soos uit die studie verkry. Versagtings koste word bereken as die totale uitgawe aangegaan (insluitende konsultasiefooie, koste van medisyne, hospitalisasie en vervoerkoste) as gevolg van behandeling van 'n laaste geval (voor die onderhoud) van 'n lugbesoedeling-verwante siektetoestand. Verlore werksdae word bereken as die aantal dae wat verlore gegaan het tydens die laaste periode van afwesigheid (voor die onderhoud) as gevolg van 'n lugbesoedeling-verwante siektetoestand. Sover dit werkende respondente betref, is dit bereken op die aantal dae wat hulle nie in staat was om na hul werksplekke te gaan nie; vir persone in eie diens of werklose respondente, is dit bereken as die aantal dae waar sulke persone nie in staat was om daaglikse take of aktiwiteite uit te voer nie.

Vir studerende respondente is die berekening gedoen op die aantal dae van afwesigheid van skool. Faktore wat hierdie ekonomiese parameters beïnvloed, (versagtings koste en verlore werksdae) is met behulp van die "Ordinary Least Square (OLS)" Regressiemodel ondersoek. Die Gebeurlikheids analise -vrae het maatskaplike verliese bereken deur middel van die hipotetiese vraag oor die bereidwilligheid, al dan nie, van 'n huishouding om vir beter lugkwaliteit te betaal. Sodanige bereidwilligheid om te betaal vir beter lugkwaliteit is deur middel van 'n dubbelbindende herhalende bod *("double bounded iterative bidding")* bepaal. 'n Aanvangsbod van R100, gebaseer op die loodsproefneming en die beramings verkry vanuit vorige studies, is gekies. Die gesamentlike bereidwilligheid om te betaal per huishouding, is bereken deur middel van die boonste en onderste bod wat deur elke respondent in sodanige huishouding verskaf is. Drie stappe om respondente se gewilligheid om te betaal vir beter lug-kwaliteit te verklaar, is gevolg: Eerstens is die Cragg's Model gebruik om te bepaal of die keuse om te betaal, sowel as die bedrag betaalbaar vir verbeterde lugkwalitieit, 'n een-besluit of 'n twee-besluit beslissing was. 'n "Probit" model is gebruik om die faktore te bepaal wat die besluit om te betaal, al dan nie, beïnvloed. Laastens is 'n "Truncated" Regressiemodel aangewend om die faktore te bepaal wat die bedrag betaalbaar deur respondente vir beter lugkwalitieit, beinvloed.

Die empiriese resultate het bewys dat die gemiddelde verlore werksdae en versagtings koste as gevolg van lugbesoedeling-verwante siektes in beide studie-areas 3.43dae en R112.27 onderskeidelik was. Gesondheid, duur van siekte, ouderdom, distrik (Phahameng of Rocklands), versagtings koste en aantal doktersafsprake of besoek aan 'n apteek vir behandeling, was die hoofoorsaak van verlore werksdae. Hoë inkomstevlakke, duur van siekte, distrik (Phahameng of Rocklands), aard van siekte (voorval van lugbesoedeling-verwante siekte), verlore werksdae, behandeling en werkloosheid was die hoofoorsake wat die versagtings koste beïnvloed het. Die gemiddelde mate van bereidwilligheid van 'n huishouding om op 'n maandelikse basis te betaal vir beter lugkwaliteit in beide areas, was R110.59. Die Cragg's Model het aangedui dat die keuse om te betaal vir beter lugkwaliteit, sowel as die hoeveelheid betaalbaar, is twee afsonderlike besluite en behoort so aangedui te word in die model. Resultate van die Probit Model het aangedui dat opvoeding en siekte (voorval van lugbesoedeling-verwante siekte) die hoofoorsake van die besluit om te betaal, al dan nie, beïnvloed. Die "Truncated"

Regressiemodel het aangedui dat die besluit oor die bedrag betaalbaar, bepaal word deur opvoedingspeil en hoë vlak van inkomste.

Die gevolgtrekking verkry uit die studie is dat die invloed van lugbesoedeling verder as die nadelige gesondheidstoestand strek. Lugbesoedeling kán wel beheer word, deur omgewingsbewustheid in die studie-areas, sowel as die hele Suid-Afrika, te kweek.

Sleutelwoorde: Lugbesoedeling, Lugkwaliteit, Verlore werksdae, Versagtings koste, Bereidwilligheid om te betaal, Gebeurlikheids analise, Cragg's Model.

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CHAPTER 1

INTRODUCTION

1.1 Background and motivation

Over the past two decades, there has been continued deterioration in air quality. Air pollution, both indoors and outdoors, is a major environmental health concern, affecting people in both developed and developing countries. No solutions to reduce air pollution to an acceptable level that will not be detrimental to health and the economy have been identified (UNEP & WHO 1992; WRI *et al*., 1998). Past research has indicated that many major cities in developed and developing countries experience severe levels of air pollution which poses a major environmental risk to human health (WHO, 2007). Intensified processes of industrialisation coupled with the rapid growth of transportation have resulted in the degradation of the air quality (Molina and Molina, 2004). Combustion of traditional biomass fuels and coal, poor environmental regulations, less efficient technology of production, congested roads, age and poor maintenance of vehicle are other factors contributing to air pollution.

To evaluate the effects of air pollution, the valuation of its health impacts is crucial. Air pollution effects worldwide have been found to contribute over 90% of the total health cost in monetary terms (ExternE 1998; 2000; 2004). There are more than 2.7 million deaths that occur worldwide due to air pollution (WHO, 2003). There is substantial evidence from both developed and developing countries of strong correlation between exposure to ambient air pollution concentration and health risk and very high health costs (Dockery *et al*., 1993; Schwartz, 1993; Pope *et al*., 1995). Recent epidemiological studies by Alberini and Krupnick (2000), Kumar and Rao (2001), Murty *et al*. (2003) and MJA (2004) also provide similar evidence. A large number of health-damaging air pollutants are associated with both indoor and outdoor pollution which include the particulate matters $PM_{2.5}$ and PM_{10} and gaseous pollutants, $S0_{2,}$ $N0_x$ and CO (PERN, 2003). These air pollutants pose a range of negative effects on human health. Constant exposure to air pollution often leads to morbidity and mortality (Murty and Kumar, 2002). Conservative estimates of mortality due to indoor air pollution reveals that approximately 2 million premature deaths occur worldwide per year which accounts for 4-5% of total mortality worldwide (Smith, 2003). The observed health effects include eye irritation, respiratory diseases, cardiovascular diseases, and premature deaths especially in children (CEAP, 2004).

Studies done by Kyung-Min Nam *et al*. (2010), Mayeres and Van Regemorter (2008) have revealed that labour and leisure loss are major economic impacts of air pollution that can affect market equilibrium. Computable general equilibrium (CGE) modelling approach was used by these authors to assess the economic impacts of air pollution. When economic damages accumulate, it leads to a loss in income which means lower gross domestic product (GDP) and savings and therefore less investment and lower economic growth will occur over time. The economic impact of air pollution can also be measured in terms of the economic cost of air pollution. The economic cost is the total cost incurred due to air pollution associated health problems. Jakarta is one of the most polluted cities in the world and it was estimated according to World Bank that the health cost of air pollutants was approximately $US220 million in 1994. In Cairo, the estimated cost of mortality in 1990 was between $US186 - $US992 million and morbidity cost was $US157-$US472 million. In Mexico, the estimated cost of mortality and morbidity in 1990 was $US480 million and $US358 million respectively (World Bank, 1997). High economic cost as a result of air pollution related health problems results in low GDP.

Respiratory disease, which is the major impact of air pollution on human health, is the second most frequent cause of death in children (0-5 years) in South Africa (Department of Environmental Affairs, 2009). Outdoor air pollution in urban areas in South Africa was estimated to cause 3.7% of the national mortality from cardiopulmonary disease and 5.1% of mortality attributable to cancers of the trachea, bronchus and lungs in adults aged 30 years and older, and 1.1% of mortality from acute respiratory illness in children under 5 years of age. These diseases amounts to 4 637 or 0.9% (95% uncertainty interval 0.3-1.5%) of all deaths and about 42 000 years of life lost in persons in South Africa in 2000 (Department of Environmental Affairs, 2008).

In Mangaung metro municipality, about half of the households have shifted from traditional biomass fuels to fossil fuels or electricity. The remaining half, comprising mostly the low income earners, continues to use paraffin for space heating due to unavailability of electricity or the high cost of its usage (Department of Environmental Affairs, 2009). Biomass fuel (wood) and coal are still being used by some households for cooking. In indoor environments, cigarette smoke and paraffin fumes are the most important pollutant sources in Mangaung metro municipality while for the outdoor environment; smoke from burning of refuse by households is the primary source of a large number of health-damaging air pollutants (Department of Environmental Affairs, 2009). Air pollution, both indoors and outdoors, is thus a major environmental health problem affecting everyone.

1.2 Problem statement

Indoor air quality has continued to deteriorate in the townships of Mangaung metro municipality due to households' energy choice for their domestic activities most especially for cooking and space heating. There is also deterioration in the quality of air outdoors which arises from burning of refuse by households. As a result, people suffer from illnesses such as bronchitis, heart problems, respiratory problems, etc., which invariably reduce the efficiency of people at work. Air pollution is thus a cause of concern because it has serious economic, health and social implications.

Globally, numerous studies on ambient air pollution have been conducted all over the world especially in developed countries. Studies by Chavez (2010), D'Amato *et al*. (2010), Manawadu and Wijesekara (2009), Usha Gupta (2008), Pope *et al*. (2006), are few amongst many that have investigated air pollution in diverse ways but in urban environments.

Past researches in South Africa have explored the impacts of air pollution on health and the focuses have been on industrial areas and urban settlements. White (2003) investigated the impacts of a petrochemical refinery on health in the urban settings of Northern area of Cape Town, South Africa. Measurable health effects were revealed with school children affected the most. Scorgie (2004) also conducted a study reviewing the adverse health effects associated with particulate matters ($PM_{2.5}$ and PM_{10}) on residents in industrially developed urban settings in Durban, South Africa. The sources of PM emissions were revealed and it was found to be significantly associated with decrements in lung function among children with persistent asthma.

Annegan, Sithole and Wahn (2002) discusses air quality measurements and issues in South African cities, giving examples of recent research findings on the physical and chemical nature of pollutants that are relevant to health impacts. An urban area, as viewed by these authors, is considered a hot spot for investigating air quality due to high pollution levels as a result of industrialisation and transportation. Problems and prospects for protection of public health against the adverse health effect of air pollution in the semi-urban and rural environments have not been explored. Interventions by national or international organisations to improving air quality in the semi-urban or rural settlements of South Africa is difficult because no research was found within South Africa exploring the economic impact of air pollution and benefits of improved air quality in the semi-urban and rural environments.

1.3 Objectives of the study

The primary objective of this study is to investigate the economic impact of air pollution on residents of Phahameng and Rocklands in Mangaung metro municipality, Free State Province, South Africa. In order to meet this primary objective, the following secondary objectives will be addressed:

- Quantify the economic cost of air pollution by quantifying workdays lost and mitigating cost as a result of air pollution related illness.

- Determine the factor(s) that influences the economic cost of air pollution. Factors that influence workdays lost and mitigating cost will be explored.

- Quantify willingness to pay for clean air to avoid a loss in health status. Willingness to pay estimated from the survey using a double-bounded iterative bidding approach will be determined.

- To investigate the principal factor(s) influencing the willingness to pay for improved air quality. Within this study, the factors that influence the decision of whether or not to pay and the actual amount people are willing to pay for improved air quality will be determined.

1.4 Research area

The Free State is the third largest province in South Africa and covers 10.6% of the country's surface area (IDP, 2003). Mangaung metro municipality has a population of 645,455 and is South Africa's seventh largest municipality area and the sixth-largest growing city. Mangaung metro municipality governs Bloemfontein and surrounding towns (Botshabelo and ThabaNchu) in the Free State Province. The research is conducted at Phahameng and Rocklands, located in the township area of Bloemfontein. Figure 1.1 shows the location of Mangaung metro municipality in the Free State.

Source: IDP, 2010

Figure 1.1: Location of Mangaung metro municipality (highlighted red)

1.4.1 Background to socio-economic characteristics of Mangaung metro municipality

Census and community survey data is used to discuss Mangaung metro municipality in terms of population, employment, income but more extensively on energy sources for cooking and space heating. The discussion is based on a comparative analysis of the 2001 census and 2007 community survey of Mangaung metro municipality

The population and number of households of Mangaung metro municipality have increased marginally. The percentage increase in population is 14.27% while the number of households has increased by 6.85% between 2001 and 2007 (IDP, 2010).

The employment status of the people of Mangaung metro municipality has been undergoing a steady movement for the better. The unemployment rate has marginally decreased (10.12%) and the employment rate has increased substantially (41.07%) between 2001 and 2007. According to IDP (2010), the employment absorbing sectors in Mangaung metro municipality (in order of magnitude) over the years remain public service, manufacturing and financial services.

Linked to the above employment status is the monthly income level distribution of the people of Mangaung metro municipality. There are still a large number of income earners in the no income and low income category (less than R3000) and could be as a result of migration of people from Sol Plaatjie (Kimberly), Mathjabeng (Welkom), Lesotho and other smaller towns which has made economic and employment opportunities to reduce (IDP, 2010).

1.4.2 Household energy/fuel sources

Tables 1.1 and 1.2 shows the energy sources for cooking and space heating respectively in Mangaung metro municipality based on the 2001 census and a community survey done in 2007.

Table 1.1 **Comparison of household energy sources for cooking in Mangaung metro municipality in 2001 and 2007**

	Census 2001		Community survey 2007	
	Number	**%**	**Number**	**%**
Electricity	112 108	60.60	162 660	80.22
Gas	5 572	3.01	3 385	1.67
Paraffin	60 121	32.50	33 835	16.69
Wood	2 500	1.35	1 460	0.72
Coal	917	0.50	274	0.14
Animal dung	2 788	1.51	1 018	0.50
Solar	518	0.28	0	0.00
Other	485	0.26	129	0.06
Total	185 009	100.00	202 761	100.00

Source: Statsa, 2007

The statistics from Table 1.1 show that households use mostly electricity (60%) for cooking. From 2001, the number of households who use electricity as an energy for cooking increase by 20 percentage points to 80% in 2007. Paraffin, the second most used energy source by households for cooking has decreased from 32.50% in 2001 to 16.69% in 2007 which can explain the increase for electricity usage for cooking. It is quite surprising to see a decrease from 0.28% to 0% in the usage of solar energy by households for cooking. It was expected to have increased since 2001 being a clean energy source compared to wood, coal or animal dung amongst others. The usage of gas, wood, coal and animal dung by households for cooking has marginally decreased from 2001 to 2007 ranging from less than 2% to 0.5%. It could be inferred that these energy sources have been replaced with electricity usage.

Table 1.2 Comparison of household energy sources for heating in Mangaung metro municipality in 2001 and 2007

	Census 2001		**Community survey 2007**	
	Number	**%**	**Number**	**%**
Electricity	100 639	54.40	117 006	57.71
Gas	2 834	1.53	3 774	1.86
Paraffin	56 905	30.76	65 228	32.17
Wood	7 011	3.79	4 846	2.39
Coal	8 650	4.68	4 853	2.39
Animal dung	3 026	1.64	1 528	0.75
Solar	434	0.23	108	0.05
Other	5 510	2.98	5 419	2.67
Total	185 009	100.00	202 762	100.00

Source: Statsa, 2007

Table 1.2 shows that electricity usage by households for space heating has increased marginally from 54.40% in 2001 to 57.71% in 2007. Similarly, paraffin use has also increased from 30.76% in 2001 to 32.17% in 2007. Paraffin is being used more for space heating by households in Mangaung metro municipality and thus contributes to the indoor air pollution posing negative effects on the health of occupants. Solar energy for space heating has gradually reduced from 0.23% in year 2001 to 0.05% in 2007. The percentage point change is smaller compared to the other energy sources with wood showing a 2.39% decrease, coal (2.39%) and animal dung (0.75%). The reason(s) why people are not adopting the use of solar energy for domestic purposes is not tested. However, the high cost of installation of solar energy could be a factor. Households mainly use electricity source for cooking.

The community survey from 2007 shows that the population, household number and employment rate of Mangaung metro municipality have increased and that most of the people are in low income categories.

Although the use of electricity has increased from 2001 to 2007, there are still a number of households using energy sources associated with indoor air pollution. This study is relevant as it not only provides a current picture of the state of air pollution (both indoor and outdoor) in Mangaung metro municipality but also measures the economic impact as a result of air pollution.

1.5 Outline of the study

The rest of this study is organised into five chapters. Chapter 2 presents a review of relevant theoretical literature on air pollution, the impacts of air pollution and the measuring of economic impact of air pollution. Chapter 3 provides the data collection method, socio-economic characteristics of the household heads, households' energy/fuel source for cooking and space heating and time of the year indoor and outdoor air pollution occurs. Chapter 4 discusses the procedures used to meet the objectives of the study. The results and discussion follows in Chapter 5. The last chapter, Chapter 6, deals with the summary, general conclusions and some policy recommendations.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

Air pollution is the accumulation of harmful substances in the atmosphere, which damages the environment and poses serious dangers to human health and it also affects quality of life. Pollution occurs for many reasons, and many generations of economist have devised a number of techniques for valuing the health and economic impact of air pollution. The adverse health effect which results from deterioration in air quality is well known. Health damages have been estimated to contribute 75% of the total damages associated with air pollution (Matus *et al*., 2011). The loss of human health creates external costs which invariably lead to overall loss to social welfare. As recently as the 1990's and 2000's, many epidemiological studies have assessed the effects of pollutants on mortality (Lipfert and Wyzga, 1995; Verhoeff *et al*., 1996; Katsouyanni *et al*., 1999 and Ostro *et al*., 2000), measure the health and economic impacts of air pollution (Alberini and Cropper, 1997; Navrud, 2001). Some of these studies have used household health production function models, dose-response functions, and exposure-response functions while others have used damage functions and cost of illness methods.

This chapter provides a review of theoretical literature on air pollution and its impacts. It begins by looking at indoor and outdoor air pollution. Literature on the health and economic impact from exposure to air pollution are also reviewed. In addition, selected studies relevant to the methodology involved in economic valuation of air pollution are also included. The concluding part deals with how the economic impact of air pollution is measured for households in Phahameng and Rocklands areas of Mangaung metro municipality.

2.2 Outdoor air pollution

Developed and developing regions often face critical outdoor air pollution due to rapid growth in industrial activities and from vehicle emissions (Bouilly *et al*., 2005). Dust from roads and deforestation are another key emissions of pollution outdoors. Research findings have shown that emissions of carbon monoxide from automobiles are the major source of pollution (Bouilly *et al*., 2005). Industries are also often identified as a significant polluter (Bouilly *et al*., 2005). Research and studies have also shown that outdoor air pollution leads to detrimental impacts on the environment such as smog, haze and acid rain particularly in large urban and industrial centres with a high vehicle population (Pope *et al*., 2002; CEAP, 2004; Molina and Molina, 2004; Norman *et al*., 2007). Typical outdoor air pollutants are carbon monoxide (CO), particulate matter of diameter 2.5 ($PM_{2.5}$) and sulphur dioxide (SO_2) which result from electricity generation, industrial and commercial activities and non-domestic fuel-burning appliances operated by businesses, schools and hospitals, petrol and diesel driven vehicle tailpipe emissions, vehicle-entrained road dust, brake and tyre wear fugitives, rail and aviation related emissions, waste treatment disposal, mining and wild fires (DEA, 2008).

2.3 Indoor air pollution

Indoor air pollution is a concern in developing countries especially where there is energy inefficiency. One half of the world population, and up to 95% in poor countries, continues to rely on solid fuels, coal and paraffin for cooking and heating (Duflo *et al*., 2007). People spend more time indoors than outdoors, and indoor pollutant levels are greater than outdoor pollutant levels (Ao *et al*., 2003). Thus, indoor air pollution remains a potentially large global health threat and an important cause of morbidity and mortality (Bruce *et al*., 2000). Based on a number of observational studies in developing countries, the health effects of high levels of indoor air pollution, such as higher mortality rates and increased risks of respiratory illness, fall mainly on children and women, who spend a good deal of time indoors (Smith *et al*., 2002). Conservative estimates of global mortality due to indoor air pollution from solid fuels show that 1.5 million to 2 million deaths were attributed to indoor air pollution (Von Schirnding *et al*., 2002), which accounts for approximately 4-5% of total mortality worldwide (Smith *et al*., 2002). According to a comparative risk study of World Health Organization (WHO), 28% of all deaths are caused by indoor air pollution in developing countries (Massey *et al*., 2009). Typical indoor contaminants include gaseous and particulate pollutants from indoor combustion processes (such as cooking, heating and cigarette smoking), toxic chemicals and odours from cleaning activities, odours and viable micro-organisms from humans, odour-masking chemicals used in several activities and a wide assortment of chemicals released from indoor construction materials and furnishing (e.g. from asbestos, formaldehyde, vinyl chloride) (Mitchell *et al*., 2007). When these contaminants, especially small particulates, are generated in indoor environments in excessive concentrations, they may impair the health, safety, productivity and comfort of the occupants. In African countries, there is a paucity of information related to indoor air pollution, especially for poor rural or semi-urban populations for whom indoor air pollution are most serious. Empirical studies have not defined the precise relationship between indoor emissions and health damages to date.

2.4 Health impacts from exposure to air pollution

There has been a realisation in recent times that health impacts are a major way by which people realise the extent of the damage associated with air pollution (Zhang *et al*., 2008). Health damages have been estimated to contribute 75% of the total damages associated with air pollution (Cropper and Oates, 2002). Both indoor and outdoor air quality are important in knowing the health effects of air pollution. Global estimates show that about 2.5 million deaths occur each year due to indoor exposure to particulate matter in rural and urban areas in developing countries, thus representing 4.5% of the 50-60 million annual deaths that occur globally (Bruce *et al*., 2002). The most common illness due to air pollution is respiratory diseases. Five of the other air pollution related diseases include ischemic heart disease, acute lower respiratory infections (ALRI), chronic obstructive pulmonary disease, tuberculosis, and cancers of the respiratory tract. These diseases are among the ten leading causes of death globally (Murray and Lopez, 2007). In addition to contributing to respiratory diseases, exposure to cooking smoke seems to cause or exacerbate eye problems such as cataracts (WHO, 2004), harm new-borns (Dherani *et al*., 2008), and reduce birth weight (Boy *et al.*, 2002). The main sources of air pollutants and their effects on health are described in Table 2.1.

Table 2.1 Sources and health effects of common air pollutants

Pollutant	Primary source	Health effects
CO	Formed when substances containing carbon are burned with an insufficient supply of air. The combustion of fuels such as petrol, gas, coal and wood. Incomplete combustion from motor vehicles.	Reduces oxygen delivery to organs and tissues. Disturbs the function of the placenta development. Has an adverse effect on foetal brain development. Low birth weight and premature mortality. The most serious threat is to the cardio- vascular system.
NO_2	Formed when gases are burned at high temperature. It is principally from motor vehicle exhaust and stationary source such as electrical utilities and industrial broiler.	Short-term exposure may reduce lung function and airway responsiveness and increased reactivity to natural allergens. Long-term exposure may increase the risk of respiratory infection in children. May lead to intra uterine mortality and deficit in lung growth.
O_3	A secondary pollutant formed in the presence of sunlight by photochemical reactions of O_3 precursors in the air: non-methane volatile organic compounds, NO, CO_2 and methane.	Can affect the human cardiac and respiratory systems, irritating the eyes, nose, throats, lungs and pulmonary congestion. May aggravate asthma, reduce lung capacity and increase susceptibility to respiratory diseases like pneumonia and bronchitis.
SO_2	Generated from the burning of fossil fuels (coal and oil) and the smelting of mineral ores that contain sulphur. Volcanic eruption is a natural source Of SO_2 emissions	Can affect the respiratory system, the functions of the lungs and irritate the eyes. Can cause temporary breathing difficulties for people with asthma who are active outdoors. Long term exposure can cause respiratory illness and aggravate existing heart and chronic lung diseases such as bronchitis or emphysema.

$PM_{2.5}$ or PM_{10}	Trucks, wood stoves etc.	Effect on breathing and respiratory system. Lung cancer, premature death and damage to lung tissue. People with chronic lung disease, influenza or asthma are very sensitive to particulate matters.
Pb	Car exhaust from leaded gas. Paints.	For children: damage to the brain and nervous system, behaviour and learning problems, slowed growth, hearing problems and headaches. For adults: reproductive problems, high blood pressure, nerve disorders, muscle and joint pains, digestive problems and memory and concentration problems.

Source: Gauderman, 2001; Ritz and Yu, 1999; Katsoyami *et al*., 1997; Romeo *et al*., 1997 and Lippman, 1993

Few studies have been conducted around cities, towns or even villages in South Africa. Rollin *et al*. (2004) conducted a study to compare indoor air quality in electrified and un-electrified dwellings in rural South African villages. The study provided scientific evidence that electrified homes in South Africa have lower levels of air pollution (particulate matter and carbon monoxide) relative to their non-electrified counterparts. Cairncross *et al*. (2007) also investigated the daily mortality associated with exposure to common air pollutants in South Africa. The authors discovered on a linear index of 10 that there is a daily incremental mortality risk due to exposure to the common air pollutants. Wright *et al*. (2010) used a predetermined risk threshold framework to determine population exposure to ambient air pollution levels in Durban, South Africa. The semi-urban wards located in a known air pollution hot spot had highest pollution levels with experience of high levels of associated health impacts.

