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Valuing welfare effects of air pollution in the Jinchuan mining area

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Rijksuniversiteit Groningen

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Chapter 1

Introduction

1.1 CHINA’S ECONOMIC DEVELOPMENT

Prior to 1978, China maintained a centrally planned economy. The entire country’s economy was directed and controlled by the Central Government through setting production goals and controlling prices. As a result, by 1978, state-owned enterprises produced nearly three-fourths of industrial production (Morrison, 2006). Moreover, the Chinese government wanted China’s economy to be relatively independent and self-sufficient; foreign trade was generally limited to obtaining only those goods that could not be made or obtained in China. Thus, foreign-invested firms and private enterprises were few and far between.

In order to build a market-oriented economy, beginning in 1978 fundamental reforms of the economic system have been undertaken. See Chow (2004) and Laurenceson and Chai (2003) for an overview. Up to now, China has successfully integrated into the global economy. Moreover, since the economic reforms in 1978, the Chinese economy has been growing at a rapid pace for over thirty years. From 1979 to 2012, growth in the GDP averaged 9.86 percent per year (See Figure 1.1), resulting in a more than a 20-fold increase in output which has lifted more than 500 million people out of poverty (Morrison, 2012). In 2010, China passed Japan and became the world’s second-largest economy behind the United States. It is increasingly playing an important and influential role in the global economy.

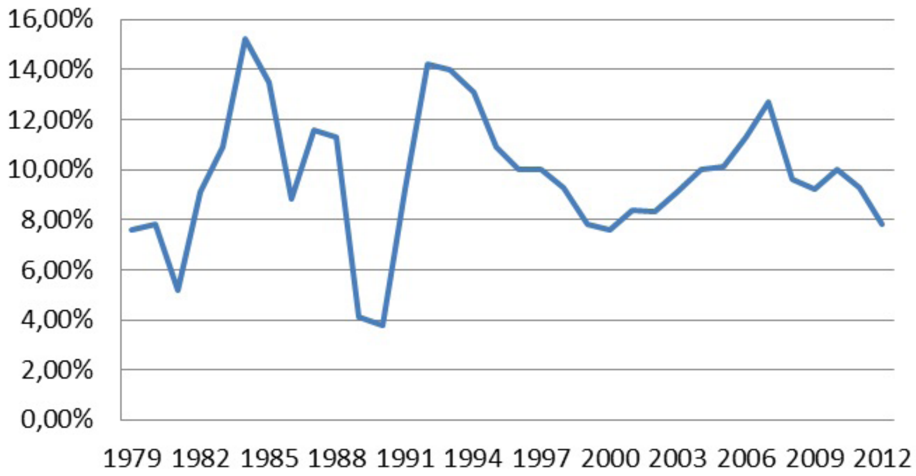

Figure 1.1 China’s Average Annual Real GDP Growth Rates, 1979-2012
Source: Chinese Year book, 2012

1.2 MINING IN CHINA AND ITS HEALTH EFFECTS

In order to sustain rapid economic growth, China needs huge amounts of resources, from non-metallic and metallic minerals to energy minerals. In 2005 alone, China used 47 percent of the world’s cement and 26 percent of its steel (World Watch Institute 2006). China is already the world’s largest consumer of refined lead (Mining Magazine 2006). The demand for resources and energy has shaken up the mining industries and China has since long been one of the world’s largest mining countries. In 2010, the production value of the mining industry was 69.281 billion US dollars, which accounted for 1.2% of China’s GDP (ICMM, 2012).

China’s mining sector is dominated by coal: it is one of the world’s largest coal producers. Coal production in 2009 was 3050 million tonnes accounting for 45.55% of the world’s total (BP Statistical Energy Survey, 2010). China is also the world’s largest consumer of coal. In 2009, coal consumption was 1537.41 million tonnes which accounted for 46.89% of the world’s total (BP Statistical Energy Survey, 2010). Coal takes up about 75% of all energy sources of China (Kan et al., 2009).

China is facing serious resource and energy shortage. For example, China’s copper ore reserves only account for 7% of world supplies, whilst its consumption of copper reaches 22% of the world’s copper supplies. China, which is also the world’s largest iron ore importer, was responsible for 40 percent of global iron ore imports in 2005.

China’s mining industry has led to serious environmental issues through the production of huge amounts of waste gases, waste water and dust. These kinds of pollution, in their turn, have adverse impacts on human health - both in the short and the long run - ranging from small reversible reductions in lung function to early death from pulmonary and cardiovascular diseases. The dramatic impacts stem from operations such as blasting enormous open pits, applying massive quantities of toxic chemicals including cyanide and sulfuric acid, and smelting, all of which produce harmful pollution (Aimee and Alexandra 2004).

Qu et al. (2012) assessed the potential health risks in the Qixia lead-zinc mining area, Jiangsu province, and found that heavy metal pollution (Pb, Cd, and Hg) may pose high health risks to local residents, especially those who live close to the mine. The health risks correlated with heavy metals come from soils and the intake of (self – produced) vegetables. High levels of heavy metals in human bodies will pose chronic health risks including nausea, vomiting, stomach cramps, or diarrhea, liver and kidney damage and even death (ATSDR 2004).

Gu et al. (2009) investigated air quality in three mining cities: Anshan, Fushun and Benxi which are located in Northeast China, Liaoning Province. They found that the air in the three mining cities was seriously polluted. The main pollutants were suspended particles and sulfur dioxide. The World Health Organization (2006) pointed out that air pollutants, even in relatively low concentrations, can lead to a range of adverse health effects. For instance, exposure to suspended particles, especially, can result in an irregular heart-beat, non-fatal heart attacks, and aggravated asthma. Suspended particles also can decrease lung function and increase respiratory symptoms, such as coughing or difficult breathing, and even premature death for people with heart or lung diseases (Seaton et al., 1995; Pope III et al., 1995). Sulfur dioxide can react with other compounds in the atmosphere to form small particles which can penetrate deeply into the lung's sensitive parts and lead to, or aggravate, respiratory diseases, for example, emphysema and bronchitis. The particles can also aggravate existing heart diseases, resulting in increased hospitalization and premature death (Nadel et al., 1965; Devalia et al., 1994).

1.3. JINCHUAN MINING AREA

The Jinchuan mining area (abbreviated as Jinchuan), which is part of Jinchang city, is located in the northeast of the Hexi Corridor in Gansu Province (see Figure 1.2). The total area of Jinchuan is 3370 square kilometers, and the total population in 2011 was 229,000.

Gross Domestic Product of Jinchuan totaled 18.84 billion CNY (US$2.98 billion) in 2011, an increase of 16.32% percent from 2010 (Jinchuan Yearbook, 2012). In 2011, Jinchuan's per capita GDP totaled 82160 CNY (US$12,721). In 2011, Jinchuan reported 9.27 billion CNY of fixed asset investment, an increase of 37.71percent year-on-year (Jinchuan Yearbook, 2012). The disposable per capita income averaged 20074 CNY (US$ 3177.98) in 2011, an increase of 13.55 percent year-on-year (Jinchuan Yearbook, 2012).

Jinchuan, which is a typical mining city, has the largest nickel resources in China. Its economy is dominated by mining and smelting industries. The two industries employed nearly 55% of Jinchuan's workforce and contributed to 70% of the government receipts in 2011 (Statistical Yearbook 2012). However, they have also resulted in serious environmental issues, especially air pollution. Jinchuan is one of the ten cities with the most polluted air in China (Wei, 2008). Sulfur dioxide is the major air pollutant, followed by particulate matter (Xiao, 2003; Wei, 2008). Figure 1.3 shows the 10-years trend of annual average levels of sulfur dioxide and particulate matter in Jinchuan (2001 to 2010). Regarding sulfur dioxide, although huge improvements (about 68 % change) have been made since 2001, the level still exceeds national standard Class II.[1] Particulate matter has a similar trend as sulfur dioxide. In 2010, Jinchuan had an annual average particulate matter concentration of 71 $\mu g/m^3$, although it attained the national standard Class II, which is 3.5 times higher than the WHO Air Quality Guideline of 20 $\mu g/m^3$ (Figure 1.3).