There is substantial literature indicating that ambient air pollution levels substantially affect human health, especially the health of infants and young children being the vulnerable groups. For example, air pollution in cities in developing countries is responsible for some 50 million cases per year of chronic coughing in children younger than 14 years of age (Cohen *et al*., 2005). Chay and Greenstone (2005) found that higher concentrations of total suspended particulates (TSPs) are strongly associated with higher rates of infant mortality. The authors found that 1% increase in ambient TSPs result in a 0.35% decrease in the fraction of infants surviving to 1 year of age. Their results suggest a non-linear relationship between pollution and infant mortality. Maternal exposure to pollution also raises infant mortality. Dherani *et al*. (2008) also conducted a meta-analysis of pneumonia risk from indoor air pollution in children aged less than 5 years. The authors were able to provide sufficient consistency to conclude that risk of pneumonia in young children is increased by exposure to unprocessed solid fuels by a factor of 1.8. However, this study was not able to further examine how indoor air pollution intensity affects health. Chay *et al.* (2003) and Neidell (2004) studied the impact of reduced pollution exposure on elderly people, infants and children mortality rates. The authors used both cross-sectional and time series analysis. NO_2, O_3 and SO_2 have been found to elevate risk of death due to cardiovascular diseases; impairing functioning or exacerbating existing conditions of the respiratory system. Frackenberg *et al.* (2005) have found that unusually high levels of pollution impacted individuals' abilities to perform strenuous activities and negative health outcomes which include lung function reductions, immune system impairness, lung cancer etc. In South Africa, investigators found that Zulu children living in homes with wood stoves were almost five times more likely to develop a respiratory infection severe enough to require hospitalisation compared to children living in homes without wood stoves (Wichmann and Voyi, 2005). Likewise, in a study conducted in Gambia, it was discovered that children carried on their mother's backs while cooking over smoky cook stoves contracted pneumococcal infections which is one of the most serious kinds of respiratory infections at a rate 2.5 times higher than non-exposed children (Ezzati and Kammen, 2001). Many respiratory infections in the developing world results in death, and evidence shows that exposure to smoke may contribute to higher mortality rates (Ezzati and Kammen, 2001). A study in Tanzania found that children younger than 5 years of age who died of acute respiratory diseases (ARI) were 2.8 times more likely to have been sleeping in a room with an open cook stove than healthy children (Mtango and Neuvians, 2002). Bruce *et al.* (2002) concluded that air quality is associated with an adverse health impact on infants and children. These studies have all confirmed that reduction in air pollution is beneficial to health especially for infants, children and the elderly.

Adults suffer the ill effects of severe air pollution as well. Several studies found strong links between chronic lung diseases in women and exposure to smoke from open cook stoves (Bruce *et al*., 2006). One Colombian study found that women exposed to smoke during cooking were more than three times more likely to suffer chronic lung diseases (Cesar *et al*., 2005) whereas a study in Mexico by Holguin *et al*. (2003) showed that women who had been exposed to wood smoke for many years faced 75 times more risk of acquiring chronic lung diseases than unexposed women. Other studies suggest that risk of health effects associated with air pollution increases in response to the years of exposure to smoke which is about the level of risk that heavy cigarette smokers face (Holguin *et al*., 2003). Lung cancer is also associated with high levels of smoke especially coal smoke, which contains a plethora of carcinogenic compounds. Most studies of coal-smoke exposures have been conducted in China, where residential use of coal is still common (Chen, 2007). More than 20 studies suggest that urban women who use coal for cooking and heating for many years are subject to risk of lung cancer. Rural coal-smoke exposures, which tend to be higher, seem to increase lung cancer risks by a factor of nine or more (Bruce *et al*., 2000). Exposure to high smoke levels has also been linked with pregnancy-related problems like still births and low birth weight. One study in Western India found a 50% increase in still births associated with the exposure of pregnant women to smoke (Duflo *et al*., 2007). Indoor air pollution has been found to contribute to excess heart diseases in developing countries. In developed countries, outdoor pollution at levels far below those found in smoky indoor environments has been linked with heart diseases as well. One analysis of Jakarta (Jakarta is one of the most polluted cities in the world) estimated that some 1,400 deaths, 49,000 emergency room visits and 600,000 asthma attacks could be avoided each year if particulate levels were brought down to WHO standards (MEB, 2002).

The health risks due to air pollution are quantified by estimating the relationship between the incidence of adverse health effects and air quality (Braga *et al*., 2001). Many of the adverse health impacts from air pollution occur in the respiratory system. The most common symptoms of respiratory diseases observed in the study areas include runny or blocked nose, asthma and sinusitis. Eye and ear irritations are also part of the health effects of air pollution observed in the study areas. Thus, the health impacts that will be considered in this study will be limited to respiratory diseases, eye and ear irritations (as a health endpoint).

In summary, studies of impact of air quality on health are of great interest because of the potential implications for economic growth, medical costs and quality of life. These impacts of air quality have thus made recent studies to focus on the adverse health impact from exposure to air pollution.

2.5 Economic impacts from exposure to air pollution

In measuring the cost of air pollution, it is important to look further than just the main effects on health. The link between the economic indicators and air pollution has been noted in the exposure science literature. Most studies infer or link the economic impact from air pollution to its effect on the gross domestic product (GDP). In a study conducted by Kuebler *et al.* (2001), ozone concentrations were highly correlated with the European Union gross national product and industrial production growth rates. Both are indicators of economic activity. The economic indicators thus provide direct evidence of the hypothesis that there is a significant impact of exposure to pollution on economic activities and ultimately human health (Davis *et al*., 2007). Xin Deng (2006) conducted a study to estimate the economic cost of motor vehicle emissions in China. The total cost of air pollution caused by road transport was equivalent to 3.26% of China’s GDP which infers that transport may cause more damage in China other than other pollution sources with the same amount of pollutants emitted. Kyung-Min Nam *et al*. (2010) and Mayeres and Van Regemorter, (2008) have revealed in their studies that labour and leisure loss are major economic impacts of air pollution and can affect market equilibrium. Computable general equilibrium (CGE) modelling approach was used to assess the economic impacts of air pollution over time. The CGE model estimate the total economic impact valuing both work and non-work (i.e. leisure), time as well as the economic cost of reallocating economic resource to the health care. When economic damages accumulate, it leads to lost income which means lower gross domestic product (GDP) and savings and therefore less investment and growth occur over time.

2.5.1 Measuring the economic impact of air pollution

It has been argued that if people's preferences are a valid basis upon which to make judgement concerning changes in human well-being, then it follows that changes in human mortality and morbidity should also be valued according to what individuals are willing to pay or willing to accept as compensation to forgo the change in health status (Maddison *et al*., 2004). The economic impact of air pollution can be measured in terms of morbidity or restricted activity days (RAD) and mortality. Smith (2000) uses morbidity/ mortality relationships for the diseases attributable to both indoor and outdoor air pollution to estimate the economic impact, in terms of sick days. The annual benefit burden for India from indoor, outdoor air pollution is 1.6-2.0 billion days of work lost. In Latin America, exposure of some 81 million city residents, which is more than one quarter of all city dwellers in the region, to high air pollution levels is believed to cause an estimated 65 million days of illness each year (Diaz *et al*., 2007). Pollution mortality is always a crucial question as to whether to multiply the number of premature deaths by value of statistical life (VSL) or whether one should take into account the years of life lost (YOLL) per death. There are also ethical arguments against placing a monetary value on human life. Based on this issue, mortality valuation will not be considered in this study.

2.5.1.1 Morbidity valuation

Morbidity as defined by Peterson (1975) is departure from a state of physical or mental well-being, resulting from diseases or injury, which the affected individual is aware of. The degree of impairment of activity is an important way of measuring morbidity. There are several categories of degrees of activity impairment, namely Restricted Activity Days (RAD), Bed Disability Days (BDD), and Workdays Lost (WDL). RADs are those on which a person is able to undertake some activities but not all. BDDs are those in which a person is confined to bed, either at home or hospital. WDLs are those in which a person is unable to engage in ordinary gainful employment (Freeman, 1993). For convenience, this study incorporates the workdays lost (for workers) and restricted activity days (for non-workers). The morbidity valuation is complicated due to the various potential health outcomes with different levels of severity and duration. In one of the studies by Chestnut *et al*. (2006), it was found that the time lost during the recovery period at home is about five times longer than the time lost from work during hospitalisation among cardio-respiratory patients.

2.5.1.2 Monetary valuation of air pollution impacts

Once the links between emissions to pollution effects have been established, the next stage requires the assignment of economic (monetary) value to the predicted effect. The health damage from air pollution incurs direct and indirect costs to society. The most controversial part of the estimation of air pollution is the cost of its impacts. This is because other cost associated with air pollution, such as loss of human productivity, as well as damage to buildings, vehicles and crops are very difficult to estimate. The monetary cost of air pollution in this study is therefore limited to the total cost associated with air pollution health damage. Freeman (2003) divides the health damage associated cost into four categories: medical cost, labour cost, averting cost and welfare loss (discomfort, suffering).

The monetary valuation of health damage due to air pollution can be based on several approaches. Each approach has its own strengths and limitations. Ideally, these methods should represent all the losses to individuals and to society that result from adverse health effects of air pollution. The economic valuation of health effects can be evaluated based on two approaches: willingness to pay (WTP) or willingness to accept (WTA) and the cost of illness approach (COI). The COI is the sum of lost productivity and medical costs (Quah and Boon, 2003). It incorporates lost wages and direct medical expenses and is not a measure of individual or social welfare as it does not address discomfort and pain among other factors. The COI (damage function) approach uses data to estimate how various levels of a particular pollutant will affect human health (called dose-response function) and then connect these health outcomes with cost of illness. The WTA is the appropriate measure in a situation where an agent is being asked to voluntarily give up a good. The WTP method aims to measure what individuals would be willing to pay in exchange for improved health. This approach is based on trade-offs between health, wealth or income. WTP studies uncover actual trade-offs (revealed preference) or ask respondents to make hypothetical decisions with regards to trade-offs (stated preference). Carson (1999) states that the property right to a good that is to be marketed is the correct measure to know whether to use WTP or WTA. If a consumer does not currently have the environmental good and does not have a legal entitlement to it, the correct measure is WTP. If the consumer has a legal entitlement to it and is being asked to give up that entitlement, the correct measure is WTA. WTA questions are usually much harder to successfully implement due to the need to convince respondents of the legitimacy of giving up an environmental good. From the economic efficiency standpoint, Levy (2003) has argued that the use of multiple valuation frameworks to determine the health cost of air pollution’s effect is useful compared to using any single method due to inherent uncertainties. Thus, total cost associated with health damage should be estimated by the individual’s willingness to pay (WTP) to avoid such health damages and the cost of illness (COI). As a result, the preferred approach for environmental damage evaluation has shifted from the cost of illness approach only to the combination of the two approaches (WTP and COI) which is adopted in this study.

Majority of studies however have used cost of illness (COI) or damage function approach only to quantify the health cost from air pollution related illness. Hon (1999), Shahwahid and Othman (1999) and Ruitenbeek (1999) calculated the economic cost associated with health effects from the 1997 haze in Southeast Asia. Hon (1999) and Shahwahid and Othman (1999) estimated original dose-response functions to obtain predicted health outcomes caused by wildfires in Singapore and Malaysia and then connected these outcomes with country-specific costs of treatment to arrive at a final cost of illness. Ruitenbeek (1999) applied the estimated dose-response function from Shahwahid and Othman (1999) to translate the haze density in Indonesia into predicted health outcomes. The author then used economic costs from World Bank studies to calculate associated medical costs and the value of lost wages resulting from the wildfires and haze. Butry *et al*. (2001) used results obtained from Sorenson *et al*. (1999) on the health effects experienced during the 1998 Florida fires (asthma and bronchitis) and connected these with previously obtained estimates of medical expenditures to estimate the total cost of illness from these fires. Health effects resulting from air pollution causes disutility to their recipient such as pain, discomfort or a loss of recreation days and this would not be captured in a simple cost of illness approach. Dickie (2003) and Freeman (2003) have made it well understood in the economics literatures that the cost of illness and damage function methods underestimate the economic costs associated with health effects from exposure to a pollutant. Handful of studies also have estimated the economic cost of health effects from air pollution exposure by incorporating WTP and COI values into their estimates. Martin *et al*. (2007) and Rittmaster *et al*. (2006) used dose-response functions and connected estimated health outcomes with a mix of COI and WTP. Cardoso de Mendonca *et al*. (2004) also estimated an original dose-response function and calculated the economic cost of health damages from fire used by farmers in the Amazon, applying WTP values transferred from Seroa de Motta *et al.*(2000a; 2000b). In a study by Baby (2001), health effects due to air pollution was estimated using household production function approach. The study reveals that air pollution creates a large amount of external costs. An averting behaviour approach, which infers people's willingness to pay, was estimated having a background that it is being influenced by environmental and socio-economic characteristics. Income was the major factor which influences WTP and education has a negative influence on WTP.

2.6 Empirical methods to estimate willingness to pay

There are several empirical methods that have been used to estimate willingness to pay measures. Among them, the most popular are the "compensating-wages" method, contingent valuation, and the averting behaviour method or mitigating method.

2.6.1 The compensating-wages method

According to World Bank (1997), the compensating-wage method is an application of the hedonic pricing theory in the labour market. The 'compensating-wages' method uses labour market data on wage differentials for jobs with different levels of health risks, assuming that workers understand the work place risk involved, and that the additional wage that workers receive when they undertake risky positions reflect risk choice. In other words, the 'compensating-wage' approach relies on the assumption that workers will accept exposure to some level of risk in return for some compensation. This is to say that the higher the job-related mortality and morbidity risks a worker bears, the higher his/her wage would be in equilibrium. Thus, the compensating wage method is used when there is need to apply hedonic pricing theory to labour markets.

2.6.2 The mitigating or averting behaviour method

The defensive behaviour method, also referred to as the averting behaviour method, is a revealed preferences approach based on the health production function first authored by Grossman (1972) with extensions to the model undertaken by Cropper (1981) and Harrington and Portney (1987). The defensive behaviour method is based on the assumption that individuals respond to threats of pollution and other environmental contaminants by taking defensive actions. Defensive actions are sub-divided into what are referred to as averting and mitigating actions. Averting actions are actions taken to decrease the chance of being exposed to the pollutant that causes the negative health outcome while mitigating actions are taken after experiencing the health outcome in an effort to mitigate its negative effects. Mitigating actions considered in this study are medical care or prescription medications by a practitioner, over-the-counter medication and traditional treatment. The cost incurred on any of these actions is the mitigating cost. These include doctor's fee, hospitalisation fee, cost of travel to doctor's clinic or pharmacy etc. The mitigating cost represents the cost of illness typically measured as the cost of health damages from exposure to air pollution.

2.6.3 Contingent Valuation method

The Contingent Valuation method was first proposed by Ciriacy-Wantrup in 1947 to reveal preferences on externalities. Exxon Valdez oil spill study (Carson *et al*., 2003) propelled CV into the main stream. Contingent Valuation (CV) is more and more accepted by both economists and policy makers as a valid and efficient way to value non-market goods. Contingent Valuation is a survey method in which respondents are asked to state their preferences in hypothetical or contingent markets, allowing analysts to estimate demands for goods or services that are not traded in markets. In general, the survey draws on a sample of individuals who were asked to imagine that there is a market where they can buy the good or service evaluated, stating their individual maximum willingness to pay for a change in the provision of the good or service, or their minimum compensation (willingness to accept) if the change is not carried out. A contingent valuation technique was employed in this study to obtain a monetary value on the individual WTP to prevent a set of air pollution related symptoms. Before discussing the implications of the research, getting the willingness to pay of a respondent can be asked in several ways. Each technique possesses certain strengths and weaknesses.

2.6.3.1 Bid design

The iterative bidding is also known as sequential bidding techniques is the oldest and most frequently used contingent valuation procedure. It is based on continuous responses. The interviewer proposes an initial starting bid which the respondent accepts or rejects. If the initial bid is accepted, the interviewer revises the bid upward until a final value is reached. If the initial bid is rejected, the initial value is revised downward until a final value, which can be zero is reached. According to Boyle *et al*. (1998), the inherent weakness of this technique is that the initial bid can influence the bidding process. A payment card was introduced by Mitchell and Carson (1989) as an alternative to iterative bidding to avoid starting point problem. The payment cards are formulated in such a way that a sequence of prices are portrayed beginning at zero. These prices represent for instance estimates of what people in a specific income category paid for selected public services in the preceding year. The respondent is then asked if he or she is willing to pay one of the prices. The answer is final and no bidding is involved. Another bidding technique commonly used apart from iterative bidding is the dichotomous choice which was first used by Bishop and Heberlin (1979). The respondent is asked to answer yes or no to the take-it-or-leave-it offer for the object being valued. Dichotomous choice technique analyses qualitative answers (yes/no) which provide much less information about the respondents' actual values (preferences) than is utilised when continuous numerical responses are obtained with iterative bidding. Willingness to pay for clean air was elicited in this study using a double-bounded iterative bidding.

2.7 Implications of the research

Semi-urban and rural settlements face challenges due to air pollution that need to be addressed. Given that air pollution is generated from many sources (including motor vehicles, industry, home cooking and heating as well as from cigarette smoke and from numerous natural sources), a variety of pollutants are present from each source. These pollutants have a range of negative effects on human health. From the literature, some inferences can be drawn regarding the procedures for measuring the economic impact of air pollution.

- Estimating the economic impact of air pollution depends on the health impact as a result of air pollution related illness. The health impacts will be supported by the workdays lost and mitigating cost incurred by the respondents in the study areas. Duration of illness, the treatment methods amongst other factors are expected to influence the workdays lost and mitigating cost.

- The economic valuation question, to measure the willingness to pay for improved air quality, need to be measured to know people's perception, knowledge and comprehension of air pollution and its impact within their frame of reference.

The results from the economic impact of air pollution on individuals will provide information that could be used to know the significance of air quality, to value the benefits of air pollution control programs, social benefits (in terms of government subsidising clean energy source), policies or strategies to ensure a safe and acceptable air standard to minimise health effects.

CHAPTER 3

DATA & CHARACTERISTICS OF RESPONDENTS

Chapter 3 focuses on the data collection methods and the characteristics of respondents. The discussion starts with the procedures for data collection in the study areas. The characteristics of the respondents in the study areas are discussed extensively with the main focus on socio-economic characteristics, health status, household energy sources especially for cooking and space heating practices. Pollution types and time of occurrence are also discussed in this section.

3.1 Data collection

Primary data was used in this study. A structured questionnaire was used to gather information of the households in order to estimate the economic impact of air pollution and the willingness to pay for improved air quality. Data was collected on some socio-economic characteristics of the respondents followed by households' knowledge about indoor and outdoor air quality. The data also captures the household energy sources for cooking and space heating and the season(s) of the year indoor and outdoor air pollution is rampant.

3.1.1 Questionnaire design

In order to obtain relevant information from households, a Contingent Valuation (CV) questionnaire (see appendix A) was designed. A questionnaire developed by Alberini (2004) to value the health effects of air pollution in developing countries was used as a basis to design the questionnaire. Alterations were made to the questionnaire to include sections on indoor and outdoor air quality. The questionnaire consists of 26 questions in the four sections including socio-economic characteristics, indoor and outdoor air quality, health valuation and economic valuation. The 26 questions were evaluated from interaction with knowledgeable individuals.

The socio-economic characteristics of the respondents include variables such as age, gender, level of education and employment status. The data was collected to explore the influence socio-economic factors will have on the household willingness to pay for improved air quality.

Section two of the questionnaire was developed to attain information on air pollution. A series of questions about indoor and outdoor air pollution and the degree of importance of air pollution were posed. Posing such questions was fundamental since asking people about their willingness to pay (section 4) would make no sense if they are not aware of any environmental problems. Thus, questions were asked on indoor and outdoor air pollution, the source(s) of the pollution and the time of the year the pollution occur. One survey of indoor air pollution issues found that cigarette smoke is an important indoor air pollutant (Smith, 1988). Cigarette smoke and the energy source for cooking and space heating were used to determine the sources of indoor air pollution. The common energy sources used in the study areas for cooking and space heating include paraffin, coal, wood, electricity and gas. Respondents were asked to choose the energy source they use most of the time to cook their food and for space heating. The most common outdoor air pollution types in the study areas include smoke, smog and dust. The outdoor air pollution types were to be ranked, ranging from most problematic to not problematic. The time of the year pollution occurs was included in the questionnaire in order to know the season(s) in which pollution occurs. To be able to explore the value people place on air pollution, respondents were to specify the degree of importance of air pollution with other societal problems which include crime, violence against women and children, unemployment and poor service delivery.

The third section of the questionnaire was developed to measure respondent's health status. The reason for probing into the health challenge(s) of respondents is based on the hypothesis of Gupta (2008) which states that an individual who has a chronic disease is more susceptible to negative health effects of air pollution and is likely to have higher medical expenses and number of workdays lost. The questions were developed to explore the incidence of symptoms of acute illnesses linked to air pollution exposure. This is to test the awareness of households about the illnesses that occur due to air pollution. The air-pollution related ailments are mostly respiratory linked and it include runny or blocked nose, sore throat, cough, eye irritation, ear irritation and sinusitis. The questions include the method of treatment (mitigating activities), cost of treatment (mitigating cost), number of visits for treatment, number of workdays lost (morbidity), duration of illness and number of deaths (mortality). The questions on morbidity, mitigating activities and cost follow the economic concepts mentioned in the literature review which is embedded in the monetary valuation of air pollution impact. Considering that some respondents may have chronic diseases, its sub-section contained information on whether respondents had chronic diseases which include high/low blood pressure, asthma, tuberculosis, pneumonia and diabetes.

The final section, comprise of only one question on economic valuation. The question dealt with household willingness to pay for clean air. Using contingent valuation method to determine willingness to pay for clean air is a difficult task and problematic to explain to respondents. Many studies such as Rowe *et al*. (1980) and Shechter *et al*. (1991) used photographs of both visibly polluted and relatively clean days before asking the respondents what they would be willing to pay for clean air. However, in order to avoid the difficulty of explaining the hypothetical question to respondents to estimate their willingness to pay for a clean air, the question started with a description of pollution types and effects of pollution (health, pain, and suffering). The medical expenditure, the time spent visiting medical practitioners, work days lost or number of days of restricted activities and disruptions to leisure time were also included in the description. The respondents were asked how much they are willing to pay on a monthly basis to reduce air pollution in their area. This is similar to the method used by Alberini *et al*. (1997).

3.1.2 Site selection, sampling technique and size

This research was carried out in Phahameng and Rocklands located in the township area of Bloemfontein within Mangaung metro municipality. These two areas were selected for the study as they are considered hot spots for air pollution (Queensland Government Environmental Protection Agency, 2008). Also, the two main hospitals in the township are located in these two areas and the ambient air quality monitoring station is located near these hospitals.

Samples of the households in the areas were selected using the stratified random sampling technique. Westfall (2009) stated that the stratified random sampling method is used when representatives from each sub-group (strata) within the population need to be represented in the sample. Following Scheaffer *et al*. (1979), a stratified random sample technique was used to separate the population elements into non-overlapping strata. Phahameng was divided into 12 strata and Rocklands into 20 strata based on the total number of households. Phahameng has 27

083 households and Rocklands has 69 250 households. Each stratum is homogenous in the sense that it belongs to a specific district which includes similar environments. Choosing a sample size is usually based on estimating the natural maximum likelihood method using the relative frequency (Ayer, 1995). The population size is equal to 96 333 based on 2001 population census. The sample size to choose must be accurate in the sense that a 95% confidence interval for it is not too large. According to the approach of Ayer (1975), a total of 700 to 800 households should have been surveyed. However, due to financial and time constraint, 300 households were surveyed. In Phahameng, 111 households were included in the sample and 189 in Rocklands. The implication of the sample size surveyed is that 300 households is not a representative of the population but gives a picture of the population.

A pilot survey was conducted in which 20 households were surveyed in Phahameng (this part of Phahameng was not surveyed again during the final interview). The purpose of the pilot survey was to ascertain that terminologies were clearly understood, to indicate the number of subjects that could be handled with ease during one data collection session, to correct misunderstandings and to include other relevant questions. The pilot study also served to decide the starting bid (R100/month) for estimating the willingness to pay for improved air quality which was used in the final interviews. The questionnaire was modified after the pilot survey and then used to interview all 300 households in face-to-face interviews during November and December, 2011.

3.2 Characteristics of respondents

The purpose of this section is to provide a brief description of the surveyed households in the study areas, according to socio economic characteristics, household knowledge of air pollution, its impacts, the rating of air pollution by respondents and health status of the households.

3.2.1 Socio-economic characteristics of the respondents

The socio-economic characteristics to be considered include age, gender, household size, education, employment and income. Figure 3.1 and 3.2 shows the age and gender distributions in Phahameng and Rocklands respectively.

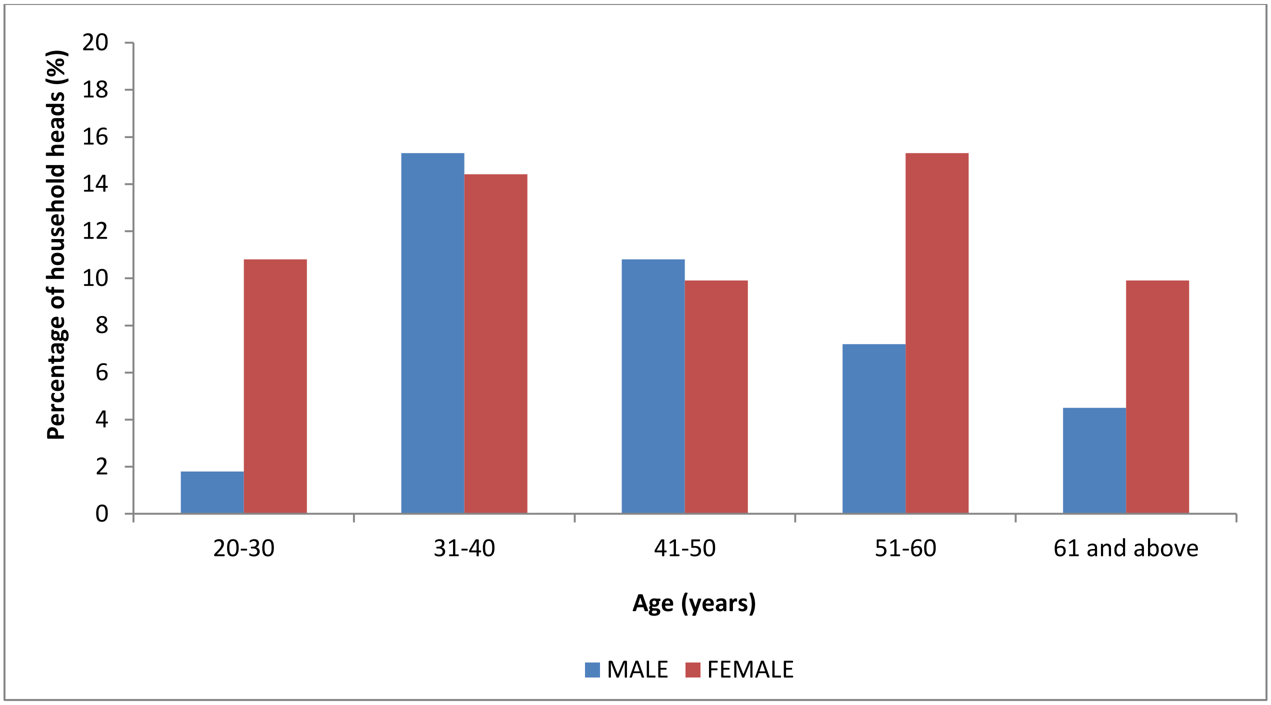


Figure 3.1 Age and gender distribution of household heads in Phahameng

Figure 3.1 shows the division of age and gender of Phahameng household heads. About 11% of female household heads are of the age group 20-30 years while their male counterparts are less than 2%. Also, about 25% of female household heads and less than 15% of male household heads are in the age group 51-60 and 61 and above. However, there seems not be a wide difference between the percentage of males and females household heads in the middle age group 31-40 years and 41-50 years. It then follows that there is a variation in the age and gender distribution among Phahameng household heads. The distribution of gender and age in Rocklands is quite different from that of Phahameng as shown in Figure 3.2.