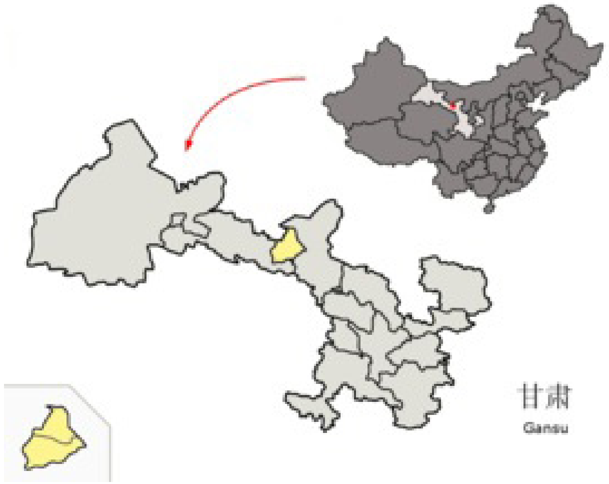

Figure 1.2 The Location of Jinchuan
Note: The yellow part represents Jinchang city. The Jinchuan mining area is located in upper left part of Jinchang city (see the lower left corner)

In 2007 the total number of deaths in Jinchuan reached 927 (Fan and Liu, 2009). The death rate of males was 0.0056, and of females 0.0035. These death rates are substantially higher than the national average levels for urban areas which were 0.0031 and 0.0025, respectively. Fan and Liu (2009) conducted a statistical analysis of the causes of deaths in Jinchuan in 2007, and found that the main causes of death were tumours, defections of the cardiovascular and respiration system, injury and poisoning (see Table 1.1). Fan and Liu (2009) conclude that there were strong correlations between these death causes and air

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[1] China's current air quality standards include two classes of limit values. Class I standards apply to special regions such as national parks. Class II standards apply to all other areas, including urban and industrial areas. The national class II standards of sulfur dioxide and particulate matter are 60 $\mu g/m^3$ and 100 $\mu g/m^3$, respectively.

pollution. They proposed that the local government should take more effective measures to control air pollution.

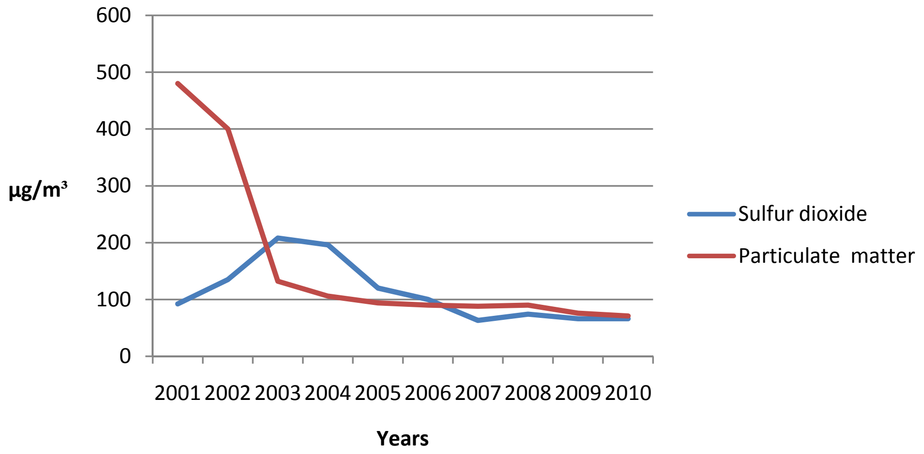

Figure 1.3 Air Quality Trends in Jinchuang (2000-2010)
Source: Wei (2008), Li (2013)

Jinchuan has also seen high levels of lead in children. Sai et al. (2007) found that Jinchuan's children between the ages of two and seven had lead levels between 28.3 and 268.0 g/dL, with 62.54% with levels higher than 100 g/dL (WHO limit 100 g/dL). High lead levels l pose chronic health risks including bio-accumulation of toxic elements in organisms, which can result into kidney and liver problems, gastrointestinal tract issues, joint pain, as well as nerve, respiratory and reproductive system damage and unpredictable health problems in the future (Goyer, 1990; Mudipalli, 2007).

1.4. ENVIRONMENTAL POLICY

In order to improve air conditions in Jinchuan and reduce the health risk caused by air pollution, the local government of Jinchuan has implemented the following policies (Jinchuan Environmental Quality Monitoring Report, 2011).

1. To increase the intensity of industrial emission control, the local Government plans to closely monitor the major companies, especially the mining company. Companies that exceed their emission quotas will be fined
2. To encourage the use of cleaner fuels and technologies and to facilitate the transition, the Government will offer financial support, for instance, low interest loans for investment in clean technology. This is intended to move companies away from the inefficient utilization of energy sources and from polluting technologies.
3. The Government has developed strategies for sustainable urban development and land-use planning. Particularly, new residential areas will be located in zones with low levels of air pollution.

Table 1.1 Death Causes and Rates in the Jinchuan mining area (2007)

Cause	Male		Female		Sum	
	Rate	Order	Rate	Order	Rate	Order
Tumours	0.00149	1	0.00079	2	0.00116	1
Cardiovascular system	0.00127	2	0.00096	1	0.00112	2
Respiratory system	0.00071	4	0.00046	3	0.00059	3
Injury and poisoning	0.00087	3	0.00027	4	0.00058	4
Infectious diseases	0.00027	5	0.00011	5	0.00027	5

Source: Fan and Liu (2007)

The above mentioned policies of controlling air pollution are based on ad hoc information, notably practices and standards applied elsewhere in China. For the further development and implementation of environmental policies in Jinchuan, people's preference for reducing air pollution should be considered. This thesis will provide further information for the development of long and short run air pollution reduction policies by uncovering residents' understanding and assessment of Jinchuan's environmental issues, especially air pollution. Before turning to the objectives and an outline of this thesis, I present a synopsis of valuation methods of environmental quality related to health issues.

1.5. VALUATION OF THE HEALTH EFFECTS OF AIR QUALITY

Air quality is a non-traded commodity. Consequently, it has no price which can be used to measure people's valuation of health effects air quality. Hence, to uncover people's preferences for improving air quality, alternative approaches need to be applied. In this thesis I apply two types of methods, viz choice experiment (CE) and the averting behavior method (ABM). They are based on the notion that to reduce the negative health effects of air pollution, people take risk reducing actions, for instance, installing air filters and purchasing health care services. The methods are based on the assumption that individuals maximize their utility or well-being, made up of a composite good and health status, subject to a budget constraint (Um et al., 2002). The outcome of this constrained utility maximization exercise is that optimal behavior is a function of*, inter alia*, the level of pollution, the price of risk reducing behavior, and socio-economic and demographic characteristics.

Specifically, consider an individual whose utility depends on consumption of a composite good (X), and health status (H). Hence, the individual's utility maximization problem can be expressed as

$$U = U\,(X, H) \tag{1.1}$$

where. Health status, in turn, is produced by combining risk reducing behavior (RRB) and air pollution level (P):

$$H = H\,(RRB, P) \tag{1.2}$$

Where . The individual maximizes utility subject to the budget constraint

$$X + CB\,(CH, P)\,RRB = Y \tag{1.3}$$

where Y is income and CB(.), which is the cost of RRB. The latter is functionally related to air pollution (P) and the individual's socioeconomic characteristics (CH) including age, education level, perceived health risk, etc. (see Um et al., 2002). By convention, the price of one unit of the composite good (X) is set to 1 (See Besanko., et al., 2011).

The Lagrangian of the above constrained utility maximization problem is:

$$L = U\,(H, X) - \lambda\,(X + CB\,(CH, P)\,RRB - Y) \tag{1.4}$$

Solving the first-order equations of equation (1.4) gives the optimal choices of X, RRB and λ as functions of all exogenous variables (Bresnahan, 1997). We thus obtain the individual's risk reducing demand function (1.5):

$$RRB = RRB\,(CH, P, Y) \tag{1.5}$$

Equation (1.5) indicates that RRB is a function of air pollution level (P), income (Y) and the individual's characteristics (CH).