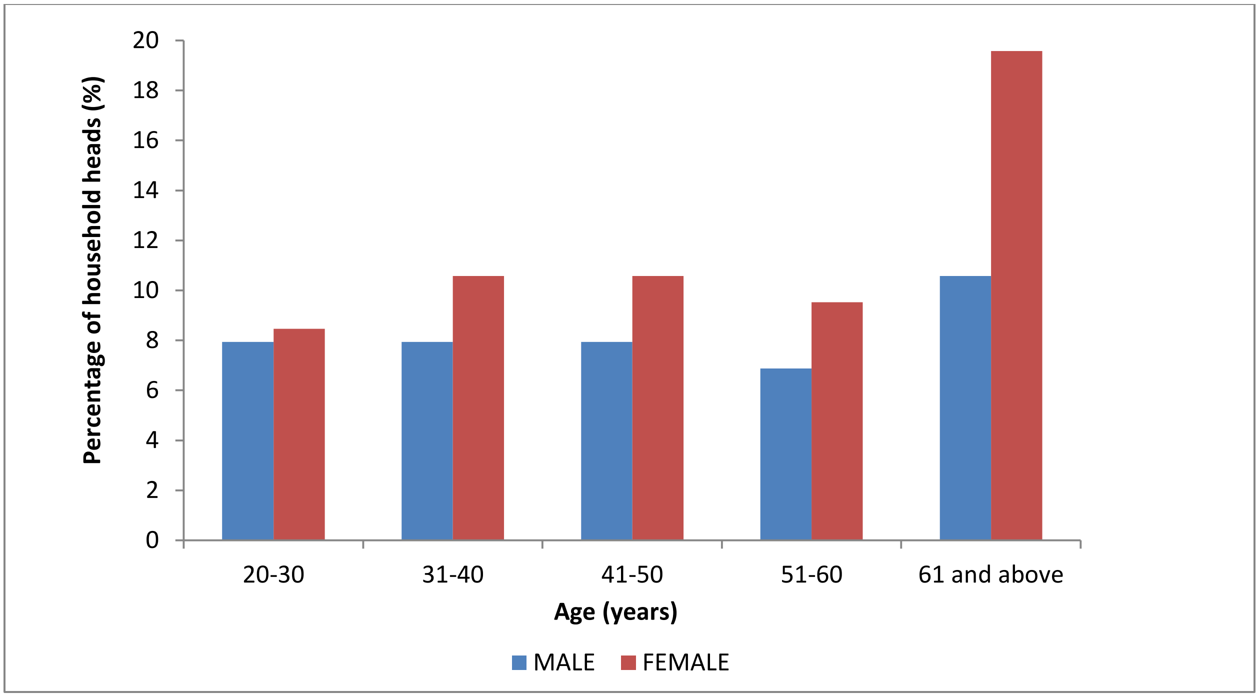


Figure 3.2 Age and gender distribution of household heads in Rocklands

From Figure 3.2, the percentage of females that are household heads for all age groups are greater than their male counterparts. Another point of interest is that more than 18% of the female household heads falls to the age group 61 and above whilst the male household heads in the same age group are just 10%. It can be inferred from the distribution in Rocklands that females are mostly the household heads.

The household size is defined as the number of people who are under the direct responsibility of the household head and residing in the house for at least six months as at the time of the interview. Figure 3.3 shows the household size distribution in the study areas.

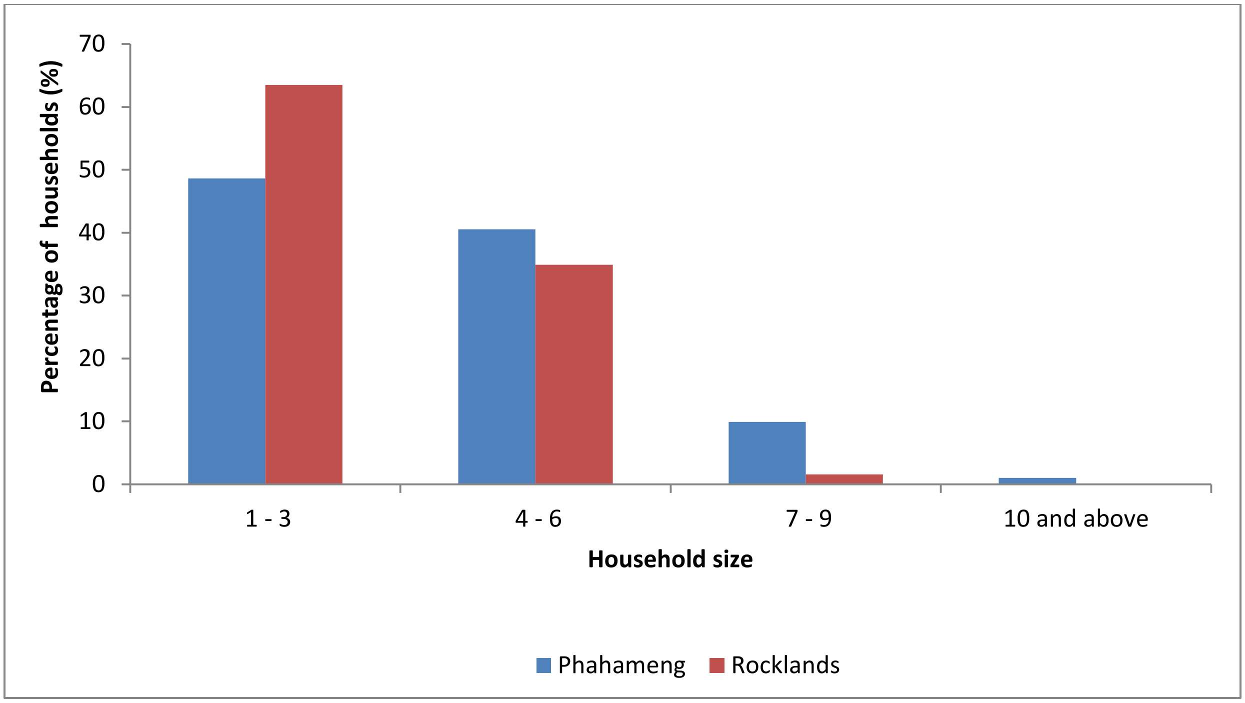


Figure 3.3 Household size distributions in Phahameng and Rocklands

Figure 3.3 shows that the household size of one to three members is most predominant in both study areas. Phahameng has more than 45% whilst Rocklands has more than 65% of households in this category. As the household size increases for both study areas, the percentages decreased. The number of household size with four to six members for Phahameng is 40% and only 10% of the household have seven to nine members. In Rocklands, about 35% of the households consist of four to six members and only 1.5% consists of seven to nine members. None of the households in Rocklands has more than ten members. What the study areas reveals is different from the African traditional norm of a large family size which is about 8 people as stated by Amos (2007).

The levels of education were divided into four levels: no formal education, primary, secondary and tertiary education. Table 3.1 represents the level of education of household heads in Phahameng and Rocklands.

Table 3.1 Level of education of household heads in Phahameng and Rocklands

	Percentage (%)	
	Phahameng (n=111)	Rocklands (n=189)
No formal education	1.80	4.23
Primary	29.70	20.11
Secondary	52.30	67.72
Tertiary	16.20	7.94
Total	100.00	100.00

Table 3.1 shows that 52.30% of the sampled households in Phahameng attended (not necessarily mean they completed) secondary school while 67.72% from the sampled households in Rocklands attended secondary school. In both study areas, the highest percentages of the sampled households attended secondary school. Household heads with no formal education in both study areas are less than 5.00%. In general, 98.20% and 95.77% of the sampled household heads in Phahameng and Rocklands respectively have some formal education.

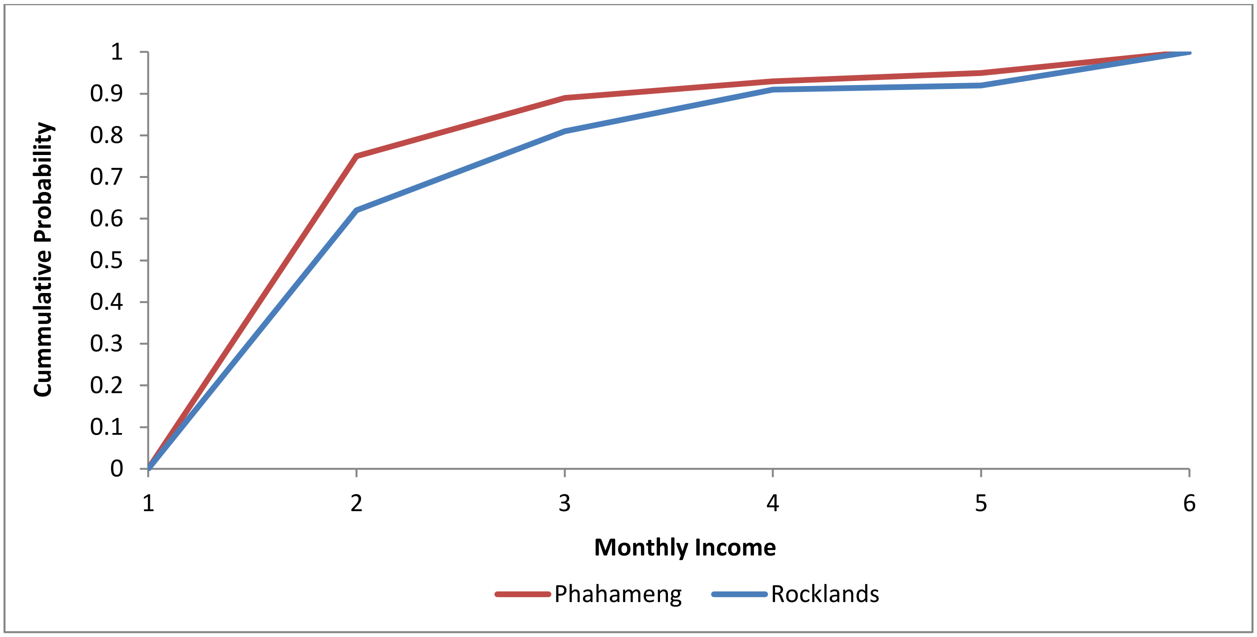
Table 3.2 shows the category of employment in the study areas. There are three categories of employment which include: employed/self-employed, unemployed and student.

Table 3.2 Category of employment in Phahameng and Rocklands

	Percentage (%)	
	Phahameng	Rocklands
Employed/self-employed	36.00	30.20
Unemployed	57.70	62.90
Student	6.30	6.90
Total	100.00	100.00

Table 3.2 shows that 36% of the household heads in Phahameng are employed/self-employed and 57.7% are unemployed. In Rocklands, 30.2% are employed or self-employed while 62.9% are unemployed. Less than 7% of household heads in Phahameng and Rocklands are students. On aggregate, 60.3% of the sampled households in both study areas are unemployed.

Figure 3.4 provides the income distribution among Phahameng and Rocklands households.



Note: 1 represent <=R2000; 2 represent >R2000-R3500; 3 represent >R3500-R5000; 4 represent >R5000-R6500; 5 represent >R6500

Figure 3.4 Households' monthly income distributions in the study areas

From Figure 3.4 it can be seen that 62% and 75% of households in Rocklands and Phahameng respectively earn R2000 or less per month. The percentage of household earning more than R2000 monthly is about 25% to 38%. The rest of the household monthly income categories in both study areas are less than 20%. Thus, the monthly income distributions in the study areas reveal that most households are in the lower income level. However, the study areas reveal that households in the lower income level seem to be greater than households in the middle or upper income levels.

Next, the health status of the respondents in the study areas will be discussed.

3.2.2 Health statuses of household heads in Phahameng and Rocklands

The household heads from Phahameng and Rocklands were questioned about their health status in order to know if they have any chronic diseases. The health statuses of other members of the household were also asked during the completion of the questionnaire. Although it was the household head who provided the information on the other household members' health status, therefore the correctness of the information is doubted. Thus, the study discusses the health statuses of the household head only. The chronic illnesses considered in the study areas are high/low blood pressure, tuberculosis, pneumonia, diabetes, asthma and bronchitis. The health status of household heads in the study areas is revealed in Figure 3.5.

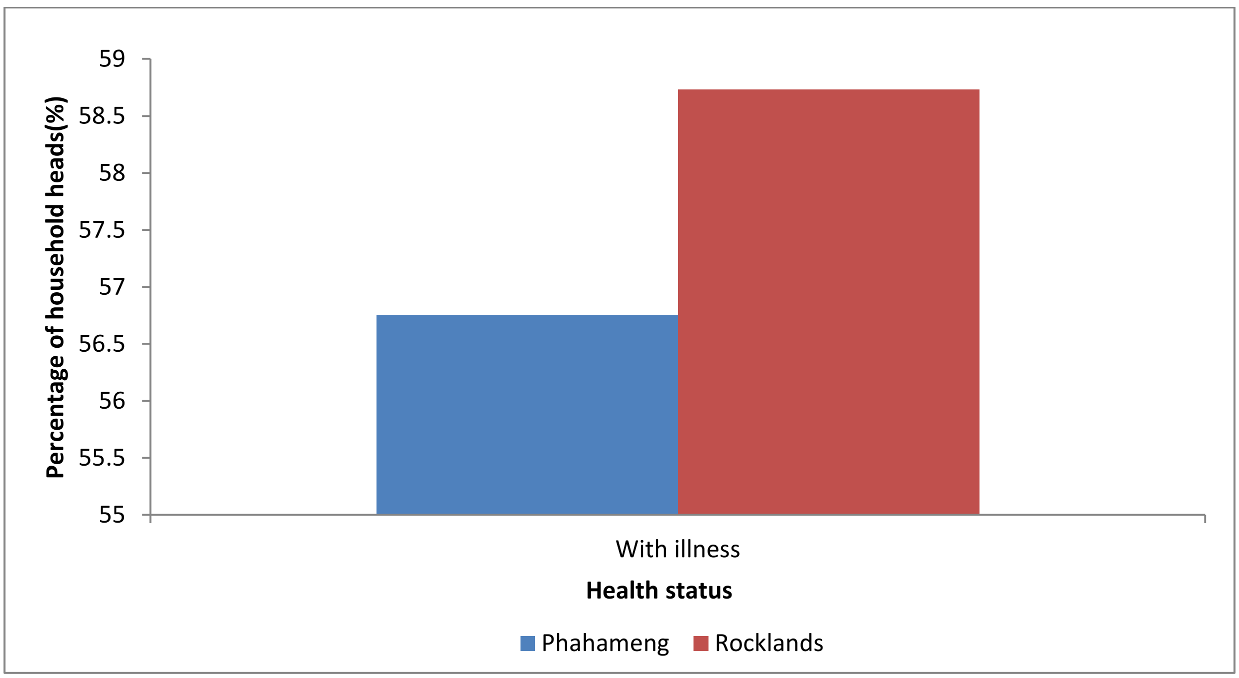


Figure 3.5 Health statuses of household heads in Phahameng and Rocklands

Figure 3.5 indicate that 56.75% and 58.50% of the sampled household heads in Phahameng and Rocklands respectively have a chronic illness. The figures relate with the age distribution of household heads in both study areas. From the sampled household heads in Rocklands, 19.57% are 61 years and above while 10.58% are above 61 years of age in Phahameng. It is assumed that as age advances, health problems arises or increases.

3.2.3 Household knowledge of air pollution

Household's perception and knowledge of air pollution were determined through a series of questions. Respondents were to indicate if air pollution is a bigger concern than other societal problems such as crime, violence against women and children, unemployment and poor service delivery to determine the degree of importance people place on air pollution. Also, respondents in the two study areas were questioned if the indoor or outdoor air is polluted. Table 3.3 represents the outcome from the respondents about their knowledge of air pollution.

Table 3.3 Outcome from respondents about their knowledge of air pollution

	Measurement index	Percentage	
		Phahameng	Rocklands
Degree of importance of air pollution	If air pollution is seen as a bigger concern like other societal problems, it takes value of 1 and 0 if otherwise. The percentage indicates responses of 1.	74.70	79.40
Outdoor air pollution	This is a binary question and a value of 1 was assigned if respondents indicated that the air outdoor is polluted, and 0 otherwise. The percentage indicates responses of 1.	100.00	99.50
Indoor air pollution	This is a binary question and a value of 1 was assigned if respondents indicated that the air indoors is polluted, and 0 otherwise. The percentage indicates responses of 1.	76.60	65.60

Table 3.3 shows that 74.7% of the sampled households in Phahameng and 79.4% from Rocklands indicated air pollution as a greater concern like other societal problems such as crime, violence against women and children, unemployment and poor service delivery. It can be inferred from these figures that the respondents see air pollution as a problem that needs to be addressed. The respondents were further asked if the air outdoor is polluted. The percentage of respondents that answered yes was 100% and 99.5% for Phahameng and Rocklands respectively. Similarly, 76.6% and 65.6% of the respondents from Phahameng and Rocklands respectively indicated there are pollution problems indoors. Air pollution, both indoor and outdoor, proves to be a big problem in both study areas.

3.2.4 Household energy source

The respondents were to indicate the energy source they use for cooking and space heating in order to discover the source(s) and factors that contribute to indoor air pollution in the study areas. To avoid respondents giving more than one energy sources as options, the question was presented to the respondents as which energy source they use most of the time for cooking and space heating. The energy source for cooking and space heating in Phahameng and Rocklands respectively are provided in radar charts and the figures are interpreted as the percentage of households that use each energy source. Figures 3.6 and 3.7 represents the energy source used by households for cooking and space heating respectively.

As shown in Figure 3.6 households in Phahameng and Rockland predominantly use electricity for cooking. The radar chart reveals 96.3% and 79.3% of households in Rocklands and Phahameng respectively use electricity for cooking. The common reasons given in the two study areas for choice of energy source for cooking were that it is faster and easier. It may imply that household's use of electricity for cooking is not seen as a safe energy source (in terms of less pollution) but rather seen as convenient. In Phahameng and Rocklands, 16.2% and 1.6% of the sampled households respectively use paraffin for cooking. Wood, coal and gas are barely being utilised by households in the study areas for cooking. It is noteworthy that households in the study areas no longer use animal dung and solar energy for their cooking. Thus, animal dung and solar energy were not included in Figure 3.6.

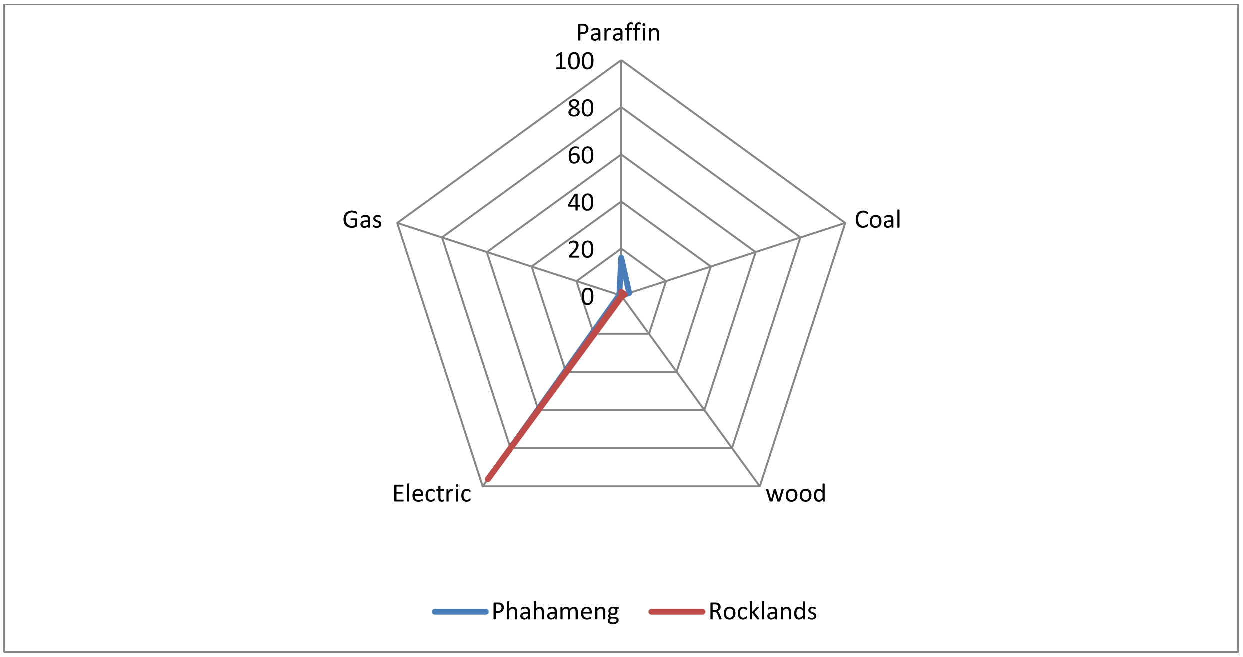


Figure 3.6 Energy source for cooking in Phahameng and Rocklands

The energy sources used for space heating in the study areas as shown in Figure 3.7 is different from the energy sources used for cooking.

It is shown in Figure 3.7 that 68.5% and 59.3% of the sampled households in Phahameng and Rocklands use paraffin for space heating which may explain why 76.6% and 65.6% of the sampled households in Phahameng and Rocklands respectively indicated that indoor air pollution is a problem. The common reason given in the study areas for the use of paraffin heaters for space heating was that it is cheaper. Electricity is barely being used for space heating in the study areas showing 7.20% use for households in Phahameng and 29.1% for Rocklands. Less than 10% of the sampled households in Phahameng and Rocklands use coal, wood and gas for space heating. It is also important to mention that solar energy and animal dung are not being used for space heating in Phahameng and Rocklands. However, the use of paraffin, wood or coal by households contributes to indoor pollution which poses negative effects on health.

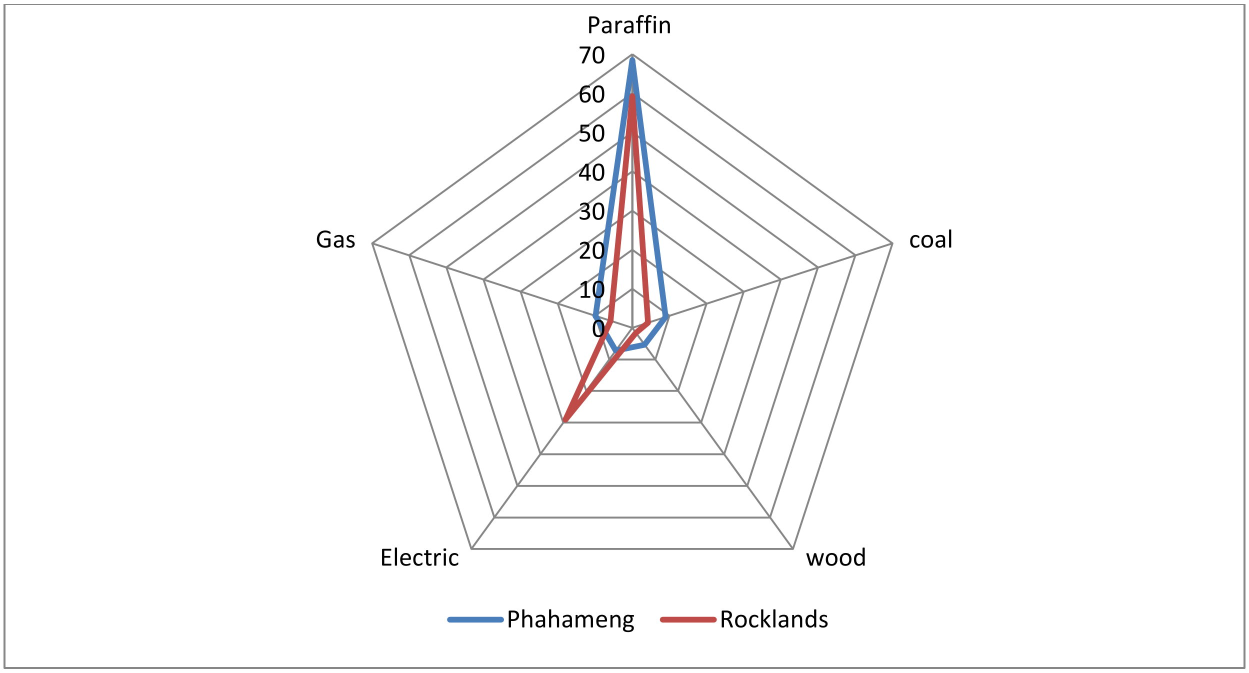


Figure 3.7 Energy source for space heating in Phahameng and Rocklands

3.2.5 Seasons of the year outdoor air pollution occurs

The common outdoor air pollutant in the study areas includes smog, smoke and dust. Outdoor air pollution occurs at different seasons of the year as observed in the study areas. Figure 3.8 shows season(s) when outdoor air pollution is most rampant in Phahameng according to the respondents.