People's Willingness To Pay (WTP) for reducing air pollution can be calculated by maintaining constant utility and observing how the cost of RRB varies with air pollution. The WTP for a small (unit) change of air quality is (Freeman, 2003):

$$\mathrm{WTP} = \frac{\partial \mathrm{CB}}{\partial \mathrm{P}} \tag{1.6}$$

ABM is a cost-based model. That is, the costs of commodities used to avoid negative health effects from pollution are taken as indications of the valuation of environmental quality. The model is based on the assumption that when people expect negative impacts of pollution on their well-being, they will adapt their behaviours to avert or reduce these negative effects. Therefore, information on what individuals do to protect themselves against environmental and other risks can be used to infer individuals' preference for reducing these risks.

The advantage of ABM is that the data reflect real behavior (though in this thesis obtained via a survey) and take into account various constraints on individual decisions, such as market imperfections, budgets and time constraint (Louviere et al., 2000). The disadvantage of ABM is that it is limited to individual's behaviors which are taken to offset environmental degradation (Hadley et al., 2011).

In a CE, the analyst designs choice alternatives, in the present thesis diseases of varying duration, with varying symptoms, and cures with different prices. Respondents are asked to choose the preferred alternative. More generally, the alternatives vary by levels of factors or features of the non-market good (e.g. health risk) and price (cost) which is the amount of money that people are willing to pay for purchasing the alternative. In a CE the impacts of the attributes that influence choices are analyzed from which the WTP for reducing health risk or improving air quality are derived.

CE has been criticized because the behavior analyzed is intentional rather than real (Cummings et al., 1986; Mitchell and Carson 1989) and thus fails to take into account certain types of real market constraints on individual decisions, for example market imperfections, budget and time constraints (Louviere et al., 2000). Nonetheless, CE mimics consumers' purchase situations by presenting a set of predetermined choices to them. It is a suitable method for valuing environmental goods that typically are multi-attributes goods (Baarsma, 2003) in that it focuses on changing attribute levels rather than on losing (or gaining) the environmental bad (good) as a whole (Hanley et al., 1998). A disadvantage of CE compared to ABM is that the latter in principle takes the entire spectrum of risk reducing behaviors into while CE only considers a limited number of alternatives. CE and ABM are complements rather than substitutes in that the former is an in-depth analysis while the latter is a comprehensive analysis.

1.6. RESEARCH QUESTIONS

The main objective of this thesis is to analyze how Jinchuan residents' welfare is influenced by local air pollution. For that purpose their behavioral responses to air pollution will be analyzed. The behavioral responses are the activities taken by residents to protect themselves and their family members from serious air pollution risks. In addition, a comprehensive analysis will be undertaken by estimating the impacts of air pollution on Jinchuan residents' happiness.

Based on this general objective, the following four research questions will be addressed based on a survey among the residents of Jinchuan:

1. *What is the relationship between environmental knowledge and perceived health risk caused by air pollution? In addition, how are both variables influenced by socio-demographic characteristics?*

Conventional economics assumes that individuals are utility maximizers, based on perfect knowledge. In spite of its widespread use, a disadvantage of this assumption is that it neglects psychological and sociological factors that are also important determinants of people's behavior. Specifically, Folmer (2009) argues that knowledge is imperfect, and that perception, expectations and habits are also strongly correlated with people's behavior. Ignoring an individual's internal process of behavior formation, and the factors that play a role in it, notably perceptions and knowledge, will lead to inadequate explanations of people's behavior (Temme et al., 2008; Johansson et al., 2006). Hence, to better understand people's behavioral responses to air pollution, insight into psychological factors, particularly, environmental knowledge and perceived health risk,in addition to conventional explanatory variables like socio-economic characteristics, is needed.

2. *What are the determinants of Jinchuan residents' choices in a choice experiment (CE) aimed at reducing the acute health risks*[2] *acute upper respiratory tract infection, acute bronchitis and acute pneumonia? Furthermore, how much are people willing to pay for reducing these acute health risks correlated with air pollution?*

Conventional CE studies conducted to value people's preference for reducing health risks caused by environmental degradation commonly explain choice behaviors in terms of illness characteristics like type of illness, duration, and price of cure, and socio-demographic characteristics such as age, income, education, and so on. However, they tend to ignore the role of psychological factors in preference formation (notably perception and knowledge) which may lead to biased estimators and thus inadequate explanation of behavior (Ajzen, 1991; Um et al., 2002; Menon et al., 2008; Folmer, 2009; Folmer and Johansson-Stenman, 2012). To the best of our knowledge, psychological factors are not routinely incorporated in CEs of health risk related to environmental issues including air pollution. Therefore, in a bid to reduce possible model under-specification, we include the latent psychological variables environmental knowledge and perceived health risk in the Jinchuan s CE study, in addition to the conventional explanatory variables, notably illness characteristics and socioeconomic characteristics.

3. *What are the kinds of averting behaviors that the residents of Jinchuan take to reduce all possible kinds of perceived health risks associated with air pollution? Additionally, how much are people willing e to pay for reducing health risks?*

Traditionally, the costs of risk reducing actions and socio-economic characteristics (e.g. age and education) are considered when explaining averting behaviors. However, various researchers have pointed out that socio-psychological factors, such as knowledge, perception, attitude and expectations may have substantial impacts on (environmental) behavior (Ajzen, 1991; Menon et al., 2008; Folmer, 2009; Folmer and Johansson-Stenman, 2011; Duerden and Witt, 2010; Shogren and Taylor, 2008; Hammitt, 2013). For instance, Cottrell (2003) found that environmental attitudes explain 23.8% of the total variance in people's environmental behavior whereas Tang et al. (2013) shows that perception is the most important determinant of irrigation water use efficiency in the Guangzhong Plain, China. Therefore, extending averting behavior research with psychological factors – particularly perceived health risk and environmental knowledge – is likely to lead to a better understanding of decision processes (Temme, 2008). Hence, averting behavior research should not only consider socio-economic characteristics (income, age), but also knowledge of environmental issues and their perception of health risks.

4. *What are the determinants of happiness? Particularly, how does air pollution impact on happiness?*

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[2] These illnesses are common and clearly discernible risks of air pollution. This feature facilitates respondents' understanding of the health problem at hand, and thus of making a choice. See amongst others Bresnahan (1997) who points out that people are more sensitive to take actions against acute health problems than to chronic health impairments.

The traditional economic yardsticks to the measurement of well-being, such as equivalent and compensating variation, are money measures derived from the notion that individuals maximize utility under a budget constraint (Varian, 1992; Suzanne and Lynne, 2005). Despite their widespread use, there is consensus among a growing group of economists that the traditional money measures of well-being are subject to fallacies (see e.g. Gowdy, 2004; Rehdanz and Madison, 2008; Welsch, 2009). Specifically, they ignore the fact that individuals are not merely acting to maximize utility under a budget constraint (Folmer, 2009, and the references therein); nor do they fully cover the relevant dimensions of well-being (Sumner, 2006; Folmer, 2009). To fill the gap between the narrowly defined money measures and a more comprehensive notion of well-being, the notion of happiness has been introduced into the environmental economics literature (see inter alia Welsch, 2009). As a final step in the evaluation of air pollution in Jinchuan, I will estimate its impact on happiness.

1.7. OUTLINE OF THESIS

Chapter 2 analyzes the interaction between environmental knowledge and perceived health risks due to air pollution. It is based on the assumption that ignoring individual's psychological factors, which are internal processes of behavior formation, will lead to inadequate explanations of people's behaviour. In this chapter, I develop a comprehensive theoretical environmental knowledge- perceived health risk model and a set of observable test items of the latent variables. I apply structural equation modeling (SEM) to test the validity of the indicators of the latent variables and to estimate the environmental knowledge - perceived health risk model.