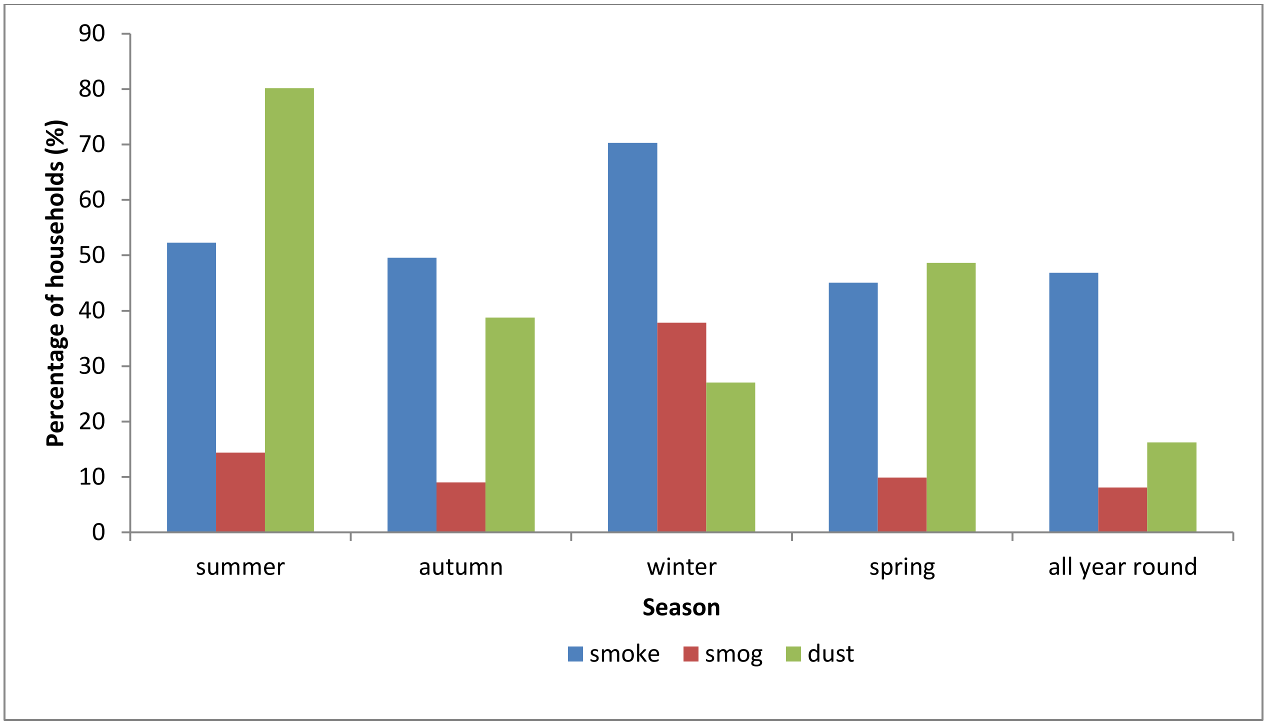


Figure 3.8 Seasons of the year outdoor air pollution occurs in Phahameng

From Figure 3.8, dust is the most problematic outdoor air pollutant occurring during summer as indicated by 80% of the sampled households in Phahameng. Summer is the windy season and thus explains why dust seems to be rampant during summer. During the winter months, smoke is a big concern in Phahameng. However, more than 45% of the sampled households see smoke as a problem that occurs all year round. The reason could be as a result of a poor service delivery of refuse disposal which results in the burning of refuse by households most of the time. Smog seems to be a problem only during winter, indicated by 37.83% of the sampled households but is less of a problem in the other seasons. The seasons when outdoor air pollution is experienced as shown in Figure 3.9 by households in Rocklands appear similar to that observed in Phahameng.

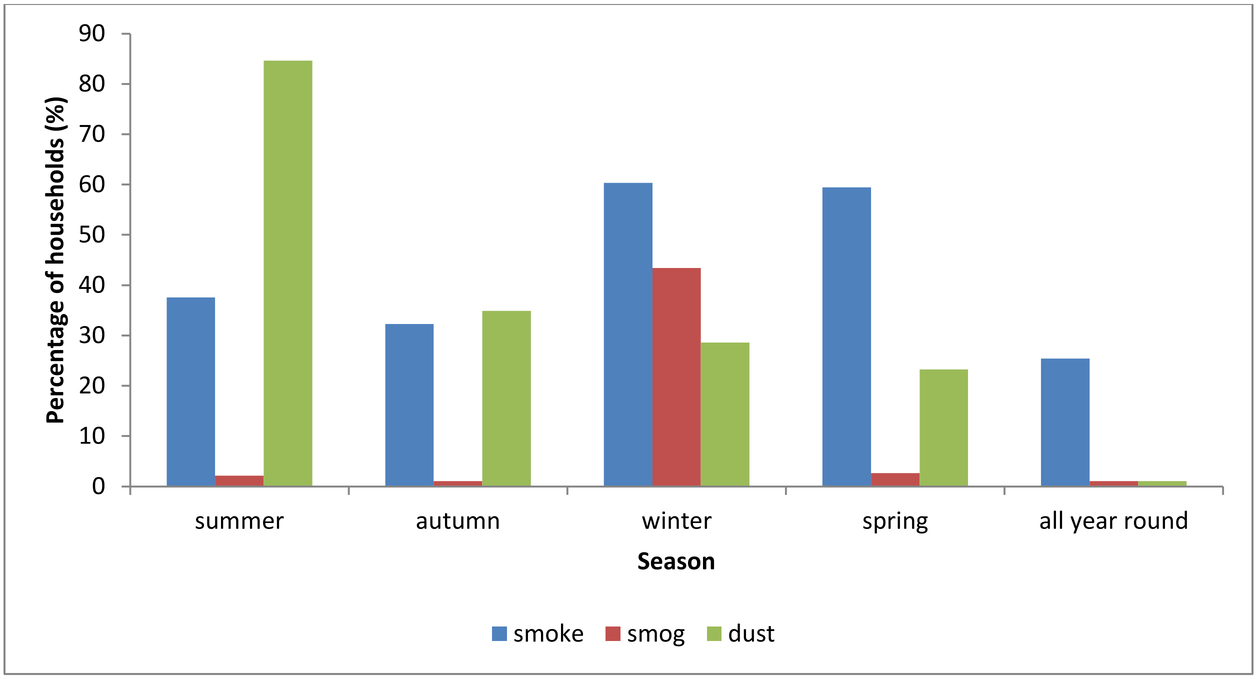


Figure 3.9 Seasons of the year outdoor air pollution occurs in Rocklands

In Figure 3.9, more than 80% of the households in Rocklands indicated dust as a big problem during summer months. Dust seems less of a problem in the other seasons. In winter and spring, more than 55% of the sampled households said there are smoke problems. In general, smoke is a big concern all year round. During the winter months, smog is also a concern as indicated by 43.38% of the sampled households but is rarely a problem during the other seasons.

3.2.6 Seasons of the year indoor air pollution occurs

Indoor air pollution mostly arises as a result of household energy choices for their domestic activities. The common sources of indoor air pollution discovered in the study areas include paraffin, smoke from cigarette and coal. Figure 3.10 shows the time of the year indoor air pollution mostly occurs in Phahameng.

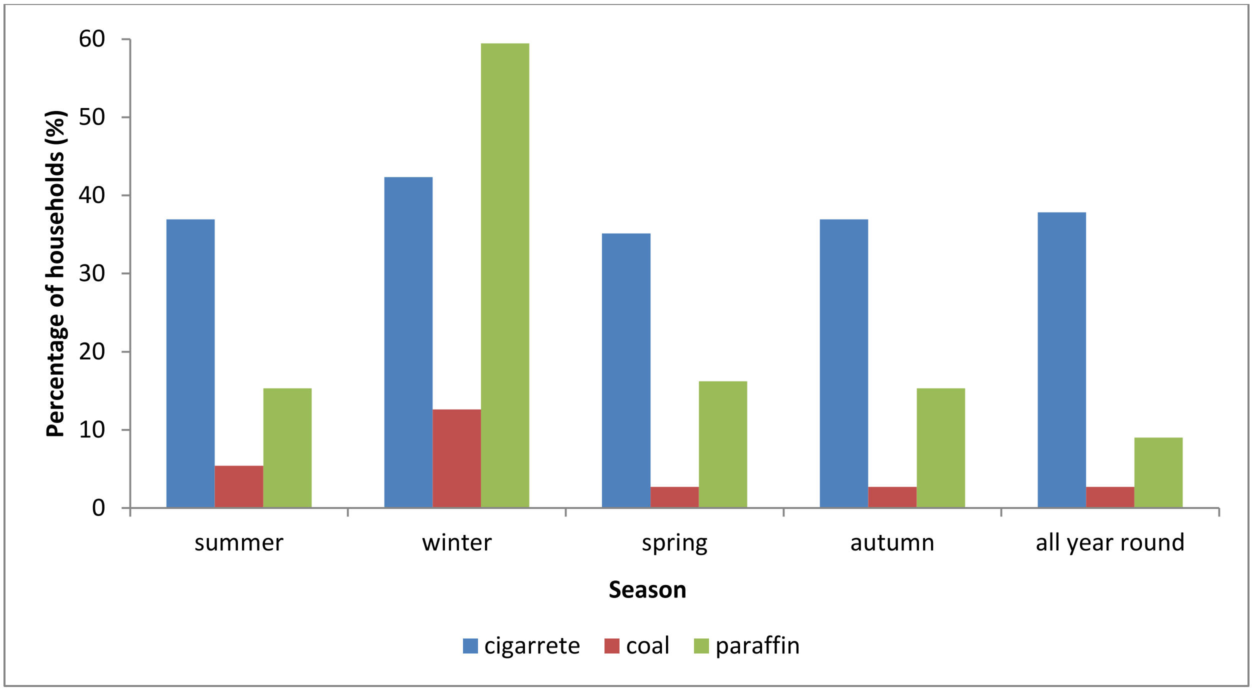


Figure 3.10 Seasons of the year indoor air pollution occurs in Phahameng

In Figure 3.10, more than 30% of the sampled households from Phahameng indicated cigarrete smoke as a source of indoor air pollution occurring in all the seasons and all year round. Paraffin is only a problem during winter as indicated by 59.45% of the respondents. As mentioned in the section of household energy source for space heating, households mostly use paraffin heaters for their space heating explaining why paraffin is seen as a pollutant during winter. Coal seems not to be a major cause for concern other than in winter as indicated by less than 5% of the sampled households. Figure 3.11 shows the season of the year indoor air pollution occurs in Rocklands.

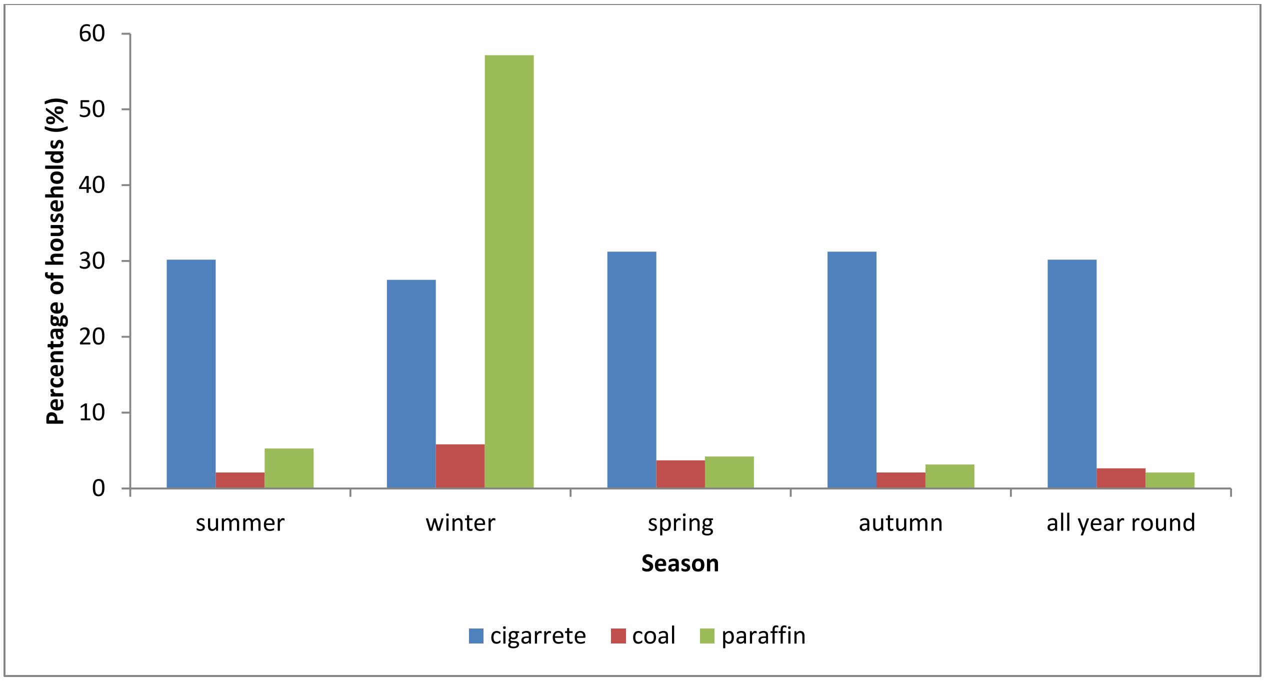


Figure 3.11 Seasons of the year indoor air pollution occurs in Rocklands

Figure 3.11 shows that 57.14% of the sampled households indicated paraffin as a major source of indoor air pollution occurring during winter probably as a result of paraffin heaters. However, paraffin is not a major problem for the rest of the seasons as indicated by less than 6% of the sampled households. About 30% of the sampled households indicated cigarrete smoke as a consistent indoor air pollutant for households in Rocklands as it occurs all year round. Coal seems not to be a common indoor air pollutant, indicated by less than 4% of the sampled households in Rocklands.

3.3 Summary

Identifying factors that could influence the willingness to pay for clean air is of great importance to provide households and policy makers with correct and relevant advice to reduce air pollution, both indoors and outdoors, to a level that will not be detrimental to health. The indoor and outdoor air quality and socio-economic characteristics that were measured were selected from interaction with knowledgeable individuals.

Household energy choice for cooking and space heating was explored in the study areas to know the source of indoor air pollution. Paraffin heaters and cigarette smoke were found to be major cause of indoor air pollution in the areas of study. Smog, smoke and dust are the common outdoor air pollutants observed in the study areas. Smoke was found to be a problem that occurs in all the seasons and conclusively all year round. Most of the respondents disclosed that poor service delivery of refuse removal is probably the cause of smoke problems as households burn their own refuse most of the time. Dust is a predominant problem in summer in the study areas which is not surprising to know as summer is known as the windy season. Smog seems to be less of a problem in both study areas. It is important to remember that a substantial number of the respondents in the study areas ranked air pollution as serious as other societal problems (i.e. crime, unemployment, poor service delivery and violence against women and children). Thus, it can be inferred in the two study areas that air pollution (both indoor and outdoor) is a big problem.

From the measured socio-economic characteristics of respondents in the study areas, it was found that there is a variation in age and most of the household heads are female. Majority of the respondents attended secondary school and on average 60.30% of the sampled households are unemployed. A greater percentage of the sampled households in the study areas earn less than R2000 per month and more than half of the sampled respondents have chronic illness.

The next chapter discusses the procedures used to meet the objectives of the study.

CHAPTER 4

PROCEDURES

The aim of this chapter is to describe the procedures used within the study to meet the sub-objectives. The chapter consists of four main sections. The first section provides the explanation of workdays lost and mitigating cost in the study areas. In the second section, the econometric model used to determine factors that influence workdays lost and mitigating cost is discussed. Hypothesised variables influencing workdays lost and mitigating cost are discussed as well. The third section focuses on measures developed and used to estimate willingness to pay for improved air quality and the specification of the regression models used to determine the factors influencing the willingness to pay decisions for improved air quality.

4.1 Explaining workdays lost and mitigating cost

The first aim of this study is to explore the economic impact of air pollution which is measured in terms of workdays lost and mitigating cost. Workdays lost is measured as the number of days lost for the last episode (prior to interview) of an ailment related to air pollution. For employed respondents, workdays lost is considered as the number of days they were not able to go to their place of work. If the respondent for the household is a student, the workdays lost is measured as number of days absent from school. For self-employed or unemployed respondents, workdays lost is measured as the number of days not able to perform daily routine or activities. Mitigating cost on the other hand is the total cost incurred as a result of treating the last episode (prior to interview) of air pollution related ailments. The cost include consultation fee, cost of medication, hospitalisation and transportation fee.

4.1.1 Quantifying workdays lost and mitigating cost

The first sub-objective of this study is to quantify the economic cost of air pollution- workdays lost and mitigating cost. The determination of workdays lost and mitigating cost is from the survey data. The next step is to specify the model to use to determine the factors influencing workdays lost and mitigating cost.

4.1.1.1 Specification of econometric model to determine factors that influence workdays lost and mitigating cost

The economic impact of air pollution can be described in different ways. Economic impact from air pollution can be inferred to its effect on the Gross Domestic Product (GDP), labour and leisure loss. For the purpose of this study, the economic impact of air pollution is considered in terms of workdays lost and mitigating cost. The method of estimation has been strongly and clearly guided by the form of the dependent variables considered in this study. The dependent variables (workdays lost and mitigating cost) considered takes the form of a numeric or continuous variable. Knowing the nature of the dependent variables, which is continuous, Ordinary Least Square method (OLS) is found appropriate to investigate the factors that influence workdays lost and mitigating cost. OLS is probably the most widely used statistical methodology in existence and is found appropriate to determine the factors that influence workdays lost and mitigating cost. OLS is a statistical technique that uses sample data to estimate the true population relationship between two variables and has been successful in solving problems with a continuous dependent variable (Gujarati, 2003). Thus, two OLS models was fitted. The first model was used to investigate the factors that influence workdays lost while the second OLS model investigate the factors that influence mitigating cost. The analysis of the data was done in Eviews 7. The generic equation of the OLS model is written as:

$$Y_i = \beta_0 + \beta_1 X_i + \ldots\ldots\ldots\ldots\ldots\ldots + u \qquad (1)$$

Where:

Y_i is the workdays lost or mitigating cost of respondents,

X_i is the selected characteristics of the respondents i,

β_1 is the corresponding vector of coefficients and

u is the normally distributed error term with mean and zero variance σ^2 (N (0, σ^2)).

From the survey data, one would assume that the explanatory variables will be correlated with one another. Thus, Number Cruncher Statistical System, NCSS (2007) was used to test for multi-collinearity.

4.1.1.2 Testing for multi-collinearity

Multi-collinearity may cause lack of significance of individual explanatory variables while the overall model may be strongly significant. It may also result in incorrect signs and magnitudes of regression coefficient estimates, and consequently in inaccurate conclusions about the relationship between explanatory variables (Gujarati, 2003). Variance inflation factor (VIF), tolerance, eigenvalue, condition number and correlation matrix are the widely used criteria to detect multi-collinearity (See appendix B for results). Each of the above mentioned methods to detect multi-collinearity is discussed in brief.

- **Tolerance and variance inflation factor**

According to Clark Carter (2009) and Ho and Edmonds (2007), tolerance is the proportion of variance in an independent variable which is not predicted by the other independent variables. The R^2 from a multiple regression equation is put into the equation below:

$$\text{Tolerance} = 1 - R^2$$

The rule of thumb to detect multi-collinearity is a large R^2, VIF of 10 and a small tolerance value. A tolerance value of less than 0.1 is often given as the guideline when multi-collinearity is likely to be a problem. With mitigating cost as the dependent, the VIF found in this study ranges from 1.10 - 6.40 while the tolerance value ranges from 0.16 – 0.92. Based on the values of VIF and tolerance value found, multi-collinearity seems not to be present. With workdays lost as the dependent variable, VIF values ranging from 1.10 – 1.70 and tolerance value ranging from 0.57 – 0.90 was found. Based on the values of VIF and tolerance found, multi-collinearity is not likely to be present.

- **Eigenvalue and condition number**

Eigenvalues of zero indicate linear dependencies or exact collinearities. Very small eigenvalues indicate near-linear dependencies or high degrees of multi-collinearity (Rudolf and Ramon, 2000). Sometimes, eigenvalues seem close to zero but not small in magnitude relative to the values. Thus, a condition number is preferably used to know the extent at which multi-collinearity is present (Rudolf and Ramon, 2000). Condition number is a square root of the ratio of the largest to smallest eigenvalue. Criteria for a condition number to signify serious multi-collinearity are arbitrary, with the value of 30 often quoted (Rudolf and Ramon, 2000). According to Douglas *et al*. (2012), a condition number of less than 100 shows there is no serious multi-collinearity. Condition numbers between 100 and 1000 imply moderate to strong multi-collinearity and if number exceed 1000, severe multi-collinearity is indicated. In this study, the highest condition number found with mitigating cost as the dependent variable is 24.74 while the eigenvalues ranges from 0.083 - 2.051. The eigenvalues and condition number found with mitigating cost as the dependent variable indicated there is no problem of multi-collinearity. With workdays lost as the dependent variable, the highest condition number found was 6.06 and the eigenvalues ranges from and 0.356 - 2.163. Thus, the eigenvalues and condition number found indicated there is no problem of multi-collinearity.

- **Correlation matrix**

A simple measure of multi-collinearity is inspection of the off-diagonal elements r_{ij} in $X^{'} X$. If regressors' x_i and x_j are nearly linearly dependent, then r_{ij} will be near unity. Thus, a correlation coefficient exceeding 0.9 shows a sign of multi-collinearity (Bonate, 2011). Multi-collinearity could also be present if the correlation coefficient is less than 0.9 in the case of more than two explanatory variables (Bonate, 2011). A correlation matrix was calculated on all the explanatory variables selected to influence workdays lost. From this study, the minimum value found is 0.003 and the maximum is 0.45 with workdays lost as dependent variable. With mitigating cost as the dependent variable, the minimum value found was 0.0009 while the maximum value was 0.78. Thus, multi-collinearity seems not to be present. Similarly, a correlation matrix was calculated on all the explanatory variables selected to influence mitigating cost.

Since the criteria shows there is no multi-collinearity problem, the next step, which is the second sub-objective, is to determine the factors that influence the workdays lost and mitigating cost.

4.1.2 Variables hypothesised to influence workdays lost and mitigating cost

Various researchers have identified different factors influencing workdays lost and mitigating cost, though no studies of such have been done in South Africa. Among the factors hypothesised to influence workdays lost; health, duration of illness, age, treatment methods, income, district, ailment, number of visits for treatment, number of times ailment associated with air pollution occurred in a year and mitigating cost stood out the most. The variables hypothesised to influence mitigating cost include income, duration of illness, district, treatment methods, employment status, workdays lost and number of visits to pharmacy or to see a doctor for treatment.

The variables associated with the treatment method used include over-the-counter medication, traditional method and no medication. Seeing a medical practitioner was used as the base dummy. District is a dummy which takes value of 1 if Phahameng and 0 if Rocklands. Monthly income is a categorical variable. Middle income level is the base dummy ranging from >R3500 – <R5000. The low income level is from <= R2000 – R3500 while the high income level ranges from R5000 and above. Employment status is also a categorical variable comprising of employed, self-employed, unemployed and students. Employed respondent is used as the base dummy. The next section discusses the expected signs of the variables hypothesised to influence workdays lost.

4.1.2.1 Variables hypothesised to influence workdays lost

The variables hypothesised to influence workdays lost and their expected signs is shown in Table 4.1.

Table 4.1 Variables hypothesised to influence workdays lost, measurement index and expected signs

Variable name	Measurement index	Expected sign
Dependent variable		
WKDLOST	Number of workdays lost (for employed respondents) or number of days not able to perform daily routine or activities (for self-employed or unemployed respondent) or absenteeism from school (for student) (in days)	
Independent variables		
HEALTH	Dummy=1 if ill, 0= not ill (note: illness is not necessarily air-pollution related)	+
DLNES	Duration of illness (in days)	+/-
AGE	Age of respondent (in years)	+/-
OTC	1 if over-the-counter medication is used, 0 otherwise	+
TRAD	1 if traditional treatment is used, 0 otherwise	+
NMED	1 if no medication is taken, 0 otherwise	+
LOWINC	Monthly income of household ranging from <= R2000 – R3500	+
HIGHINC	Monthly income of household ranging from >R5000 to R6500 and above	-
DISTRICT	1=Phahameng, 0= Rocklands	+
AILMENT	1 if episode of air-pollution related ailment, 0 otherwise	+
VSTNR	Number of visits to pharmacy or to a doctor for treatment	+
NRTIMES	Number of times ailment linked to air pollution occurred in a year	+
MGTCOST	Total cost incurred on treatment of air pollution ailment (include transportation fee)	+/-

From Table 4.1, the treatment methods variables (OTC, NMED, TRAD), health (HEALTH), district (DISTRICT), ailment (AILMENT), number of visits to a doctor or pharmacy for treatment (VSTNR) and number of times air-pollution related ailment(s) occurred in a year (NRTIMES) are all expected to positively influence workdays lost. Respondents that use over-the-counter medication, traditional treatment or took no medication are expected to have more workdays lost compared to those that when to see a medical practitioner for treatment (base dummy).

Duration of illness (DLNES), age (AGE), and mitigating cost (MGTCOST) are ambiguous variables hypothesised to positively or negatively influence workdays lost. Mitigating cost is included as part of the variables hypothesised to influence workdays lost. Mitigating cost is influenced by the treatment methods used. Respondents that choose to see a medical practitioner for treatment are assumed to spend more than those that use over-the-counter medication or traditional treatment or took no medication. Thus, mitigating cost is expected to either positively or negatively influence workdays lost depending on the treatment method used. High mitigating cost leads to fewer workdays lost while low mitigating cost leads to increase number in workdays lost. Duration of illness is also hypothesised to positively or negatively influence workdays lost. Long duration of illness leads to more workdays lost and vice-versa. Age was hypothesised to influence workdays lost positively or negatively. Older respondents are likely to have more workdays lost while young respondents will have fewer workdays lost. This is in accordance with the study of Reid and Dawson (2009) who reported that older people with health problems have more workdays lost. Truchon and Fillion (2000) suggested that a higher rate of workdays lost for older people could be related with the inherent diminishing body resilience that occurs in association with aging. Chau and Hite (2009) stated that in general, health status is negatively associated with workdays lost because good health reduces the number of days lost at work.

The monthly income variables are low income (LOWINC) and high income (HIGHINC). High income is expected to have a negative influence on workdays lost, meaning that respondents in the high income category are assumed to spend more, compared to middle income earners (base dummy), to get better quickly which will results in less workdays lost. Low income earners are assumed to spend less, compared to middle income earners, implying more workdays lost. Kumar and Kumar (2010) stated a negative association between income and workdays lost.

4.1.2.2 Variables hypothesised to influence mitigating cost

The variables hypothesised to influence mitigating cost include income, duration of illness, district, ailment, treatment methods, employment status, workdays lost and number of visits to pharmacy or see a doctor for treatment. Table 4.2 shows the variables hypothesised to influence mitigating cost and the expected signs.

From Table 4.2, the variables associated with the employment status of respondents are self-employed, unemployed and student (as stated earlier). Respondents that are working on their own (SELFEMPLYD) are expected to have a positive sign while those that are not working (UNEMPLYD) or studying (STUDENT) are expected to have a negative sign. The negative sign for a variable in the employment category means that the respondents that are not working or studying pays less compared to respondents that are working (base dummy) and thus have a negative influence on mitigating cost. The positive sign means that the respondents that are self-employed pay as much as the respondents that are working and thus have a positive influence on mitigating cost.