Chapters 3 and 4 focus on the question: what are the determinants of Jinchuan residents' behaviors to protect themselves and their family members to health risk caused by air pollution? Chapter 3 focuses on people's choice of cures that can be used to avoid acute health risks correlated with air pollution. In the literature, much attention has been paid to how people's socio-demographic characteristics influence their choice mode; however, there is little knowledge of the effects of psychological factors, notably environmental knowledge and perceived health risk on choice mode, Thus, in Chapter 3, apart from socio-demographic characteristics, the explanatory power of people's psychological factors on their choice mode will be considered. Previous methodological research will be extended by merging random parameter logit models (RPL) with structural equation modeling (SEM). Moreover, Jinchuan residents' mean household WTP for avoiding selected acute illnesses are estimated.

Chapter 4 focuses on Jinchuan residents' total averting behaviours related to air pollution. When people face serious air pollution, three categories of action can be taken to mitigate negative health effects (Brenham et al.,1997):

- Investments that improve air condition indoors; for example, installation of air filters.
- Taking preventive and curing medication and foods.
- Adjusting activities, particularly spending more time indoors, by limiting, rescheduling, or otherwise changing planned outdoor leisure activities.

Averting behavior is taken as a latent variable and measured by the above three categories of actions. Moreover, the effects of people's socio-demographic characteristics, and their psychosocial factors - notably, environmental knowledge and perceived health risk - on their averting behaviour is analyzed with structural equation modeling (SEM). In addition, Jinchuan residents' mean household willingness to pay (WTP) for avoiding health risk correlated with air pollution is estimated.

Chapter 5 presents an empirical analysis of the determinants of happiness. Happiness is taken as an individual's evaluation of her or his overall quality of life (Veenhoven, 1999). This chapter presents a four-equations, structural equation model (SEM) of happiness, as influenced by environmental knowledge, perceived health risk and socio-economic and demographic variables.

Finally, Chapter 6 presents a summary of the main findings of the study and their policy implications. It also contains some suggestions for further research.

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Chapter 2

Environmental Knowledge and Perceived Health Risk among the Residents of the Jinchuan Mining Area, China

ABSTRACT

This paper applies a structural equation model (SEM) to analyze the formation of environmental knowledgeand perceived health risk correlated with air pollution, based on a cross-sectional dataset of 759 residents of the Jinchuan mining area, Gansu Province, China. We find that perceived risk due to intensity of exposure is influenced by ability and proximity to pollution source. Environmental knowledge, family health experience, family size and proximity to the pollution source are important determinants of perceived health risk due to hazard pollutants risk. Environmental knowledge in its turn is functionally correlated with age, work environment and ability. On the basis of our findings, we conclude that virtually all Jinchuan residents perceive air pollution as a serious health risk. To assist the residents to take appropriate preventive action, the local government should develop counseling and educational campaigns and institutionalize disclosure of air quality conditions. The programs should pay special attentionto young residents who have limited knowledge of air pollution in the Jinchuan mining area.

2.1 INTRODUCTION

Economic development, particularly rapid industrialization, has greatly increased energy consumption in China in recent decades. As a consequence, since the 1980s, many cities have suffered from rapidly increasing air pollution. In the early 1990s, less than one of over 500 cities reached as far as Class I (the least serious of three levels) of the national air quality standards (He, 2002). Wei et al. (2012) points out that China's Pollution Control Performance (PCP) has improved rapidly but that there is a large regional imbalance with the PCP of Eastern China being much better than that of Central and Western China.

Jinchuan, which is located in the West, is one of the ten cities with most polluted air in China (Wei, 2008). It has the largest nickel resource and mining and smelting industries dominate its economy and thus make a substantial contribution to its development. However, the two industries also create serious environmental problems including industrial solid wastes, and soil, water and air pollution. The main pollutants of Jinchuan's air pollution include suspended particles, sulfur dioxide, chlorine gas and carbon dioxide. (Xiao, 2003; Wei, 2008; Li and Zhao, 2004; Huang et al., 2009). The first three of them contribute to illnesses such as cancer, respiratory illnesses, and cardiovascular illnesses (Kampa and Castanas, 2008).