Low income (LOWINC) is hypothesised to have a negative influence on mitigating cost while high income (HIGHINC) is expected to have a positive influence on mitigating cost. This is different from what was hypothesised for workdays lost. Low income earners are expected to pay less mitigating cost for treatment of air pollution ailment compared to middle income earners (base dummy) while high income earners are expected to pay high cost for treatment (compared to the base dummy). Kumar and Kumar (2010) have found income and employment to exhibit a positive association with the health effect of air pollution. Kumar and Kumar (2010) stated that with increase in income levels of individual, there will be a reduction in medical expenses.

Table 4.2 Variables hypothesised to influence mitigating cost, measurement index and expected signs

Variable	Measurement index	Expected sign
Dependent variable		
MGTCOST	Total cost incurred on treatment of the last episode of air pollution ailment (include transportation fee)	
Independent variables		
WKDLOST	Number of workdays lost (for employed respondents) or number of days not able to perform daily routine or activities (for self-employed or unemployed respondent) or absenteeism from school (for student) (in days)	+/-
DLNES	Duration of illness (in days)	+/-
OTC	1 if over-the-counter medication is used, 0 otherwise	-
TRAD	1 if traditional treatment is used, 0 otherwise	-
NMED	1 if no medication is used, 0 otherwise	-
LOWINC	Monthly income of household ranging from <= R2000 – R3500	-
HIGHINC	Monthly income of household ranging from >R5000 and above	+
DISTRICT	1=Phahameng, 0= Rocklands	+
AILMENT	1 if episode of air-pollution related ailment , 0 otherwise	+
VSTNR	Number of visits to pharmacy or a doctor for treatment	+/-
SELFEMPLYD	1 if self-employed, 0 otherwise	+
UNEMPLYD	1 if unemployed, 0 otherwise	-
STUDENT	1 if student, 0 otherwise	-

Duration of illness (DLNES), number of visits to pharmacy or to see a doctor for treatment (VSTNR) and workdays lost (WKDLOST) are ambiguous variables hypothesised to have either positive or negative influence on workdays lost. If the duration of illness takes a positive sign, it means the more the number of days of illness, the higher the mitigating cost and otherwise (if a negative sign). It is assumed that if the duration of illness was for a long time, the number of visits to see a doctor or to the pharmacy for treatment will increase and the total cost incurred on treatment will be increasing. Workdays lost is also hypothesised to have a positive or negative influence on mitigating cost. The assumption is that number of days lost is related to the duration of illness, meaning that the longer the duration of illness, the more the number of days lost and the higher the mitigating cost.

The treatment methods are all expected to have a negative influence on mitigating cost. It is assumed that respondents that use over-the-counter medication (OTC) or traditional treatment (TRAD) or took no medication (NMED) will have lower treatment cost compared to respondents that visited a medical practitioner for treatment (base dummy).

4.2 Explaining willingness to pay for improved air quality

The third sub-objective of this study was to determine the value people place on air pollution by determining their willingness to pay. Following the method used by Alberini *et al*. (1997), the willingness to pay for improved air quality was based on the responses to the hypothetical question presented to the respondents. A binary choice question of yes or no response was asked to determine whether the respondents are willing to pay for improved air quality. Next, the respondents were asked how much they will be willing to pay on a monthly basis to support a program that will reduce air pollution to a level that is not detrimental to health. The respondents were explicitly reminded of the cost on mitigating activities, the pain and suffering of their last episode of ailment linked to air pollution. A double bounded iterative bidding technique was used to determine the willingness to pay for improved air quality. The bidding started from R100, obtained as an average minimum cost of illness from the pilot survey and also by considering the starting bids of other studies. If the respondent accepts the starting bid, the interviewer revises the bid upward until the respondent gave a ‘no’ response. The amount before the respondent gave a ‘no’ response is recorded as the upper bound. The interviewer will revise the bid downward (but not to the amount the respondent as initially accepted) until a final value is reached and recorded as the lower bound. Similarly, if the starting bid is rejected, the bid is revised downward until the respondent accepts and this was recorded as the lower bound. The interviewer revises the bid upward (but not to the level the respondents as initially rejected) until a final value is reached and thus recorded as the upper bound. Some respondents rejected the starting bid which was revised downwards until a zero is reached. The respondents that are not willing to pay were probed for the reason. The majority claimed that they pay tax and that the government should deduct to the cost to improve the air quality from taxes paid.

4.2.1 Specification of econometric model to determine the factors influencing willingness to pay decisions

Modelling willingness to pay decisions in this study is in two decision frameworks. The first framework is a one-decision making framework, meaning how much a household respondent is willing to pay for improved air quality. The second framework is a two-decision making framework, implying the decision of whether or not to pay and how much to pay (where household respondent has decided to pay) for improved air quality is two separate decisions. The econometric model that fits the single decision of how much to pay for improved air quality is discussed next.

4.2.1.1 Specification of econometric model to determine the factors that influence the single decision of how much to pay for improved air quality

The actual amount a household representative is willing to pay was used as the dependent variable in this analysis while the household representatives that are not willing to pay are assigned a value of zero. The Tobit Model was found appropriate to determine the factors that influence the continuous decision of the actual amount a household is willing to pay for improved air quality. The Tobit Model for determining the factors that influence how much to pay for improved air quality is:

$$\theta_{\iota}^{*} = \alpha + \beta x_i + u \qquad (2)$$

Subject to:

$$\theta_\iota = \theta_\iota^* \text{ if } 0 < \theta_\iota < 1$$
$$= 0 \text{ if } \theta_\iota^* < 0$$
$$= 1 \text{ if } \theta_\iota^* > 0 \quad (3)$$

Where:

θ_ι^* refers to the probability of the i^{th} individual willing to pay a positive amount and,

x_i denotes a vector of individual characteristics such as age, education, duration of illness etc.

4.2.1.2 Specification of econometric model to identify factors influencing the two-decision whether or not to pay and how much to pay for improved air quality

The specification of the econometric model lies strongly on the assumption that a household representative that are willing to pay is simultaneously presented with the continuous choice of how much they are willing to pay. In this study, the econometric model to use to identify factors influencing willingness to pay decisions is modelled as two decisions: whether or not to pay, and how much to pay for improved air quality (if household respondent has decided to pay). The dependent variable in the case of whether or not to pay is the binary responses and it takes a value of 1 if yes and 0 otherwise. OLS could not be used for the estimation of the model as the dependent variable is binary. A Probit Model is thus found appropriate (Katchova and Miranda, 2005). Probit Model is used to identify the factors influencing the decision of whether or not to pay for improved air quality (first part of sub-objective 4). The dependent variable in the second aspect of how much to pay (if willing to pay) is the actual amount respondents are willing to pay. The Truncated Regression Model captures the factors that influence the decision on how much the household respondent is willing to pay for improved air quality (the second part of sub-objective 4).

- Probit Model

The decision of whether or not to pay for improved air quality consists of only two possible outcomes, zero or one. The Probit Model, also known as the Normit Model, is found appropriate to determine the factor(s) that influences the decision of whether or not to pay for improved air quality. The Probit Model is an econometric model where the regressed variable is discrete (i.e. 0 or 1). Following Maddala (2001), the Probit Model is represented as:

$$P(\alpha_1 = 0) = \phi\left(\frac{-\beta_{\alpha}^{1} X_1}{\sigma}\right) \tag{4}$$

Where:

$a_{1=}$ is the dependent variable if individual *i* answered 1=willing to pay and 0= not willing to pay,

P is a vector of respondent characteristics,

β is a vector of coefficients and,

ϕ is the cumulative probability distribution.

- Truncated Regression Model

A Truncated regression model was used to determine how much an individual is willing to pay to improve air quality. Only household representatives that are willing to pay were included in the analysis. The use of a two-step model allows different variables to influence the decision of whether or not to pay and actual amount willing to pay to improve air quality. A variable can also influence these decisions in the same way or in the opposite direction (Winkelmann and Boes, 2006). For the purpose of this study, it is assumed that the same factors that influence the decision of whether or not to pay will also affect the decision of how much to pay (if willing to pay). Equation 5 represents the Truncated Regression Model.

$$f(a_1 / a_0 > 0) = \frac{f(\alpha_1)}{P(\alpha_1 > 0)} = \frac{\frac{1}{\alpha}\phi\left[\frac{\alpha_1 - \beta_{\alpha}^{1} X_1}{\sigma}\right]}{\Phi\left[\frac{\beta_{\alpha}^{1} X_1}{\sigma}\right]} \tag{5}$$

Where Φ is the standard normal probability density function.

Equation 5 represents a Truncated Regression for positive values of the continuous decision on how much to pay for improved air quality ($\alpha_1 > 0$). The Tobit Model arises when the decision represented by the Probit Model in Equation 2 and the decision of how much to pay for improved air quality, represented by the Truncated Regression Model in Equation 5, have the same variables X_1 and the same parameter vector (β_α).

Other alternative approaches to developing a probability model for a binary response variable include the Linear Probability Model (LPM) and the Logit Model (Gujarati, 2003).

4.2.1.3 Is willingness to pay decision a one-decision or two-decision?

Within a one-decision-making framework, the dependent variable is classified as the amount to be paid to improve air quality. Within a two-decision-making framework, the dependent variables are the yes or no decision whether or not to pay and the actual amount to pay if a yes-decision is taken. A Cragg's Model specification is a combination of the Probit Model and a Truncated Regression Model. Katchova and Miranda (2004) revealed that Cragg's Model is based on the assumption that the same variables and the same parameter vector affect the decision of whether or not to pay and the amount to pay for improved air quality. An underlying feature of the specification is that it reduces to the Tobit Model and causes the variables to influence the decision of whether or not to pay and actual amount to pay in the same manner. This phenomenon can be tested by estimating a Tobit, Probit and Truncated Regression separately, using the same explanatory variables. The log-likelihood test statistic is computed as follows:

$$\lambda = 2(\ln L_{probit} + \ln L_{Truncated\ regression} - \ln L_{Tobit}) \qquad (6)$$

Where:

λ is distributed chi-square with *R* degrees of freedom,

R is the number of independent variables including a constant.

Therefore, the log-likelihood in Cragg's Model is a sum of the log-likelihood of the Probit Model and the log-likelihood of the Truncated Regression Model. In other words, the more restrictive Tobit Model will be tested against the more general Cragg's Model. The hypothesis testing is thus stated as:

H_0: Tobit, with a log-likelihood function

H_1: Cragg's Model (Probit and Truncated Regression Model estimated separately), with a log-likelihood function

The Tobit Model will be rejected in favour of the Cragg's Model if λ exceeds the appropriate chi-square critical value.

4.2.1.4 Variables hypothesised to influence willingness to pay for improved air quality

The factors considered to influence willingness to pay decisions in this study are age (AGE), education (EDUC), household size (HSIZE), income (LOWINC and HIGHINC), ailment (AILMENT), household member who suffer air pollution ailment prior to death (DAILMENT), treatment methods (OTC, TRAD and NMED), district (DISTRICT), duration of illness (DLNES), number of visits to pharmacy or to see a doctor for treatment (VSTNR) and employment (SELFEMPLYD, UNEMPLYD and STUDENT). It is assumed that the same factors that influence the decision of whether or not to pay would also influence the actual amount the household representative is willing to pay (Cragg's Model). Table 4.3 shows the expected direction of influence the hypothesised variables will have on willingness to pay decisions.

Table 4.3 Variables hypothesised to influence willingness to pay decisions, measurement index and expected signs

Variable name	Measurement index	Expected sign
Dependent variables		
WTP	It takes a binary response of 1=yes, 0=no if respondent are willing to pay	
ACTUALWTP	It takes the actual value respondent are willing to pay (in Rand)	
Independent variables		
DLNES	Duration of air-pollution related illness (in days)	+
EDUC	1 if respondent has no education or attended primary school and 0= if respondent attended secondary or tertiary school	-
OTC	1 if over-the-counter medication is used, 0 otherwise	-
TRAD	1 if traditional treatment is used, 0 otherwise	-
NMED	1 if no medication is taken, 0 otherwise	-
LOWINC	Monthly income of household ranging from <= R2000 to R3500	-
HIGHINC	Monthly income of household ranging from >R5000 to R6500 and above	+
DISTRICT	1=Phahameng, 0= Rocklands	+
AILMENT	1 if episode of air-pollution related ailment occurred, 0 otherwise	+
VSTNR	Number of visits for treatment	+
SELFEMPLYD	1 if self-employed, 0 otherwise	+
UNEMPLYD	1 if unemployed, 0 otherwise	-

STUDENT	1 if student, 0 otherwise	-
AGE	Age of respondent (in years)	+/-
HSIZE	Number of people living in a household for at least six months	+/-
DAILMENT	1 if a member suffer from air pollution ailment(s) prior to death and 0= if otherwise	+

From Table 4.3, ailment (AILMENT), if household member suffer from air pollution ailment(s) prior to death (DAILMENT), district (DISTRICT), duration of illness (DLNES), high income level (HIGHINC), self-employed respondents (SELFEMPLYD) and number of visits to pharmacy or to see a doctor (VSTNR) were hypothesised to have a positive effect on willingness to pay for an improved air quality. Self-employed respondents are expected to have a positive influence on willingness to pay just as employed respondents (base dummy). This is in accordance with findings from literature where self-employed/employed individuals working in places thought to be prone to the adverse health effect of air pollution have a positive association with WTP. High income is expected to have a positive influence on WTP, meaning respondents in the high income level will be more willing to pay for improved air quality. In a study by Baby (2009), monthly income was found to be positively related to WTP and that income is the most principal factor influencing WTP. Hammit and Zhou (2006) also found that income has a positive and significant impact on WTP. Respondent with air pollution related ailment(s) is expected to have a positive relationship with WTP. Respondents that have experienced air pollution ailments (AILMENT) will be willing to pay to reduce air pollution. Number of visits to pharmacy or to see a doctor (VSTNR) and duration of illness (DLNES) are expected to positively influence respondent's WTP for improved air quality. Respondents that have a long duration of illness are assumed to have a higher number of visits for treatment, thus expected to be willing to pay to improve air quality.

Education (EDUC), treatment methods (OTC, TRAD and NMED), low income (LOWINC), unemployed respondents (UMEMPLYD) and respondents that are studying (STUDENT) were all hypothesised to have a negative influence on WTP. EDUC is a dummy and takes value of 1 if respondent has no education or attended primary school. It is hypothesised that respondents that falls into this educational level will have a negative influence on WTP. From literature, it was revealed that education raises awareness level of individuals with respect to environmental problems and related health damages. Baby (2009) from their study found education to have a positive influence on WTP. On the contrary, Zellner and Degner (1989) found a negative influence of education on WTP. The explanation they gave was that college/university educated respondents tend to expect more from the government without having to pay extra for it. The negative sign for a variable under treatment methods means that the respondent that used over-the-counter or traditional methods or did not use any medication will not be willing to pay unlike those that went to see a medical practitioner (base dummy). Also, the negative sign in the employment category for unemployed and student indicate that respondents that not employed (UNEMPLYD) and studying (STUDENT) will not willing to pay for improved air quality compared to the employed (base dummy) or self-employed respondents.

Age and household size are ambiguous variables hypothesised to have a positive or negative effect on WTP for improved air quality. The marginal effect of age on WTP is hypothesised to be positive at a younger age but is reduced as age progresses and so also for household size. The marginal effect of household size on WTP is hypothesised to be positive for few household members, but negative if household number increases. As observed by Baby (2009), age has a negative influence on WTP. Krupnick *et al.* (2002) also discovered that age has no effect on WTP until age 70. The summary from Krupnick and others is that WTP for old people is lower (age has a negative influence on WTP) while WTP for younger people is higher (age has a positive influence on WTP). On the other hand, larger households generally have less discretionary income in willingness to pay compared to smaller households. Adepoju and Omonona (2009) from their study found household size not to significantly influence willingness to pay decisions. Household size was presumed by Aggrey and Douglason (2010) to have a positive effect on WTP. The assumption was that the more the number of people in the household, the more willing households will be to pay. Blumenschein *et al*. (2008) discovered that household size reflect a demand on income effect. The income per household member decreases with household size. Thus, household size will have a negative effect on WTP as the number increases.

The specification of the regression model to identify the factor(s) that influence the willingness to pay decisions for improved air quality and the expected signs of the variables hypothesised concludes the procedures that were followed to meet all of the sub-objectives. The results of the relevant analyses are presented and discussed in Chapter 5.

CHAPTER 5

RESULTS AND DISCUSSION

Chapter 5 presents the results of the analyses. The chapter is organised into two main sections. In the first section, the total number of workdays lost and the mitigating cost from the survey data is presented. Regression results of the factors that influence workdays lost and mitigating cost are presented. The second section presents the willingness to pay estimated from the survey data and the results of the factors influencing the willingness to pay decision.

5.1 Explaining workdays lost and mitigating cost

It is important to remember that workdays lost is measured as the number of days an individual is not able to go to work (for employed), or as the number of restricted activity days (for self-employed) or number of days absent from school (for student). Also, mitigating cost in the study areas is assessed to know the total cost incurred on ailments associated with air pollution. Mitigating cost is the total cost incurred as a result of air pollution related ailments. The cost include the medical expenditure (doctor's fee, hospitalisation fee, cost of medication) and transportation cost. The findings on workdays lost are discussed next.

5.1.1 Quantifying workdays lost

The workdays lost on average per person (for most recent episode prior to interview) due to air pollution related ailments is estimated as 3.40 days in Phahameng and 3.44 days in Rocklands. The average workdays lost in both study areas per annum is 121.53 days. Some respondents did not have any days lost during the last episode of air pollution related ailments. The maximum number of workdays lost (during the last episode of air pollution related ailments) observed in the study areas was 60 days. The Cumulative Probability Distribution in Figure 5.1 reports the workdays lost in the study areas.

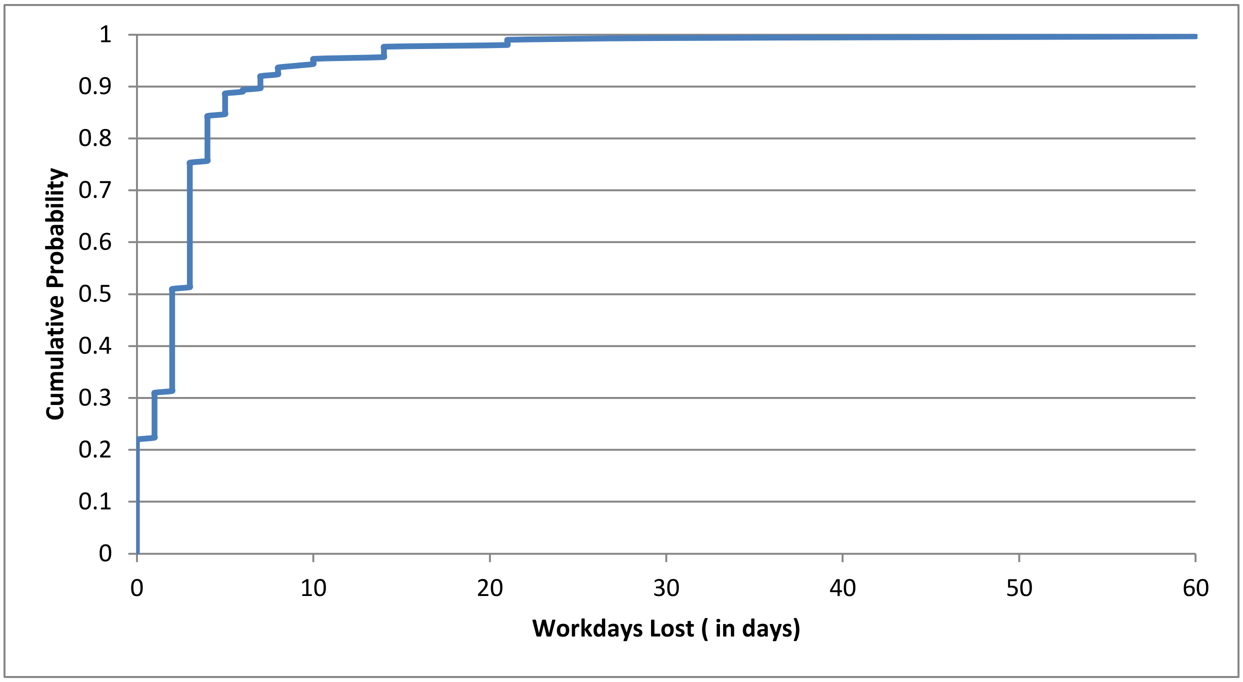


Figure 5.1: Cumulative Probability Distribution of workdays lost in the study areas

Figure 5.1 show that 20% of the sample did not lose workdays during their last episode of illness due to air pollution. About 94% have lost 10 workdays or less while 98% have lost 20 workdays or less due to illness as a result of air pollution. Only 1% of the respondents lost more than 30 workdays due to illness. The Cumulative Probability distribution of workdays lost in both study areas reveal that the economic impact of air pollution in Phahameng and Rocklands is a big concern considering the number of days lost due to ailments associated with air pollution. Thus, the economic cost of air pollution in the study areas is considered to be high. The next section reports the factors influencing workdays lost in the study areas.

5.1.2 Factors influencing workdays lost

An Ordinary Least Square Regression Model (OLS) was used to determine the factors influencing workdays lost. Table 5.1 shows the result of the OLS model of the variables hypothesised to influence workdays lost. In the interpretation of Table 5.1, the focus is on the sign of the coefficient, indicating the direction of influence of the variables on workdays lost. If a variable is not significant up to 10%, then it does not allow for explaining variation in workdays lost due to air pollution ailments.

Table 5.1 OLS regression results of factors influencing workdays lost

Variable	Coefficient	Standard error	t-Statistics	Probability
C	-0.629	0.670	-0.939	0.348
HEALTH	1.032	0.312	3.310	0.001***
DLNES	0.303	0.009	34.366	0.000***
AGE	-0.017	0.009	-1.823	0.069*
OTC	0.274	0.392	0.701	0.484
TRAD	-0.712	0.706	-1.009	0.314
NMED	-0.218	0.679	-0.321	0.748
LOWINC	-0.409	0.465	-0.881	0.379
HIGHINC	-0.009	0.627	-0.014	0.989
DISTRICT	0.693	0.292	2.372	0.018**
AILMENT	-0.431	0.468	-0.918	0.359
VSTNR	0.773	0.130	5.943	0.000***
NRTIMES	-0.067	0.057	-1.174	0.241
MGTCOST	0.007	0.001	5.240	0.000***
R-Squared		0.860		
R-Squared Adj		0.854		

Note: *** significant at 1% level, ** significant at 5% level and * significant at 10% level

From Table 5.1, the model gives an R-square value of 0.86 which indicates that the independent variables included in this study explain 86% of the variation in the dependent variable. Thus, the R-square value implies that the model is a good fit. Based on the results from Table 5.1, six variables are statistically significant at 1%, 5% and 10% level of significance. Health (HEALTH), duration of illness (DLNES), number of visits to doctor or pharmacy for treatment (VSTNR) and mitigating cost (MGTCOST) are statistically significant at a 1% level, confirming them as the principal factors influencing workdays lost. As hypothesised, health has a positive influence on workdays lost; meaning that respondents with chronic illness (such as high/low blood pressure, diabetes, tuberculosis, etc.) will have more workdays lost. This is in accordance with the findings of Gupta, (2006) where history of having chronic illness such as Tuberculosis was found to have a positive coefficient and statistically significant. Duration of illness was found to have a positive influence on workdays lost. Depending on the number of days it took an individual to recover from air pollution ailment, longer duration of illness will lead to increase in number of workdays lost and vice versa. The mean duration of illness in this study is 9.83 days; perhaps explaining the reason duration of illness has a positive influence on workdays lost. Number of visits to the pharmacy or to see a doctor was predicted to have a positive influence on workdays lost. As predicted, number of visits was found to have a positive coefficient meaning that as the number of visits to pharmacy or to see a doctor increases, the number of workdays lost will also increase. Mitigating cost was found to have a positive influence on workdays lost as hypothesised. As the number of visits for treatment increases, the mitigating cost will increase resulting to more workdays lost.

District (DISTRICT) is statistically significant at 5% level, and has a positive coefficient as predicted, implying that respondents in Phahameng have more workdays lost. Age (AGE) is statistically significant at 10% level of significance. Age was hypothesised to positively or negatively influence workdays lost. Age was found to have a negative influence on workdays lost. From the study areas, the mean age is 47.61 years. According to literature, the marginal effect of age on workdays lost is negative at a younger age but positive as age progresses and may explain why age in this study has a negative influence on workdays lost.

Over-the-counter medication (OTC), traditional treatment (TRAD) and no medication (NMED) may be interpreted as determinants of workdays lost. However, over-the-counter variable with positive coefficient is not significant.

5.1.3 Quantifying mitigating cost

The total cost incurred on treatment (medical fees plus transportation fee) of air pollution refers to the mitigating cost in this study. From the survey, 4.30% of the respondent have medical insurance or went to the clinic which offers free medical services. Therefore, transportation cost only is considered as their mitigating cost. An assumed amount of R80 (Rand, 2011), which is the average cost of transportation, is therefore considered as the total cost incurred.

The average mitigating cost per person (for most recent episode prior to interview) in Phahameng is estimated as R116.83 and R109.59 for the sampled households in Rocklands. The average mitigating cost in both study areas per annum is R1644.34. The maximum mitigating cost in Phahameng is R1000 while that of Rocklands is R350. It is important to remember that 99.5% of the sampled household in Phahameng indicated that the indoor air is polluted while 100% indicated that the outdoor air is polluted. The severity of pollution levels in Phahameng explains why the households in Phahameng have a higher mitigating cost. The Cumulative Probability Distribution in Figure 5.2 shows the mitigating cost of the study areas.

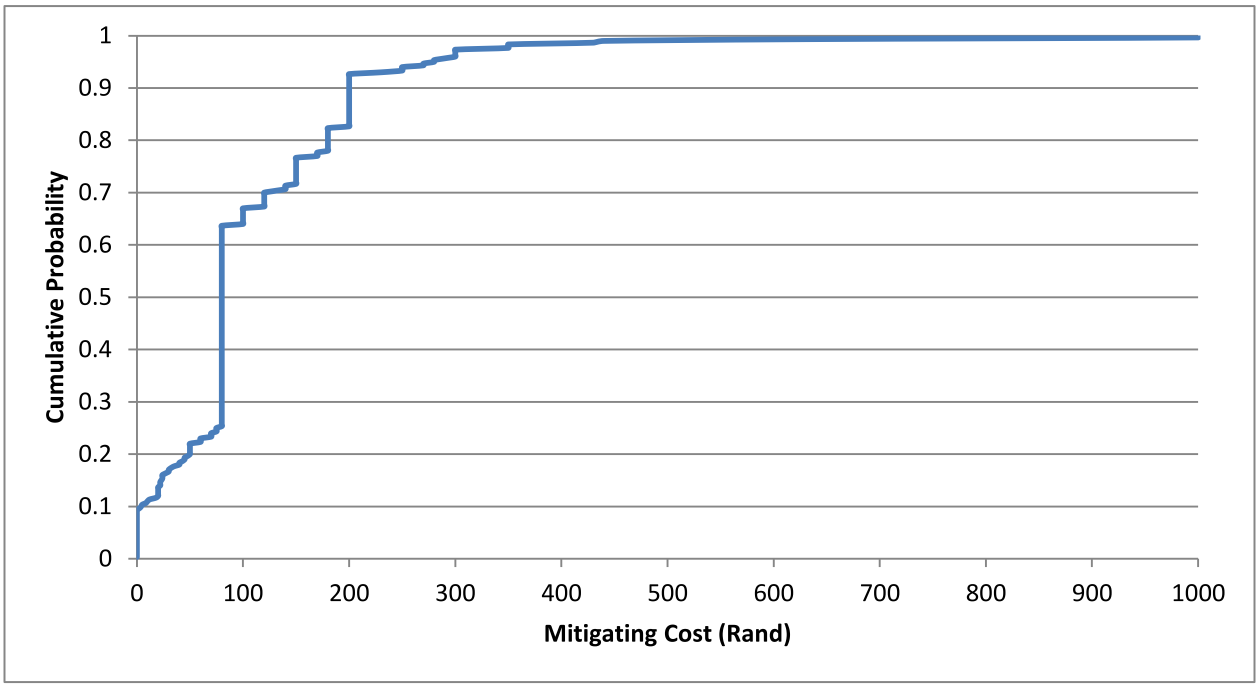


Figure 5.2: Cumulative Probability Distribution of mitigating cost in the study areas

Figure 5.2 shows that 7% of the sampled households have zero mitigating cost and it can be inferred that this 7% are those respondents who took no medication during their last episode of ailments due to air pollution or respondents that were not sick. About 64% of the respondents paid R100 or less while 99% paid R500 or less on their last episode of sickness due to air pollution. About 1% paid more than R500 on mitigating cost. It is important to remember that on average, 68.5% of the sampled households in the study areas earn R2000 or less per month.

Taking the average monthly income into consideration, the health cost as a result of air pollution is high signifying air pollution is posing a detrimental impact economically in the study areas.

5.1.4 Factors influencing mitigating cost

Ordinary Least Square Regression Model (OLS) was used to determine the factors influencing mitigating cost, the second economic parameter considered in this study. Table 5.2 shows the result of the factors influencing mitigating cost.

Table 5.2 OLS regression results of factors influencing mitigating cost

Variable	Coefficient	Standard error	t-Statistics	Probability
C	-5.210	24.649	-0.211	0.833
LOWINC	1.117	17.904	0.062	0.950
HIGHINC	65.702	23.511	2.795	0.005***
DLNES	-1.984	0.746	-2.660	0.008***
DISTRICT	23.778	11.119	2.138	0.033**
AILMENT	117.525	19.378	6.065	0.000***
WKDLOST	11.580	2.124	5.452	0.000***
OTC	-75.709	14.146	-5.352	0.000***
TRAD	-47.106	26.599	-1.771	0.078*
NMED	-48.678	26.168	-1.860	0.064*
SELFEMPLYD	-13.391	18.775	-0.713	0.476
STUDENT	26.797	23.552	1.137	0.256
UNEMPLYD	-27.057	12.951	-2.089	0.038**
VSTNR	6.281	4.746	1.323	0.187
R-Squared		0.420		
R-Squared Adj.		0.394		

Note: *** significant at 1% level, ** significant at 5% level and * significant at 10% level

From Table 5.2, the R-Square value of 0.42 indicates that the independent variables included in this study explain about 42% of the variation in the dependent variable. A small R-squared value indicates that there are some other factors not considered in this model and which have a major influence on the total cost of illness as a result of air pollution. It is of interest however, to mention that most of the variables are statistically significant. Similarly, most of the statistically significant variables have the expected signs. High income (HIGHINC), duration of illness (DLNES), workdays lost (WKDLOST), ailment (AILMENT) and over-the-counter medication (OTC) are statistically significant at 1% level of significance. High income was found to have a positive influence on mitigating cost as was hypothesised. The reason is that respondents in the high income category are assumed to choose the option of seeking a medical practitioner for treatment of air pollution ailments which will result to high mitigating cost. Unexpectedly, duration of illness was found to have a negative influence on mitigating cost. The finding indicates that respondents who took a long time (average duration of illness is 9.83days) to recover from ailments associated with air pollution face lower mitigating cost. Possible reasons for this could be that the respondents might not make subsequent visits to the pharmacy or to see a doctor after been treated at the first visit or the respondents' that have long duration of illness might have chosen other treatment methods (over-the-counter medication, traditional treatment or no medication) which are less expensive relative to consulting a medical practitioner. Workdays lost was hypothesised to positively or negatively influence mitigating cost. The results shows a positive coefficient for workdays lost meaning the higher the number of days lost as a result of air pollution ailments, the higher the mitigating cost. Ailment has a positive influence on mitigating cost as hypothesised. Respondents' ill with air pollution ailments and having chronic health challenges before are assumed to have high mitigating cost. Over-the-counter medication has a negative influence on mitigating cost as predicted; meaning that respondents that use over-the counter-medication have a lower mitigating cost.

District (DISTRICT) and respondents that are unemployed (UNEMPLYED) are statistically significant at 5% level and have the expected signs. District has a positive coefficient signifying Phahameng respondents have a higher mitigating cost. Unemployed respondents have a negative coefficient meaning respondents that are unemployed will have a lower mitigating cost.

Traditional treatment (TRAD) and no medication (NMED), variables of the treatment methods used to treat air pollution ailments, are statistically significant at 10% and also have the expected direction of influence. Traditional treatment and no medication have a negative influence on mitigating cost implying that respondents that choose these treatment methods have a lower cost to pay for treatment.

5.2 Explaining willingness to pay for improved air quality

The purpose of this section is to report the household's willingness to pay for a program that aims to improve air quality by reducing air pollution to a level that will not be detrimental to health. It is important to remember that the hypothetical question was made clear to representative of each household, by explicitly reminding them of the pain and suffering, medical expenditure, number of visits for treatment, missed work days, disruptions to leisure or daily activities before being asked how much they are willing to pay on a monthly basis to reduce air pollution in their area using a double-bound iterative bidding. The starting bid was R100 and the minimum amount (lower bound) and maximum amount (upper bound) respondents are willing to pay on a monthly basis were recorded. The next section reveals the result of the willingness to pay values obtained from both study areas.

5.2.1 Quantifying willingness to pay for improved air quality

The lower bound average of willingness to pay by respondents in Phahameng to improve air quality is R89.28 per month while the upper bound average is R114.14. Respondents in Rocklands are willing to pay on average R100.79 per month on the lower limit and R130.81 on the upper limit. Both study areas however are willing to pay maximum of R500 per month to improve air quality. Figure 5.3 show the cumulative probability distribution representing the distribution in relation to the upper bound amount household is willing to pay to improve air quality.

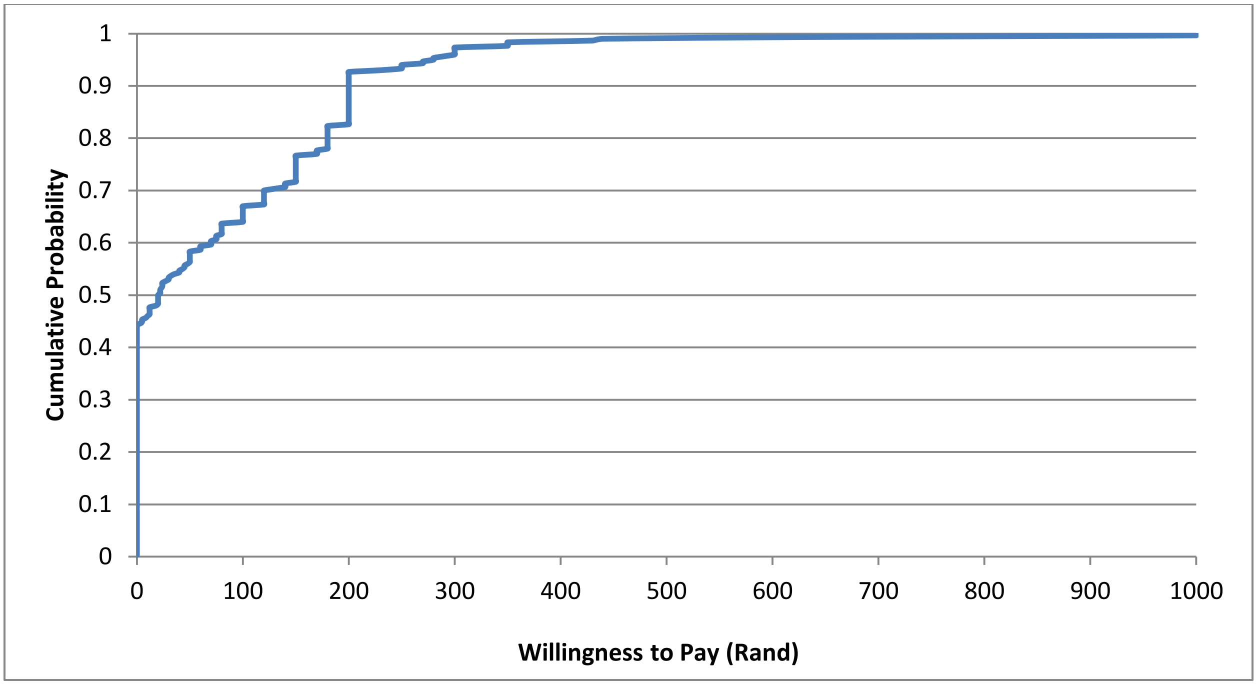


Figure 5.3 Cumulative probability distribution in relation to the upper bound amount household is willing to pay in both study areas to improve air quality

Figure 5.3 shows that about 45% of the 300 households surveyed from both study areas are not willing to pay for improved air quality. Some of the respondents that are not willing to pay claimed they are not working and therefore cannot afford to pay while some assumed that the government are supposed to deduct the cost from taxes paid. About 98% of the respondents are willing to pay R350 or less per month for improved air quality while only 1% is willing to pay more than R500 to support a program that will reduce air pollution. The mean values of 9.83 days estimated for duration of illness, 3.43 days for workdays lost and R112.27 for mitigating cost (as earlier discussed) shows that the sampled households had been affected by air pollution. On average, a larger percentage of the households stated lower WTP values with respect to the severity of air pollution impacts. The low WTP values might have been influenced by some other factors apart from the reasons stated above. Thus, a detailed investigation of the factors that influence the decision to pay and how much to pay is essential.

5.2.2 Factors influencing willingness to pay

During the estimation of willingness to pay two decision-making models was estimated. The first decision-making model, modelled the choice of how much to pay with a Tobit model. The second decision-making model determined the choice of whether or not to pay with a Probit model and the choice on how much to pay with a Truncated regression model (where respondent has decided to pay). The estimation of the willingness to pay decision with the two decision-making models allows the researcher to evaluate if the decision of whether to pay and the amount paid is affected by the same factors. A Craggs model was used to evaluate if willingness to pay and the amount paid is one decision or two.

The results of the Probit, Truncated and Tobit Models are presented in Table 5.3. The results of the three models are compared with one another to determine the feasibility of testing whether it is sufficient to model the decision of willingness to pay as one-decision or as two-decision.

From Table 5.3, the dependent variable in the Probit Model is a binary variable that measured household's decision of whether or not to pay for improved air quality. The McFadden R-squared of 0.13 indicates that the explanatory variables included in this study explains only about 13% of the variation in the decision of whether or not to pay for improved air quality. The small McFadden R-Squared value indicates that there are some other factors not considered in this model. Education (EDUC) and ailment (AILMENT) were found to be statistically significant at 1% level of significance and both have the expected signs. Education was hypothesised to have a negative influence on willingness to pay. Respondents that have no formal education or attended primary school are assumed not to be willing to pay for improved air quality. Education is a proxy for environmental awareness (Baby, 2009). Thus, education is very important in making decision of whether or not to pay for improved air quality. Ailment has a positive coefficient as predicted indicating that respondents that have experienced an episode of air pollution related ailment will be willing to pay for improved air quality.

Table 5.3 Regression results for Probit, Truncated and Tobit models of factors influencing household's decisions to pay for improved air quality

	Single decision TOBIT	Choice decision PROBIT	Quantity decision TRUNCATED
Dependent variable	Actual amount willing to pay	Dummy = 1 if willing to pay, 0 otherwise	Actual amount willing to pay
Variable	Coefficient	Coefficient	Coefficient
Intercept	165.856*** (36.814)	1.975*** (0.714)	167.127*** (49.636)
OTC	-43.639*** (16.134)	-0.493 (0.306)	-44.873** (23.300)
TRAD	-19.605 (28.996)	0.301 (0.645)	-34.944 (42.121)
NMED	-88.722*** (29.542)	-0.987** (0.483)	-119.846** (56.612)
DISTRICT	-0.733 (12.124)	0.426* (0.247)	-23.285 (16.770)
SELFEMPLYD	-43.374** (20.701)	-0.684* (0.390)	-37.093 (28.130)
UNEMPLYD	-25.586* (15.146)	-0.218 (0.324)	-33.071* (19.266)
STUDENT	-0.990 (26.530)	-0.444 (0.519)	0.816 (33.242)
AGE	-0.932** (0.415)	-0.015* (0.008)	-0.766 (0.571)
EDUC	9.355 (12.865)	-0.749*** (0.299)	48.304*** (18.680)
DAILMENT	-21.038* (12.131)	-0.452** (0.226)	-13.133 (16.752)
AILMENT	28.884 (21.577)	0.967*** (0.359)	-5.168 (29.708)
DLNES	0.514 (0.348)	0.002 (0.006)	0.602 (0.415)

VSTNR	2.988 (4.886)	-0.089 (0.094)	7.294 (6.062)
HSIZE	0.840 (3.750)	0.122 (0.083)	-2.245 (5.012)
LOWINC	-16.883 (19.671)	-0.171 (0.381)	-20.103 (25.435)
HIGHINC	76.996*** (25.853)	0.060 (0.549)	93.287*** (31.031)
GOODNESS OF FIT			
No. of observations	300	300	268
McFadden R-Squared[a]		0.130	
Log likelihood	-1633.55	-90.469	-1526.04
LR test for Tobit vs. Truncated regression			34.082[b] 0.0000[c]

Note: *** significant at 1% level; ** significant at 5% level and * significant at 10% level and standard errors are in parentheses

a= McFadden R^2 is given by one minus the ratio of the unrestricted to restricted log-likelihood function value

b= The likelihood ratio test is given by $\lambda = 2(\ln L_{probit} + \ln L_{Truncated\ regression} - \ln L_{Tobit})$

c= Numbers in parentheses are associated with chi-square probabilities

Members of households that suffered air pollution ailments prior to death (DAILMENT) and respondents that took no medication (NMED) were found to be statistically significant at 5% level of significance. DAILMENT was hypothesised to have a positive effect on willingness to pay for improved air quality. Households that have experienced death of a household member that had air pollution ailments prior to death would be willing to pay for improved air quality. Respondents that took no medication during their last episode of illness associated with air pollution have a negative sign as hypothesised; meaning that respondents who took no medication will be less willing to pay for improved air quality. Reasons could be that such respondents are unemployed or have no formal education.

District (DISTRICT), self-employed respondents (SELFEMPLYD) and age (AGE) are all statistically significant at 10% level of significance. District was found to positively influence the decision of willingness to pay for improved air quality. Respondents from Phahameng will be willing to pay for improved air quality considering that air pollution in the area is more severe. It was not expected that respondents that are self-employed would have a negative sign on the decision of willingness to pay for improved air quality. However, the negative sign indicate that self-employed respondents might not be willing to pay for improved air quality. The reason could probably be that some of the respondents that are self-employed may not have a formal education; and as stated earlier, education is paramount for environmental decision making. Age was predicted to positively or negatively influence the decision of willingness to pay for improved air quality. Age was found to have a negative coefficient. With increased age, willingness to pay for improved air quality will decrease. However, the negative sign of the coefficient of age is not surprising as some studies have found age to have a negative influence on the decision of willing to pay (Baby, 2009; Krupnick *et al*., 2002).

To identifying the factors that influences the decision of how much to pay for improved air quality (where the household respondent has decided to pay), the Truncated Regression Model was used. The dependent variable in this case is the actual amount respondents are willing to pay for improved air quality. Based on the results shown in Table 5.3, over-the-counter medication (OTC), no medication (NMED), unemployed (UNEMPLYD), education (EDUC) and high income (HIGHINC) have significant influence on the decision of how much to pay for improved air quality. Education and high income were found to be statistically significant at 1% level. Contrary to expectation, education was found to positively influence the decision of how much to pay; meaning respondents with no formal education or that attended primary school will be able to make the decision of how much to pay for improved air quality. Although the sign does not make economic sense, it may indicate that the respondents (with primary school qualification or no formal education) may decide to pay any amount for improved air quality irrespective of whether they are educated or not. High income has the expected positive sign as hypothesised. Respondents in high income level will be willing to pay for improved air quality.

Over-the-counter medication (OTC) and respondents that took no medication (NMED) are statistically significant at 5% level of significance. Over-the-counter medication has negative effect on the decision of how much to pay. Respondents who chose over-the-counter medication option will not be willing to pay any amount to improve air quality. Respondents that took no medication has the expected negative sign as well; meaning respondents that took no medication will not be willing to pay any amount to improved air quality.

Unemployed respondent (UNEMPLYD) is statistically significant at 10% and the coefficient has a negative sign; meaning unemployed respondents will not be willing to pay any amount to improve air quality.

The results from the Probit and Truncated Models indicate that different factors influence the willingness to pay attitude of households in different ways at different levels. The next section presents the formal results of testing whether it is sufficient to model the analysis as a single decision or two-decisions.

5.2.2.1 Is willingness to pay decision one-decision or two-decisions

Based on the inconsistencies in the significance of factors, it is essential to test the more restrictive Tobit Model against the more general Cragg's Model. It is important to remember that the three models were estimated with the same variables; thus, the log-likelihood of the Tobit Model was compared to the sum of those in the Probit and Truncated Regression Models. The highly significant ($P<0.01$) log-likelihood test ratio of 34.1 strongly rejects the Tobit Model specification in favour of the more general Cragg's Model specification. By implication, the variables that influence the decisions of whether or not to pay and how much to pay for improved air quality are different. Thus, modelling the decision of willingness to pay and how much to pay as a single decision will fail to identify the correct factors affecting the decision of whether or not to pay for improved air quality. The next section therefore discusses the factors that would have been missed if willingness to pay decision was modelled in a single decision making framework.

5.2.2.2 Sufficiency of two-decision over one-decision in determining the factors influencing willingness to pay decisions

The Tobit Model imposes the restriction that the coefficients that determine the probability of being censored are the same as those that determine the conditional means of the uncensored observation. Comparing the restrictive Tobit Model to the sum of the log-likelihood of Probit and log-likelihood of Truncated Regression Models (in equation 8) was carried out. The dependent variable in the Tobit Model is the actual amount household respondents are willing to pay for improved air quality. Household respondents who had never been willing to pay were assigned a value of zero.

From Table 5.3, it is observed that some variables that are identified as significant factors (DISTRICT, EDUC, and AILMENT) influencing the two-decision of whether or not to pay and how much to pay to improve air quality are not significant in the Tobit Model (one-decision). Thus, district, education and ailment as a result of air pollution would have been missed if a single decision-making model was used to determine willingness to pay and the factors that influence willingness to pay decisions.

CHAPTER 6

SUMMARY, CONCLUSION AND RECOMMENDATIONS

Introduction

Chapter 6 provides the summary, conclusion and recommendations of this study, which surveyed 300 households to determine the economic impact of air pollution in the townships of Mangaung metro municipality: Phahameng and Rocklands.

6.1 Background and Motivation

Air pollution has been a cause for concern for the past two decades in both developed and developing countries. There are many causes of air pollution and most are a result of human activities. Common sources of air pollution are from industrialisation, transportation and combustion of traditional biomass fuels and coal. Dangerous pollutants such as carbon monoxide, sulphur dioxide, nitrogen oxide and particulate matters are released to the atmosphere from the aforementioned sources posing a range of negative effect on human health (PERN, 2003). Air pollutants may have long lasting effects on general health and well-being. In fact, a growing literature indicates that the effects as a result of environmental degradation at young age can have long lasting influences on human health and productivity (Almond, 2006).

Research have shown that air pollution leads to detrimental impacts on health such as irritation to the ears, eyes and throat, cardiovascular diseases, respiratory illnesses and premature deaths especially in children (CEAP, 2004). The loss to human health invariably reduces efficiency of people at work and an overall loss to social welfare which are major economic impacts of air pollution (Mayeres and Regemorter, 2008).

Respiratory disease has been found to be the major impact of air pollution on human health and the second most frequent cause of death of children (0-5 years) in South Africa (DEA, 2009). Outdoor air pollution in urban areas in South Africa was estimated to cause 3.70% of the national mortality from cardiopulmonary disease. About 5.10% of mortality was attributable to cancers of the trachea, bronchus and lungs in adults aged 30 years and older and 1.10% of mortality from acute respiratory illness in children under 5 years of age (DEA, 2008).

According to the DEA (2009), indoor air pollution is a major environmental problem in Mangaung metro municipality as a result of energy choice for domestic activity most especially for cooking and space heating. Cigarette smoke and paraffin fumes had been found to be the predominant pollutant source indoors. Smoke from burning of refuse by households is the primary source of outdoor air pollution in Mangaung metro municipality.

6.2 Problem statement and objectives

Indoor and outdoor air quality continued to deteriorate in the township of Bloemfontein within Mangaung metro municipality. As a result, people suffer from illnesses due to exposure to air pollutants which invariably reduce their work efficiency. Air pollution is thus a cause of concern because it has serious economic, health and social implications.

Researchers in South Africa have explored the impacts of air pollution on health and the focuses have been on industrial areas and urban settlements. An urban or industrial area is considered a hot spot for investigating air pollution by the authors of the research conducted so far in South Africa. Problems and prospects for protection of public health against the adverse health effect of air pollution in the semi-urban or even rural settlements have not been explored. Also, no study has been found in South Africa exploring the economic impact of air pollution.

For this reason, this study has helped by investigating the economic impact of air pollution in the township area of Bloemfontein within Mangaung metro municipality which is the primary objective of the study. This primary objective was reached through the completion of four sub-objectives. The first sub-objective were to measure the economic cost of air pollution by quantifying the workdays lost and mitigating cost as a result of air pollution related illness.

Secondly, the factors that influence workdays lost and mitigating cost were used to explore the factor(s) that influence the economic cost of air pollution. The third sub-objective was to explore the value that people place on a loss in health status due to air pollution. Willingness to pay estimated from the survey using a double-bounded iterative bidding approach was used. Finally, the fourth sub-objective was to investigate the principal factor(s) that influence the willingness to pay for clean air. Selected characteristics of the households were considered to determine the factors that influence the willingness to pay for clean air.

6.3 Research area

The Free State Province is the third largest province in South Africa and covers 10.6% of the country's surface area (IDP, 2003). Mangaung metro municipality has a population of 645 455 and is South Africa's seventh largest municipality area and sixth-largest growing city. Mangaung metro municipality governs Bloemfontein and surrounding towns (Botshabelo and ThabaNchu) in the Free State Province. The research is conducted at Phahameng and Rocklands, located in the township area of Bloemfontein.

6.4 Literature review

6.4.1 Health impact from exposure to air pollution

There has been a realisation in recent times that health impacts resulting from air pollution are major ways by which people realise the extent of the damage associated with air pollution (Zhang *et al*., 2008). Health damages have been estimated to contribute 75% of the total damages associated with air pollution (Cropper and Oates, 2002). Few studies have been conducted around cities, towns or even villages in South Africa. Rollin *et al*. (2004) conducted a study to compare indoor air quality in electrified and un-electrified dwellings in rural South African villages. The study provided scientific evidence that electrified homes in South Africa have lower levels of air pollution (particulate matter and carbon monoxide) relative to their non-electrified counterparts. Cairncross *et al*. (2007) also investigated the daily mortality associated with exposure to common air pollutants in South Africa. The authors discovered on a linear index of 10 that there is a daily incremental mortality risk due to exposure to the common air pollutants. Wright *et al*. (2010) used predetermined risk threshold framework to determine population exposure to ambient air pollution levels in Durban, South Africa. The semi-urban wards located in a known air pollution hot spot had the highest pollution levels with experience of high levels of associated health impacts. The health risks due to air pollution are quantified by estimating the relationship between the incidence of adverse health effects and air quality (Braga *et al*., 2001). Many of the adverse health impacts from air pollution occur in the respiratory system. The most common symptoms of respiratory diseases observed in the study areas include eye irritation, runny or blocked nose, asthma, sinusitis and ear irritation. Thus, the health impact that was considered in this study was limited to respiratory diseases (as a health endpoint). Studies of impact of air quality on health are of great interest because of the potential implications for economic growth, medical costs and quality of life. These impacts of air quality have thus made recent studies to focus on the adverse health impact from exposure to air pollution.

6.4.2 Economic impact from exposure to air pollution

In measuring the cost of air pollution, it is important to look further than just the main effects on health. The link between the economic indicators and air pollution has been noted in the exposure science literature. Most studies infer or link the economic impact from air pollution to its effect on the gross domestic product (GDP). In a study conducted by Kuebler *et al.* (2001), ozone concentrations were highly correlated with the European Union gross national product and industrial production growth rates. Both are indicators of economic activity. The economic indicators thus provide direct evidence of the hypothesis that there is a significant impact of exposure to pollution on economic activities and ultimately human health (Davis *et al*., 2007). Once the links between emissions to pollution effects have been established, the next stage requires the assignment of economic (monetary) value to the predicted effect. The health damage from air pollution incurs direct and indirect costs to society. The most controversial part of the estimation of air pollution is the cost of its impacts. This is because other cost associated with air pollution, such as loss of human productivity, as well as damage to buildings, vehicles and crops are very difficult to estimate. The economic cost of air pollution in this study was therefore limited to the total cost associated with air pollution health damage and workdays lost. The results from the economic impact of air pollution on individuals was to provide information that could be used to know the significance of air quality, to value the benefits of air pollution control programs, social benefits (in terms of government subsidising clean energy source), policies or strategies to ensure a safe and acceptable air standard to minimise health effects.

6.5 Data and characteristics of respondents

Primary data was used in this study and a contingent valuation questionnaire was designed. A questionnaire developed by Alberini (2004) to value the health effects of air pollution in developing countries was used as a basis to design the questionnaire. Alterations were made to the questionnaire to include sections on indoor and outdoor air quality. The questionnaire consists of 26 questions in the four sections including socio-economic characteristics, indoor and outdoor air quality, health valuation and economic valuation. The 26 questions were answered from interaction with knowledgeable individuals.

Household energy choice for cooking and space heating was explored in the study areas to know the source of indoor air pollution. Paraffin heaters and cigarette smoke were found to be a major cause of indoor air pollution in the study areas. Smog, smoke and dust are the common outdoor air pollutants observed in the study areas. Smoke was found to be a problem that occurs in all the seasons and conclusively all year round. Most of the respondents disclosed that poor service delivery of refuse removal is probably the cause of smoke problems as households burn their own refuse most of the time. Dust is a predominant problem in summer in the study areas which is not surprising to know as summer is known as the windy season. Smog seems to be less of a problem in both study areas. It is important to remember that a substantial number of the respondents in the study areas ranked air pollution as serious as other societal problems (i.e. crime, unemployment, poor service delivery and violence against women and children). Thus, it was inferred from the two study areas that air pollution (both indoor and outdoor) is a big problem.

From the measured socio-economic characteristics of respondents in the study areas, it was found that there is a variation in age and most of the household heads are female. Majority of the respondents attended secondary school and on aggregate 60.3% of the sampled households are unemployed. Greater percentage of the sampled households in the study areas earn less than R2000 per month and more than half of the sampled respondents have chronic illness.

6.6 Procedures

The overall aim of this study is to investigate the economic impact of air pollution. Workdays lost and mitigating cost were used to determine the economic cost of air pollution in Phahameng and Rocklands within the Mangaung metro municipality. Cumulative Probability Distribution (CDF) of the economic cost parameters was determined from the survey (sub-objective 1). Once the workdays lost and mitigating cost have been determined, the next step is to determine the factors that influence workdays lost and mitigating cost. The personal characteristics of the respondents hypothesised to influence workdays lost include health, duration of illness, age, over-the-counter medication, traditional treatment, no medication, low income, high income, district, ailment, number of visits to pharmacy or to see a doctor for treatment, number of times ailment (as a result of air pollution) occur in a year and mitigating cost. Variables hypothesised to influence mitigating cost include workdays lost, duration of illness, over-the-counter medication, traditional treatment, no medication, low income, high income, ailment, number of visits to pharmacy or to see a doctor for treatment, self-employed, unemployed and respondents that are student. Ordinary Least Square (OLS) was chosen (because there was no problem of multi-collinearity) to determine the factors that influence the economic cost of air pollution (sub-objective 2).

The willingness to pay of the sampled households for improved air quality was determined based on the responses to the hypothetical question presented to the household respondents. A binary choice question of yes or no response was asked to determine whether the respondents are willing to pay and how much they will be willing to pay (if respondent has decided to pay) on a monthly basis to support a program that will reduce air pollution to a level that is not detrimental to health. The respondents were explicitly reminded of the cost on mitigating activities, the pain and suffering of their last episode of ailment linked to air pollution. A double bounded iterative bidding technique was used to determine the willingness to pay for improved air quality. A starting bid of R100 was chosen, obtained as an average minimum cost of illness from the pilot survey and also by considering the starting bids of other studies (sub-objective 3).

The responses from each household respondent were regressed against some selected personal characteristics to identify the factors that influence the decisions whether or not to pay and how much to pay for improved air quality (sub-objective 4). Due to the nature of the dependent variables, a Probit Model was used to determine the factors that influence the decision whether or not to pay (dependent variable being binary) and a Truncated Regression model was used to determine the factors that influence the decision of how much to pay (if respondent decided to pay). The dependent variable for the Truncated Regression model is continuous in nature. The Tobit model was used to identify the factors that influence the single decision of how much to pay. Household respondents that are not willing to pay were assigned a value of zero. The formal testing whether it is sufficient to model the analysis as a single decision or as two decisions was done using Cragg's model.

6.7 Results and conclusions

6.7.1 Quantifying and determining factors influencing workdays lost

Workdays lost on average per person due to air pollution related ailments is estimated as 3.40 days in Phahameng, 3.44 days in Rocklands. The workdays lost in both study areas ranges from 0 to 60 days. The zero implies that some respondents did not have any days lost during the last episode of air pollution related ailments. The result from the OLS model fitted to investigate the factors influencing workdays lost revealed that health, duration of illness, number of visits to doctor or pharmacy for treatment, district, age and mitigating cost are statistically significant confirming them as the principal factors influencing workdays lost. Over-the-counter medication, traditional treatment and no medication may be interpreted as a determinant of workdays lost. However, none of the treatment methods were found to be statistically significant. Over-the-counter medication with a positive coefficient is not significant.

6.7.2 Quantifying and determining factors influencing mitigating cost

Mitigating cost is the total cost incurred as a result of air pollution related ailments. The cost include the medical expenditure (doctor's fee, hospitalisation fee, cost of medication) and transportation cost. From the survey, 4.3% of the respondent were found to have medical insurance or went to the clinic which offers free medical services. The transportation cost only was considered as their mitigating cost. An assumed amount of R80 (which is the average cost of transportation) was considered as the total cost incurred. Average mitigating cost per person in Phahameng was estimated as R116.83 and R109.59 in Rocklands. The maximum mitigating cost in Phahameng was found to be R1000 and R350 for the sampled households in Rocklands. High income, duration of illness, district, ailment, workdays lost, over-the-counter medication, traditional treatment, no medication and unemployment were all found to be statistically significant implying that these factors are important as they influence the cost incurred on the treatment of air pollution ailment.

6.7.3 Estimating willingness to pay and factors influencing willingness to pay decisions

The average lower bound amount respondents in Phahameng are willing to pay to improve air quality is R89.28 per month while the average upper bound amount is R114.14. Respondents in Rocklands are willing to pay on average R100.79 per month on the lower limit and R130.81 on the upper limit. About 45% of the 300 households surveyed from both study areas are not willing to pay for improved air quality. Respondents that are not willing to pay claimed they are not working and therefore cannot afford to pay while some think the government should deduct the amount to be paid (indicated as willingness to pay) from taxes. The Cragg's Model was used to test whether willingness to pay is a single or two decisions. The Probit and Truncated Regression Models were used to determine the factors that influence willingness to pay as two decision frameworks while Tobit Model was used for the one-decision model framework. The dependent variable in the Probit Model is a binary variable that measured household's decision of whether or not to pay for improved air quality. No medication, district, self-employed, age, ailment, education and households where members suffered air pollution ailment prior to death were all found to be statistically significant meaning they influence the decision of whether or not to pay for improved air quality. The dependent variable for the Truncated Regression Model is the actual amount household respondents are willing to pay (after respondent has decided to pay) for improved air quality. Over-the-counter medication, no medication, the unemployed and education were found to be the factors that could influence the decision on how much to pay. The Tobit Model imposes the restriction that the coefficients that determine the probability of being censored are the same as those that determine the conditional means of the uncensored observation. The dependent variable in the Tobit Model is the actual amount household respondents are willing to pay for improved air quality. The household respondents that are not willing to pay are assigned a value of zero. The results from the Probit and Truncated Regression Models indicate that different factors influence the willingness to pay attitude of households in different ways at different levels. Thus, the Cragg's Model was used to test whether it is sufficient to model willingness to pay as a single decision or two decisions. A comparison of the restrictive Tobit Model to the sum of the log-likelihood of Probit and log-likelihood of Truncated Regression Models was carried out. The results revealed that some variables that are identified as significant factors (SELFEMPLYD, DAILMENT and AGE) influencing the decision of the actual amount to pay in the Tobit Model is not significant in the Truncated Regression Model. Similarly, education is significant in the Truncated Regression Model but not significant in the Tobit Model. Based on the inconsistencies in the significance of factors, it was essential to test the more restrictive Tobit model against the more general Cragg's Model. The conclusion from the testing was that the factors that influence the two-decision (the decisions of whether or not to pay and the decision of how much to pay for improved air quality) are different. Thus, modelling willingness to pay as a single decision will fail to identify the correct factor influencing the decision of whether or not to pay and how much to pay for improved air quality.

The overall conclusion is that air pollution is a significant problem in Phahameng and Rocklands, within Mangaung metro municipality; considering the high health cost incurred from treatment of air pollution ailments and the duration of the illness which invariably leads to more workdays lost. Most households are willing to pay for improved air quality though low willingness to pay values as stated by households considering the severity of air pollution impacts. The financial and educational statuses of the households, estimated as the income of the household and educational attainment of the household representative respectively, influences the decision of whether or not to pay and how much to pay for improved air quality. The educational status of the household representatives should be improved through education, as this can increase household willingness to pay for improved air quality. Firstly the increased education level can lead to higher income levels that can increase household willingness to pay. Furthermore, due to increased education individuals will be better equipped to evaluate information pertaining to air quality and because they are more knowledgeable about the role of the environment their willingness to pay for improved air quality can also increase.

6.8 Recommendations

Considering the results from this study and the conclusions drawn above, the following policy implications could be linked to the study:

- The greatest source of indoor air pollution experienced by the community is due the burning of paraffin heaters to heat their homes. A means to ensure the community does not experience as much air pollution related illnesses is by incentivising the rural community to use a cleaner energy source (e.g. electricity, gas) for space heating.

- The greatest source of outdoor air pollution is the burning of refuse by the community. Waste collection service level must be improved to ensure cleanliness of the community. Thus, all households in informal settlements must be provided with access to refuse removal.

- Through the education of the community, environmental awareness can be created to ensure that the community are aware of the causes and effects of air pollution.

From this study, the following recommendations for further research can be made:

- It was discovered from this study that solar energy is no longer being utilised as an energy source. Research on why solar energy is not used (being a clean energy source) is therefore suggested. Wind power is another clean energy source that should be looked into.

- The results on the willingness to pay decisions showed that there are other factors apart from income and education that are not captured in the survey but are very important in influencing the willingness to pay decisions for improved air quality. Further research to determine the major factors that could influence the willingness to pay for improved air quality is suggested.

- Research can also be extended to determine the mortality rate as a result of air pollution, to determine the economic loss from air pollution.

REFERENCES

Adepoju, A.A and Omonona, B.T. (2009). Determinant of willingness to pay for improved water supply in Osogbo metropolis, Osun State, Nigeria. *Journal of Social Sciences*, 4: 1-6 INSInet publication.

Aggrey, N. and Douglason Omortor, G. (2010). Determinants of willingness to pay for solid waste management in Kampala City. *Journal of Economic Theory*, 2(3): 119-122, ISSN: 2042-4854.

Alberini, A., Cropper, M., Krupnick, A. and Simon, N. (2004). Does the value of a statistical life vary with age and health status? Evidence from the US and Canada. *Journal of Environmental Economics and Management*, 48:769–792.

Alberini, A and Krupnick, Alan (2000). "Cost of Illness and Willingness to Pay Estimates of the Benefits of Improved Air Quality: Evidence from Taiwan", *Land Economics*, Vol. 76, No. 1, pp. 37-53.

Alberini, A. and Cropper, M. (1997), "Valuing health effects of air pollution in developing Countries: the Taiwan experience." *Journal of Environmental Economics and Management*, (34): 107-26.

Almond, D. (2006). Is the 1918 Influenza Pandemic Over? Long-Term Effects of In-Utero Influenza Exposure in the Post-1940 U.S. Population. *Journal of Political Economy*, 114(4): 672-712.

Amos, T.T. (2007). An Analysis of Productivity and Technical Efficiency of Smallholder Cocoa Farmers in Nigeria. *Journal of Social Sciences*, 15 (2):127-133

Annegarn, H., Sithole, J. and Wahn, U. (2002). Air pollution in South Africa: problems and prospects for protection of public health; Ant-Ige – a promising approach? *Current allergy & clinical immunology*, Vol 15, Iss3; Sept-Oct, 855.

Ao, C.H., Lee, S.C.,and Yu, J.C. (2003). Photo catalyst TiO_2 supported on glass fibre for indoor air purification: Effect of NO on the photo degradation of CO and NO2 [J]. *Journal of Photochemistry and Photobiology A: Chemistry*, 156(1-3): 171-177.

Ayer, M., Brunk, H.D., Ewing, G.M. and Silverman, E. (1995). An Empirical Distribution Function for Sampling with Incomplete Information. *Annals of Mathematical Statistics*, 26, p 641-647.

Baby, P.K. (2009). Valuing the health effects of air pollution: Contingent Valuation survey results from Kerala. *The Icfai University Journal of Environmental Economics*, Vol VII, No.1.

Baby, P.K. (2001). Valuing Health Effects of air Pollution: Contingent valuation Survey Results from Kerala. Sree Naruyana Guru Institute of Science and Technology, Ernakulam, India.

Bishop, R.C. and Heberlin, T.A. (1979). Measuring values of extra-market goods. Are indirect methods biased? *American Journal of Agricultural Economics*, 61.

Blanch, A., Torrelles, B., Aluja, A. and Salinas, J.A. (2009). Age and lost working days as a result of an occupational accident: A study in a shift rotation system. *Safety Science* 47: 1359-1363.

Blumenschein, K., Glenn, C. Blomquist, Johannesson, M., Horn, N., and Patricia Freeman (2008). Eliciting willingness to pay without bias: Evidence from a field experiment. *The Economic Journal*, volume 118 issue 525, pages 114-137.

Bonate, P.L. (2011). Pharmacokinetic-Pharmacodynamic modelling and simulation. Springer New York Dordrecht Heidelberg London. Page 1-233.

Bouilly, J., Limam, K., B´eghein, C., *et al*. Effect of ventilation strategies on particle decay rates indoors: An experimental and modelling study (2005) [J]. *Atmospheric Environment*, **39**(27): 4885-4892.

Boy, E., Bruce, N., and Delgado, H. (2002). "Birth weight and exposure to kitchen wood smoke during pregnancy in rural Guatemala." *Environmental Health Perspectives*, 110:109-114.

Boyle, K.J. and Bishop, R.C. (1988). Welfare measurements using contingent valuation: A comparison of techniques. *American Journal of Agricultural Economics,* No.1.

Braga, A.L., Saldiva, P.H., Pereira, L.A., Menezes, J.J., Conceic-a˜o, G.M., Lin, C.A., Zanobetti, A., Schwartz, J., and Dockery, D.W. (2001). Health effects of air pollution exposure on children and adolescents in Sa˜o Paulo, Brazil. *Pediatric Pulmonol* 31, 106–113.

Bruce, N.L. *et al*. (2006). Indoor air pollution in disease control priorities in developing countries. 2nd Edition, Jamison, D.T., *et al*, Eds. Washington D.C.: World Bank, New York: *Oxford University Press*.

Bruce, N., Perez-Padilla, R. and Albalak, R. (2002). The health effects of indoor air pollution exposure in developing countries**.** Geneva: *World Health Organization*: 11.

Bruce, N., Perez-Padilla, R. and Albalak, R. (2000). Indoor air pollution in developing countries: a major environmental and public health challenge. *Bull WHO* 78(9): 1078 – 92.

Butry, D., Mercer, D., Prestemon, J., Pye, J. and Holmes, T. (2001). What is the price of catastrophic wildfire? *Journal of Forestry* 99: 9–17.

Cairncross, Eugene, K., John, Juanette, Zonckel and Mark. (2007). A novel air pollution index based on the relative risk of daily mortality associated with short-term exposure to common air pollutants. *Vol. 41 issue 38*, P 8442- 8454, 13p.

California Environmental Protection Agency (CEAP). 2004. "Fact Sheet 2004-01-00.

Cardoso de Mendonça¸ M.J., Vera Diaz, MdC., Nepstad D., Seroa de Motta, R., Alencar, A., Gomes, J.C. and Ortiz, R.A. (2004). The economic cost of the use of fire in the Amazon. *Ecological Economics* 49: 89-105.

Carlos A. Chavez, J.K., Stranlund, W., Gomez (2011). Controlling urban air pollution cause by households: uncertainty, prices and income. *Journal of Environmental management.* Vol 92, issue 10, pages 2746-2753.

Carson, R.T. (2003). Contingent valuation: A user's guide. *Environmental Science and Technology* 34, 1413–1418.

Carson, R.T. (1999). "Contingent valuation: A user's guide." Discussion paper no 99/26, department of Economics, university of California, San Diego.

Cesar, H., *et al*. (2005). Economic valuation of improvement of air quality in the metropolitan area of Mexico City. *Institute for Environmental Studies* (IVM).

Chau-Sa Ho and Diane Hite (2009). Toxic chemical releases, health effects and productivity losses in the United States. J Community Health. 34:539-546.

Chay, K., Dobkin, C. and Greenstone, M. (2003)."The Clean Air Act of 1970 and adult mortality." *Journal of Risk and Uncertainty*, 27(3), pp. 279-00.

Chay, K and Greenstone, M. (2005). The Impact of Air Pollution on Infant Mortality: Evidence from Geographic Variation in Pollution Shocks Induced by a Recession. *Quarterly Journal of Economics*, 118(3): 1121-1167.

Chen, C., Chen, B., Wang, B., Huang, C., Zhao, J., and Dai, Y. (2007). Low-carbon energy policy and ambient air pollution in Shanghai, China: a health-based economic assessment. *SciTotal Environ*; 373:13–21.

Chestnut, L.G., Thayer, M.A., Lazo, J.K. and Eeden, S.K.V.D. (2006). The economic value of preventing respiratory and cardiovascular hospitalization. *Contemporary economic policy*. 24(1): 127-143.

Ciriacy-Wantrup, S.V. (1947). "Capital returns from soil-conservation practices." *Journal of Farm Economics*. Vol. 29, pp. 1181-1196.

Clark-Carter David (2009). Quantitative psychological research: a student's handbook. Third edition. Psychology Press. Taylor and Francis e-library. Page 326.

Cohen, A.J, Ross Anderson, H., Ostro B. (2005). The global burden of disease due to outdoor air pollution. *J Toxicol Environ Health A*. 2005; 68:1301–7.

Cropper, M.L. (2002). Measuring the benefits from reduced morbidity.' *The American Economic reviews* 71: (2) and Oates, W.E (2002), *Environmental Economics*: A survey resources for the future, Washington D.C.

Cropper, M.L. (1981). Measuring the benefits from reduced morbidity. *The American Economic Review* 71: 235-240.

Davis, M.E., Blicharz, A.P., Hart, J.E., Laden, F., Garshick, E., and Smith, T.J. (2007). Occupational exposure to volatile organic compounds and aldehydes in the USA trucking industry. *Environ Sci Technol* 41(20): 7152-7158.

Department of Environmental Affairs (National), Air quality. South Africa, 2009.

Department of Environmental Affairs (National), Air quality. South Africa, 2008.

Dherani, M.D., Pope, M., Mascarenhas, K., Smith, M., Weber, and Bruce, N. (2008). "Indoor air pollution from unprocessed solid fuel use and pneumonia risk in children aged less than five years: A systematic review and meta-analysis." *Bulletin of the World Health Organization*: 321-416.

Diaz, E., *et al*. (2007). Eye discomfort, headache and back pain among Mayan Guatemalan women taking part in a randomized stove intervention trial. *Journal of epidemiology and community health*, 61(1): 74-79.

Dickie, M. (2003). Defensive behaviour and damage cost methods. In: Champ PA, Boyle KJ, Brown TC (Eds), a Primer on non-market valuation. *Kluwer Academic Publishers*, Boston; p395-444.

Dockery, D.W., Pope, C.A., II, Xu, X., Spengler, J. D., Ware, J. H., Fay, M. E., Ferris, B. G., & Speizer, F. E. (1993). An association between air pollution and mortality in six US cities. *The New England Journal of Medicine*, 329(24), 1753–1759.

Douglas, C. Montgomery, Elizabeth, A. Peck and G. Geoffrey Vining. (2012). Introduction to Linear Regression Analysis. John Wiley and sons, Inc. Hoboken, New Jersey. Fifth edition, page 285.

Duflo, E., Greenstone, M. and Hanna, R. (2007). Cooking stoves: indoor air pollution and respiratory health in Orissa, India.

ExternE (2004). Project New Ext "New Elements for the Assessment of External Costs from Energy Technologies". *European Commission DG Research*. *Contract No. ENG1-CT2000-00129*. Coordinated by R. Friedrich, IER, University of Stuttgart. Final report.

ExternE (2000). "External Costs of Energy Conversion – Improvement of the Extern E Methodology and Assessment of Energy-Related Transport Externalities". Final Report for contract JOS3-CT97-0015. Published as *Environmental External Costs of Transport.* R. Friedrich & P. Bickel, editors. Springer Verlag Heidelberg 2001.

ExternE (1998). *ExternE:Externalities of Energy*. Published by European Commission, Directorate-General X11, Science Research and Development. Office for Official Publications of the European Communities, L-2920 Luxembourg. Results, including updates, are also available at http://www.externe.info

Ezzati, M. and Kammen, D.M. (2001). Quantifying the effects of exposure to indoor air pollution from biomass combustion on acute respiratory infections in developing countries. *Environmental health perspective*, (109)5: 481 – 488.

Frankenberg E., McKee, D. and Thomas, D. (2005). Health Consequences of Forest Fires in Indonesia. *Demography*, 42(1): 109–129.

Freeman III Myrick M. (1993). “The measurement of environmental and resource values: theory and methods”. *Resources for the future*, Washington DC.

Freeman, A.M. (2003). The measurement of environmental and resource values: theory and methods. 2nd ed. Washington, D.C. *Resources for the future.*

Gauderman, W. J., McCOnnell, R., Gilliland, F., London, S., Thomas, D., Avol, E., Vora, H., Berhane, K., Rappaport, E.F., Lurmann, F., Margolis, H.G., and Peters, J. (2001). “Association between air pollution and lung function growth in Southern California children.” *American journal of respiratory and critical care medicine*, Vol 12, no 1, pp. 43-54.

G.D’Amato, L. Cecchi, M.D’Amato and G. Liccardi (2010). Urban air pollution and climate change as environmental risk factors of respiratory allergy: an update. *J Investig Allegol clin Immunol* Vol 20(2):95-102.

Grossman, M. (1972). On the concept of health capital and the demand for health care. *Journal of Political Economy*, 80: 223-255.

Gujarati, D.N. (2003). *Basic econometrics*. Fourth edition. New York: McGraw-Hill.

Gupta Usha (2008). Valuation of urban Air Pollution: A case study of Kanpur city in India. *Environ Resource Econ*, 41: 315-326.

Hammit, J.K and Ying Zhou (2006). The economic value of air-pollution-related health risks in China: A Contingent Valuation study. *Environmental and Resource Economics* 33: 399-423.

Harrington, W. and Portney, P. (1987). Valuing the benefits of health and safety regulation. *Journal of Urban Economics*, 22: 101-112.

Holguin, F., Tellez-Rojo, M.M., Hernandez, M., Cortez, M., Chow, J.C., Watson, J.G., Mannino, D. and Romieu, I. (2003). Air pollution and heart rate variability among the elderly in Mexico City. *Epidemiology* 14, 521–527.

Integrated Development Plan: Mangaung Local Municipality (2010)

Integrated Development Plan (IDP). 2003, IDP review.

Katchova, A.L. and Miranda, M.J. (2004). Two-step econometric estimation of farm characteristics affecting marketing contract decisions. *American Journal of Agricultural Economics,* 86(1): 88-102.

Katsouyanni, K., Touloumi, G. and Spix, C. (1997). Short-term effects of ambient SO_2 and PM on mortality in 12 European cities: Results from time- series data from the APHEA Project; *Br. Med. J*. 314, 1658-1663.

Krupnick, A., A. Alberini, M. Cropper, N. Simon, B. O'Brien, R. Goeree and M. Heintzelman (2002). Age, health and the willingness to pay for mortality risk reductions: A Contingent Valuation study of Ontario residents, *Journal of Risk and Uncertainty* 24, 161–186.

Kumar, P. and Kumar, S. (2010). Valuing the health effects of air pollution from Agricultural residue burning. Invited paper to the ACIAR workshop "Policy options."

Kuebler, J., Van den Bergh, H., and Russell, A.G. (2001). Long-term trends of primary and secondary pollutant concentrations in Switzerland and their response emission controls and economic changes. *Atmos environ* 35(8): 1351-1363.

Kumar, S. and Rao, D.N (2001). Valuing benefits of air pollution abatement using health production function: a case study of Panipat thermal power station, India. *J Environ Resour Econ* 20:91–102.

Kyung-Min Nam, Noelle E. Selin, John M. Reilly and Sergey Paltsev (2010). Measuring welfare loss caused by air pollution in Europe: A CGE analysis. *Energy policy* 38 (2010) 5059-5071.

Levy, J.I. (2003). Issues and uncertainties in estimating the health benefits of air pollution control. *J.Toxicol Environ Health* A66, 1865–1871.

Lipfert, F.W. and Wyzga, R.E. (1995). Air pollution and mortality: issues and uncertainties; J. air and waste manage. Assoc.45, 949-966.

Lippman, M. (1993). "Health Effects of Tropospheric Ozone: A review of recent research findings and their implications to ambient air quality standards." *Journal of Exposure Analysis and Environmental Epidemiology*, Vol. 3, pp. 103-29.

Maddala, G.S. (2001). *Introduction to econometrics*. 3rd Edition. London: John Wiley & Sons,

Ltd.

Maddison, D., Pearce, D., Johansson, O., Clathrop, E., Litman, T. and Veroef, E. (2004). True costs of road transport, blueprint 5. London: *Earthscan publications ltd.*

Manawadu, L and S. Wijesekera (2009). Understanding air pollution dynamics and exploring reasons for aggravation of air pollution in the city of Colombo, using Geo-statistical technique. Proceedings of the second national symposium on Geo-informatics, July 31. Pp 17-31.

Martin, W.E., Brajer, V. and Zeller, Z. (2007). Valuing the health effects of a prescribed fire. In Martin, W., Raish, C. & B. Kent (Eds.), Wildfire Risk: Human Perceptions and Management Implications (pp. 244-261): Resources for the Future.

Massey, D., Masih, J., and Kulshrestha, A. (2009). Indoor and outdoor relationship of fine particles less than 2.5μm ($PM_{2.5}$) in residential homes locations in central Indian region. *[J].Building and Environment*, 44(10): 2037-2045.

Matus, K., Nam, K., Selin, N.E., Lamsal, L.N, Reilly and Paltser, S. (2011). Health damages from air pollution in China. *Global Science Policy Change* MIT Report No. 196.

Mayeres, I. and Van Regemorter, D. (2008). Modelling the health benefits of environmental policies and their feedback effects: a CGE analysis for the EU countries with GEM-E3. *Energy J.* 29: 135-50

MitraEmisiBersih (MEB) (2002). 'Action plan: integrated vehicle emission reduction strategy for greater Jakarta'.Ministry of Environment, Jakarta.

Mitchell, C.S., Zhang, J., Sigsgaard, T., Jantunen, M., Lioy, P.J., Samson, R. and Karol, M.H. (2007). Current state of the Science: health effects and indoor environmental quality**.** *Environmental Health Perspectives*, 115 (6):958-964.

Mitchell, R.C. and Carson, R.T. (1989). Using surveys to value public goods: The Contingent Valuation method. Washington D.C. *Resources for the future.*

MJA (2004). Journal of rural and remote environmental health. 176:517, 3(1): 18-28.

Molina, M.J., Molina, L.T. (2004). Megacities and atmospheric pollution. *Journal of Air waste manage. Assoc.* 54, 644–680.

Mtango, FDE and Neuvians, D. (2002). Acute respiratory infections in children under five years: control project in Bagamoyo district, Tanzania. *Trans R Soc Trop Med Hyg* 80:851-858.

Murray, C., and Lopez, A. (2007). "Mortality by cause for eight regions of the world: global burden of disease study*." Lancet*, 349 (9061):1269-76.

Murty, M. N., Gulati, S.C., and A. Banerjee (2003). "Health Benefits from Urban Air Pollution Abatement in the Indian Subcontinent." *Discussion Paper no. 62/2003, Delhi: Institute of Economic Growth, IEG Website.*

Murty, M.N and Surender Kumar (2002). *Environmental and Economic Accounting for Industry*, Oxford University Press, New Delhi.

Navrud, S. (2001).Valuing health impacts from air pollution in Europe.Environmental and Resource Economics. 20: 305-326.

Neidell, and Matthew J. (2004). "Air pollution, health, and socio-economic status: the effect of outdoor air quality on childhood asthma." *Journal of Health Economics*, 23, pp. 1209-36.

Norman, R., Cairncross, E., Witi, J. and Bradshaw, D. (2007). Estimating the burden of disease attributable to urban outdoor air pollution South Africa in 2000. South African comparative risk assessment collaboration group. *South African medical journal*, vol. 97(8): pp.782-790.

Number Cruncher Statistical System (NCSS) (2007).

Ostro, B.D., Broadwin, R., and Lipsett, M.J. (2000). Coarse and fine particles and daily mortality in the Coachella Valley, California: A Follow-Up Study. *J. Expo. Anal. Environ. Epidemiol.*10, 412-419.

Peter Ho and Richard Louis Edmonds. (2007). China's Embedded activism: Opportunities and constraints of a social movement. Routledge. *Taylor and Francis Group*. SBN 0-203-94644-8. Master e-book. Page 144.

Peterson William. (1975). Population, Macmillan, Newyork.

Pope, III, C.A., Muhlestein, J.B., May, H.T., Renlund, D.G., Anderson, J.L and Horne, B.D (2006). Ischemic heart disease event triggered by short-term exposure to fine particulate air pollution. *Circulation* (114): 2443-2448.

Pope, C.A., Burnett, R., Thun, M., Calle, E., Krewski, K., Ito, G. and Thurston (2002). Lung cancer, cardio-pulmonary mortality and long-term exposure to fine particulate air pollution. *J. Amer. Med. Assoc.* 287:1132- 1141.

Pope, C.A., II, Micheal, J. T., Namboordiri, M. M., Dockery, D. W., Evans, H. S., Speizer, F. E., & Heath, C.W., Jr. (1995). Particulate air pollution as a predictor of mortality in a prospective study of US adults. *American Journal of Respiratory and Critical Care Medicine*, 151, 669–674.

Population Environment Research Network (PERN). Cyber seminar (2003). Health Effects of Air Pollution.

Quah, E. and Boon, T.L. (2003). The economic cost of particulate air pollution on health in Singapore. *J Asian Econ*;14:73–90.

Queensland Government Environmental Protection Agency (2008): *Environmental Management*.

Reid, K. and Dawson, D., 2009. Comparing performance on a simulated 12 hour shift rotation in young and older subjects. *Journal of Occupational Environment Medicine* 58, 58–62.

Rittmaster, R., Adamowicz, W. L., Amiro, B. and Pelletier, R.T. (2006). Economic analysis of health effects from forest fires. *Canadian Journal of Forest Research* 36: 868-877.

Ritz, Beate and Yu, F. (1999)."The effect of ambient carbon monoxide on low birth weight among children born in Southern California between 1989 and 1993." *Environmental Health Perspective*, 107, pp. 17-25.141.

Rollin, H.B., von Schirnding, Y.E.R., Rollin, H.B., Mathee, A., Bruce, N. and Levin, J. (2004). Comparison of indoor air quality in electrified and un-electrified dwellings in rural South

African villages. *Health and development research group/biostatistics unit. Indoor air,* 14(3): pp208-16.

Romieu, I., Meneses, F., Ruiz, S., Huerta, J., Sienra, J.J., White, M., Etzel, R. and M. Hernandez-Avila. (1997). "Effects of intermittent ozone exposure on peak expiratory flow and respiratory symptoms among asthmatic children in Mexico City." *Archives in Environmental Health*, Vol. 52, no. 5, pp. 368-76.

Rowe, R.D., d'Arge, R.C. and Brookshire, D.S. (1980). An experiment in the economic value of visibility. *Journal Environmental Management*. 7: 1-19.

Rudolf, J.F. and Ramon, C.L. (2000). *SAS System for Regression. Third edition*. Cary, NC: SAS institute Inc. Page 101.

Ruitenbeek, J. (1999). Indonesia.In: Glover, D.; Jessup, T., editor. The cost of catastrophe. Singapore: Institute of Southeast Asian Studies; 86-129.

Scheaffer, R.L. *et al.* (1979). *Elementary Survey Sampling.* Duxbury Press. North Scituate, Massachusetts.

Schwartz, J. (1993). Air pollution and daily mortality in Birmingham, Alabama. *American Journal of Epidemiology*, 137:1136–1147.

Scorgie, Y, Annegarn H, Burger L. (2004). Study to Examine the Potential Socio-Economic Impact of Measures to Reduce Air Pollution from Combustion. Fund for Research into Industrial Development Growth and Equity (FRIDGE). Johannesburg: *Air shed Planning Professionals*.

Scott, J.L. (1997). Regression models for categorical and limited dependent variables. Advanced quantitative techniques in the social sciences. *Number 7 sage publications*.

Seroa da Motta, R., Ortiz, R.A. and Freitas, S.F. (2000). Health and economic values of mortality cases associated with air pollution in Brazil, expert workshop on assessing the ancillary benefits and costs of greenhouse gas mitigation strategies. Washington D.C.

Seroa da Motta, R., Ferraz, C. and Young, C.E.F. (2000). CDM opportunities and benefits. In D. Austin & P. Faeth (Eds.), Financing sustainable development with the clean development Mechanism (pp. 112-122): World Resource Institute.

Shahwahid, M.H.O. and Othman, J. (1999). Malaysia. In D. Glover & T. Jessup (Eds.), Indonesia's Fires and Haze: The Cost of Catastrophe. Singapore: Institute of Southeast Asian Studies.

Shechter, M. and Kim, M. (1991). Valuation of pollution abatement benefits: Direct and indirect measurement. *Journal of Urban Economics*, No. 30.

Smith, K.R. (2003). "The global burden of diseases from unhealthy buildings: preliminary results from comparative risk assessment". *Proceedings of Healthy Buildings*. 1118- 126.

Smith, K.R., Mehta, S. and Feuz, M. (2002). The global burden of disease from indoor air pollution: results from comparative risk assessment. In: indoor air: Proceedings of the 9th international conference in indoor air quality and climate, Monterey, CA, 30 June- 5 July 2002, vol 4. Santa Cruz, CA: *indoor air*; 10-19.

Smith, K. (1988). Air pollution: assessing total exposure in the United States. *Environment* 30 (8) 10-15 and 33-38.

Sorenson, B., Fuss, M., Mulla, Z.,Bigler, W., Wiersma, S. and Hopkins, R. (1999). Surveillance of morbidity during wildfires – central Florida 1998. Morbidity and mortality weekly report 48, 78-79.

Statistics of South Africa (2007).

Truchon, M. and Fillion, L. (2000). Biopsychosocial determinants of chronic disability and low-back pain: a review. *Journal of Occupational Rehabilitation* 10, 117–142.

United Nations Environment Programme (UNEP) and World Health Organization (WHO) (1992). *Urban Air Pollution in the Mega-Cities of the World*. Blackwell Publishing, New York.

Verhoeff, A.P., Hoek, G., Schwartz, J., Van Wijnen, J.H. (1996). Air pollution and daily mortality in Amsterdam. *Epidemiology*7, 225-230.

Von Schirnding, Y., Bruce, N., Smith, K.R., Ballard-Tremeer, G., Ezzati, M. and Lvovsky, K. (2002). Addressing the impact of household energy and indoor air pollution on the health of the poor: implications for policy action and intervention measures. In: working group 5 (Improving the health outcomes of the poor). Commission on Macroeconomics and Health.

Westfall, L. (2009). Sampling Methods. The Westfall team.

White, N.W., Ehrlich, R.I., Water Naudé, J., Schutte, A., Essack N, Roberts W. (2003). A Study of Allergic Diseases and the Urban Environment in the Northern Communities of Cape Town, South Africa. *First report*. Cape Town: University of Cape Town.

Wichmann, J. and Voyi, K.V. Air pollution epidemiologic studies in South Africa – need for freshening up (2005). *Rev Environ Health*; 20:265 - 301.

World Bank (1997). *Clear Water, Blue Skies: China's environment in the new century*. World Bank, Washington, DC.

World Health Organization. Indoor Air Pollution: National Burden of Disease Estimates. Geneva: WHO (2007).

WHO (2004). Comparative quantification of health risks: global and regional burden of disease due to selected major risk factors. World Health Organization: Geneva.

World Health Organization (2003). WHO guidelines for air quality. Fact Sheet No. 187.

Winkelmann, R. and Boes, S. (2006). Analysis of microdata. Page 1-309.

World Resource Institute (WRI), United Nations Environment Programme (UNEP), United Nations Development Programme (UNDP), and the World Bank (1998). *1998– 99 World Resources: Environmental Changes and Human Health*. Oxford University Press, New York.

Wright, Caradee, Y., Diab and Roseanne. (2010). Solving the puzzle of prioritization. *Journal of environmental health*, Jan/Feb, vol. 73. Issue p 56-64, 9p.

Xindeng (2006). Economic costs of motor vehicles emissions in China: a case study. *Transportation Research Part D* 11; 216–226.

Zhang, M., Song, Y., Cai, X., and Zhou, J. (2008). Economic assessment of the health effects related to particulate matter pollution in 111 Chinese cities by using economic burden of disease analysis. *J Environ Manage* ;88:947–54.

Zellner, J.A., and R.L. Degner (1989). "Consumer Willingness to Pay for Food Safety." Paper presented at the Southern Agricultural Economics Association Meet- ings, Nashville TN.

APPENDIX A: QUESTIONNAIRE

THE IMPACT OF AIR QUALITY ON HEALTH: A CASE STUDY OF BLOEMFONTEIN, FREE STATE

QUESTIONNAIRE FOR HOUSEHOLD INTERVIEW

OBJECTIVE

The main aim of this study is to investigate the impacts and quantify the costs of air pollution on residents of Bloemfontein

Enumerator	
Date of interview	
Name of location	
Household name	

Section A: Household characteristics

In the following questions, we would like to know about you and your household. The information is important because it will enable us to understand the perception of households about air pollution. The information you provide to us will be treated as confidential.

1 Gender of respondent **(Please mark appropriate answer)**

0 = Male		1= Female	

2. Age of respondent

1= 30-39 years		2= 40-49 years		3= 50-59years	
4= 60-69years		5= 70 and above			

3. Relationship of respondent to household head

1= Head		2= Spouse		3= Child/Grandchild	
4= Other (**Please Specify**)					

4. Gender of household head (**Skip if respondent is household head**)

0= Male		1= Female	

5. Age of household head (**Skip if respondent is household head**)

1= 30-39 years		2= 40-49 years		3= 50-59years	
4= 60-69years		5= 70 and above			

6. What is the highest level of educational attainment of the household head?

   Standard ____________. Other (**Please Specify**) _________________________________

7. Household income per month at time of interview

1= <R2000		2= >R2000 - R3500		3= >R3500 - R5000	
4= R>5000 - R6500		5= >R6500			

8. What is the total number of people living in the house in the past six months?

____

9. Please complete the table below about members of the household.

	1	2	3	4	5	6	7	8
Name of household member								
Gender 1=Male, 0=Female								
Age(years)								
Highest educational attainment 0=No formal education, 1=Primary (grade 1-7), 2=Secondary (grade 8-12), 3=College or University, 4= Others (**Please specify**) ____________								
Occupation 1=Employed, 2=Self-employed, 3=Student, 4=Unemployed, 5=Others (**Please specify**) ____________								
Smoker 0=No, 1=Yes, 2=Ex-smoker								

Section B: Air Quality

The questions in this section are designed to provide us some information on the household knowledge about air quality (indoor and outdoor).

1. What degree of importance do you place on the problem of air pollution compared to other problems such as crime, violence against women and children, unemployment and provision of water and sanitation?

1= Critical		2= Very serious		3= Serious	
4= Less serious		5= Not important			

2. Do you consider yourself as a person:

1= Very interested in the environment	
2= Somewhat interested in the environment	
3= Less interested in the environment	
4= Indifferent	

3. Do you have a problem with pollution of air outdoors in your area?

1= Yes		0= No	

4. If yes, **please fill in the table below**.

Type of outdoor pollution ***(Please rank below)*** 1=Most problematic 2=Problematic 3= Less problematic 4= Not problematic	**Time of the year the pollution occurs** 1=summer, 2=winter, 3=spring, 4= autumn 5= all year round	**Source(s) of outdoor pollution** 1= smoke from combustion of coal, refuse by households, 2=wind-blown dust, 3=vehicle-entrained road dust, 4=burning of grass, 5= open fire cooking, 6= Other (Please specify) ________________________
Smoke ________		
Smog ________		
Dust ________		
Other **(Please Specify)** ________ ______		

5. Do you have a problem with pollution of air indoors?

1= Yes		0= No	

6. How does your household keep warm during winter?

1= Paraffin heater or stove		2= Burning coal in a fire place		3= Burning wood in a fire place	
4= Electric heater		5= Gas heater		6= Other (**Please Specify**) __________	

7. What is the reason for your choice of heating method chosen above?

____

____

8. What does your household use for cooking most of the time?

1= Paraffin stove		2= Coal stove		3= Open fire	
4= Electric stove		5= Gas stove		6= Other (**Please Specify**) __________	

9. What is the reason for the choice of the means of cooking chosen above?

____

10. What is the major pollutant of indoor air in your household? **(Please fill in the table below)**.

Type of indoor pollution ***(Please rank below)*** 1=Most problematic, 2=Problematic, 3=Less problematic, 4= Not problematic	**Time of year** ***(indicate where relevant)*** 1=summer, 2=winter, 3=spring, 4=autumn, 5= all year round	**Source(s) of the pollution** 1=paraffin stove, 2=coal stove, 3= cigarette, 4= Other (Please specify) __________________________
Smoke from cigarette _______		
Smoke from coal _______		
Fumes from paraffin _______		
Other ***(Please Specify)*** ________________ _______		

11. How do you rate your access to the following infrastructure and services? **Please rank the rate of accessibility of the following services**.

1-Very good

2- Not so good

3-Bad

4- Very bad

	1	**2**	**3**	**4**
Water				
Electricity				
Refuse removal				

12. Do you think air pollution poses negative effects on health?

1= Yes		2 = No		3= I don't know	

13. What do you think are the likely problem(s) caused by air pollution? **(Please mark below)**

1= Triggers illness		2= Reduces enjoyment from outdoor activities		3= Causes early death on a long term effect	
4= Low yield of crops		5= Damage to vegetation and animals		6= Other (**Please specify**) ______________	

Section C: Health Valuation

The questions in this section are designed to provide us some information on the cost of air pollution in terms of health status of individual (number of workdays lost) and expenses incurred as a result of ailments related to air pollution.

1. Do you or any member of your household have the following illness(es)? **Please provide information in the table below**.

Name of household member	**Illness(es)** 1=Asthma, 2=Tuberculosis, 3=Pneumonia, 4=Bronchitis, 5=High/low blood pressure, 6=Diabetes, 7= Other illnesses (**Please specify**) ______________________

2. Did you or any member of your household experience ailment(s) linked to air pollution in the past six months for which you sought treatment? **Please provide information in the table below.**

Name of household member	**Ailments** 1=Runny or blocked nose, 2=Sore throat, 3=Cough, 4=eye irritation, 5=asthma , 6=fever, 7=Sinus, 8=Ear irritation	**How did you treat your most recent respiratory ailment(s)**? 1=Medical practitioner, 2=Over-the-counter medication, 3=Traditional treatment, 4=No medication, 5=Other (*Please specify)* _______________	**Cost of treatment (in Rand) for most recent episode** Doctor's fee, hospitalisation fee, medication fee and cost of travel to doctor's clinic or pharmacy, others (please specify) ________________	**Number of visits for treatment for most recent episode** *(indicate if relevant*)	**Duration of illness (in days) for most recent episode**	**Number of workdays lost** (*if employed*) **or absenteeism from school** ***(if student)*** **or number of days not able to perform daily routine or activities or number of sick days** ***(if unemployed or self-employed)*** **and number of days of restlessness** ***(if a child between 0-6years).*** **(All for most recent episode)**	**How many times (on average) do you experience any of these ailments in a year?** **Would you say _____ times?**

3. Have any household member(s) died in the last five year? **Please provide information in the table below.**

Name	Age at death	Cause of death (if known)	Did the person suffer any ailment(s) – **(runny or blocked nose, sore throat, cough, eye irritation, asthma, fever, sinus and ear irritation)** prior to death? 1=Yes, 0=No

Section D: Economic Valuation

This section elicits information concerning household willingness to pay for a clean air.

Suppose a program that reduces smog, smoke, dust and other harmful pollutants is to be put in place in your area. This program when implemented will keep pollution below a level that triggers adverse health effects such as sinus, sore throat and cough. With the program in place, all your pain and suffering, your medical expenditure; the time spent visiting medical practitioners, and your missed work days, disruptions to leisure or daily activities will be avoided. Are you willing to pay some amount for this program? (Yes/No). How much are you willing to pay per month on average towards this program in order to reduce air pollution in your area? Would you pay R { 100 }

1= Yes. If yes, go to question 1a

2= No. If no, go to question 1b

1a. Would you be willing to contribute a sum of R150?

1= Yes. If yes, go to question 2a

2= No. If no, go to question 3

1b. Would you be willing to contribute a sum of R75?

1= Yes. If yes, go to question 3

2= No. If no, go to question 2b

2a. Would you be willing to contribute a sum of R200?

1= Yes. If yes, go to question 3

2= No. If no, go to question 3

2b. Would you be willing to contribute a sum of R50?

1= Yes. If yes, go to question 3

2= No. If no, go to question 3

3. How much (on a maximum) would you be willing to contribute per month? R { }

APPENDIX B: MULTICOLLINEARITY RESULTS

Multiple Regression Report
Page/Date/Time 4 6/4/2012 10:39:02 AM
Database
Dependent MGTCOST
Warning: At least one value was reset to 0.0 because it was less than the machine zero of 0.0000000001.

Multicollinearity Section

Independent Variable	Variance Inflation Factor	R2 Versus Other I.V.'s	Tolerance	Diagonal of X'X Inverse
(AILMENT=1)	1.2278	0.1856	0.8144	4.997284E-02
(DISTRICT=1)	1.1507	0.1309	0.8691	1.645469E-02
DLNES	5.9780	0.8327	0.1673	7.397855E-05
(HIGHINC=1)	1.6857	0.4068	0.5932	7.355714E-02
(LOWINC=1)	1.7488	0.4282	0.5718	4.265772E-02
(NMED=1)	1.1333	0.1176	0.8824	9.112801E-02
(OTC=1)	1.1620	0.1394	0.8606	2.662994E-02
(SELFEMPLYD=1)	1.3778	0.2742	0.7258	4.691228E-02
(STUDENT=1)	1.3137	0.2388	0.7612	7.381669E-02
(TRAD=1)	1.0847	0.0781	0.9219	9.415784E-02
(UNEMPLYD=1)	1.5979	0.3742	0.6258	0.0223205
VSTNR	1.4482	0.3095	0.6905	2.99747E-03
WKDLOST	6.4004	0.8438	0.1562	6.004453E-04

Eigenvalues of Centered Correlations

No.	Eigenvalue	Incremental Percent	Cumulative Percent	Condition Number
1	2.0513	15.779	15.779	1.000
2	1.8998	14.614	30.393	1.080
3	1.4263	10.971	41.364	1.438
4	1.3377	10.290	51.654	1.533
5	1.2794	9.841	61.496	1.603
6	1.1363	8.741	70.237	1.805
7	1.0440	8.031	78.268	1.965
8	0.8264	6.357	84.625	2.482
9	0.6559	5.045	89.670	3.127
10	0.5446	4.190	93.859	3.766
11	0.3679	2.830	96.690	5.575
12	0.3474	2.673	99.362	5.904
13	0.0829	0.638	100.000	24.738

All Condition Numbers less than 100. Multicollinearity is NOT a problem.

Multiple Regression Report
Page/Date/Time 4 6/5/2012 2:37:08 AM
Database
Dependent WKDLOST
Warning: At least one value was reset to 0.0 because it was less than the machine zero of 0.0000000001.

Multicollinearity Section

Independent Variable	Variance Inflation Factor	R2 Versus Other I.V.'s	Tolerance	Diagonal of X'X Inverse
AGE	1.3655	0.2677	0.7323	1.680106E-05
(AILMENT=1)	1.4610	0.3156	0.6844	0.0421454
(DISTRICT=1)	1.1463	0.1276	0.8724	1.639239E-02
DLNES	1.2090	0.1729	0.8271	1.496128E-05
(HEALTH=1)	1.3663	0.2681	0.7319	1.869576E-02
(HIGHINC=1)	1.7315	0.4225	0.5775	7.555765E-02
(LOWINC=1)	1.7017	0.4124	0.5876	4.150842E-02
MGTCOST	1.3981	0.2847	0.7153	3.769012E-07
(NMED=1)	1.1022	0.0927	0.9073	8.862151E-02
NRTIMES	1.2726	0.2142	0.7858	6.29249E-04
(OTC=1)	1.2861	0.2225	0.7775	2.947399E-02
(TRAD=1)	1.1021	0.0926	0.9074	9.566695E-02
VSTNR	1.5749	0.3651	0.6349	3.259755E-03

Eigenvalues of Centered Correlations

No.	Eigenvalue	Incremental Percent	Cumulative Percent	Condition Number
1	2.1632	16.640	16.640	1.000
2	1.8710	14.393	31.033	1.156
3	1.6306	12.543	43.576	1.327
4	1.1133	8.564	52.140	1.943
5	1.0982	8.448	60.587	1.970
6	1.0058	7.737	68.324	2.151
7	0.9404	7.233	75.558	2.300
8	0.7609	5.853	81.411	2.843
9	0.6934	5.334	86.745	3.120
10	0.5324	4.095	90.840	4.063
11	0.4329	3.330	94.170	4.998
12	0.4015	3.088	97.258	5.388
13	0.3565	2.742	100.000	6.068

All Condition Numbers less than 100. Multicollinearity is NOT a problem.

MGTCOST	*LOWINC*	*HIGHINC*	*DLNES*	*DISTRICT*	*WKDLOST*	*AILMENT*	*OTC*	*TRAD*	*NMED*	*SELFEMPLYD*	*STUDENT*	*UNEMPLYD*	*VSTNR*
LOWINC	1												
HIGHINC	-0.61716	1											
DLNES	0.05485	0.048622	1										
DISTRICT	0.114487	-0.03123	-0.0671	1									
WKDLOST	0.00591	0.097792	0.897829	-0.00389	1								
AILMENT	0.01859	0.010536	-0.04648	-0.04849	-0.00094	1							
OTC	-0.03176	0.081692	-0.11884	0.224292	-0.1006	0.145677	1						
TRAD	0.090189	-0.06155	-0.05079	0.054963	-0.046	0.004755	-0.09455	1					
NMED	0.005462	-0.06417	-0.0527	0.074261	-0.07291	0.066932	-0.09859	-0.04344	1				
SELFEMPLYD	-0.10404	0.009636	-0.06329	0.039497	-0.0341	0.073335	0.116482	-0.0174	-0.07482	1			
STUDENT	-0.07022	0.070149	0.03266	-0.0292	0.08241	-0.01387	-0.04868	0.016762	0.213526	-0.09142	1		
UNEMPLYD	0.234922	-0.15225	0.065415	-0.04721	0.043898	-0.06247	-0.00274	0.059894	-0.02972	-0.43661	-0.32294	1	
VSTNR	-0.05722	0.098203	0.112723	-0.03765	0.265495	0.343632	0.003489	0.179077	-0.11645	0.01041	0.060967	0.035632	1

WKDLOST	*HEALTH*	*DLNES*	*AGE*	*OTC*	*TRAD*	*NMED*	*LOWINC*	*HIGHINC*	*DISTRICT*	*AILMENT*	*VSTNR*	*NRTIMES*	*MGTCOST*
HEALTH	1												
DLNES	0.167894	1											
AGE	0.459667	0.141379	1										
OTC	-0.19019	-0.11884	-0.22222	1									
TRAD	0.035843	-0.05079	0.059568	-0.09455	1								
NMED	-0.01791	-0.0527	-0.10143	-0.09859	-0.04344	1							
LOWINC	0.208638	0.05485	0.185194	-0.03176	0.090189	0.005462	1						
HIGHINC	-0.18327	0.048622	-0.18269	0.081692	-0.06155	-0.06417	-0.61716	1					
DISTRICT	-0.0193	-0.0671	-0.09231	0.224292	0.054963	0.074261	0.114487	-0.03123	1				
AILMENT	-0.0755	-0.09599	-0.0247	0.130269	-0.02002	0.083478	0.012379	0.011826	0.016248	1			
VSTNR	-0.14518	0.112723	-0.03018	0.003489	0.179077	-0.11645	-0.05722	0.098203	-0.03765	0.428585	1		
NRTIMES	-0.01181	0.010938	-0.05189	-0.00324	0.042453	-0.0561	0.029369	-0.02052	0.122823	0.35148	0.36551	1	
MGTCOST	-0.00808	0.296082	-0.00551	-0.19691	-0.06352	-0.06176	-0.12397	0.225948	0.031419	0.199189	0.312915	0.135981	1