The present paper analyses Jinchuan residents' perceived health risk correlated with air pollution. Perceived risk, which is people's judgment or assessment of hazards or dangers that might pose immediate or long-term threats to their well-being (Adeola, 2007), is thought to be a reliable predictor of preventive behavior. For instance, Ajzen (1991) points out that a better perception and understanding of risk will allow people to make better informed risk reducing behavioral choices for themselves and their families and thus increase their welfare. When people face environmental pollution, a variety of morbidity or mortality risks reducing actions can be observed, for example, installing air and water filters, visiting health clinics for preventive care, changing planned leisure activities, and so on. Put differently, people's averting behaviors are influenced by the risk they perceive. For instance, Um et al. (2001) studied the use of tap water in Korea and found that risk perception is an important determinant of averting behavior. Therefore, it is important to understand what determines perceived risk.

Conventional economics assumes that individuals are utility maximizers, based on perfect knowledge. In spite of its widespread use, a disadvantage of this assumption is that it neglects psychological and sociological factors that are also important determinants of people's behavior. Specifically, Folmer (2009) argues that knowledge is imperfect, and that perception, expectations and habits are also strongly correlated with people's behavior. Ignoring an individual's internal process of behavior formation,and the factors that play a role in it, notably preferences, but also other variables that are not directly observable, such as attitudes, perception and knowledge, will lead to inadequate explanations of people's behavior (Temme et al., 2008; Johansson et al., 2006). Hence, to understand people's responses to air pollution, insight into psychological factors, particularly, environmental knowledge and perceived risk, is needed. This insight in its turn is a prerequisite for adequate and effective advise, counseling and education.

Perception of environmental health risks has become a multidisciplinary field of research. Several studies on perceived risk correlated with environmental issues have been done by psychologists, economists, anthropologists, geographers and sociologists. Below we present a very brief review. Lau and Tao (2003) analyzed people's perceived risk of 25 environmental hazards (e.g. earthquakes, indoor air pollution, loss of wetland, etc.) based on a sample of Hong Kong residents, and found that women, older participants, and less educated individuals consider the hazards to be more threatening than did men, younger participants, and more educated individuals. Robinsona et al.(2012) conducted a study in Amelia County, VA, and Knoxville, TN, US, on bio-solids recycling to assess current knowledge, attitudes and risk perceptions. Significant gender differences were observed with females perceiving greater risks to health and safety than males. Toma and Mathijs (2007) found that environmental risk perception is the strongest determinant of farmers' propensity to participate in organic farming programs. Hanley (2001) identified risk perception as an important determinant of the willingness to pay for risk-reduction in a study on radioactive contamination following nuclear accidents in Norway and Scotland. Arcury et al. (2002) conducted a survey among 293 farm workers in eastern North Carolina, US, and found that farm workers had fairly high levels of perceived health risk from pesticides. Doria et al. (2009) analyzed public perception of the quality and risks of drinking water based on data collected in the UK and Portugal, and found that health risk perception is influenced by flavor, perceived water chemicals (lead, chlorine, and hardness), past health problems, and trust in water suppliers. Zhang and Fan (2013) investigated the perception of health risks among college students in China, and found that natural catastrophes, pollution (chemical pollution, air pollution), and pesticides in food were ranked as being relatively high health risks, while long-term environmental risk (global warming) were less important.

Studies on perceived health risk correlated with air pollution are less common. Richardson (2011), who analyzed the economic health costs of exposure to wildfire smoke, found that perceived risk has a positive and significant effect on households' averting activities. Elliott (1999) assessed the potential health risks associated with adverse air quality in Hamilton, Ontario, Canada, and observed that perceived health risk correlated with air pollution is an important determinant of health concern. Catalán-Vázquez et al. (2009) analyzed the relationship between air pollution and perception of health risk in a sample of students in Mexico City, and found that gender and zone where the school is located are determinants of health risk perception.

The main objective of the present paper is to get further insight into the determinants of perceived health risk of local air pollution, which, as mentioned above, has received relatively little attention in the literature. This applies, especially to China. A better understanding of the factors that shape perception of health risks correlated with air pollution could stimulate the national and local governments to develop counseling and education campaigns in the short run and air pollution abatement and management programs in the long run. Since cognitive aspects are strongly correlated with perceived health risk (Menon et al., 2008), we will take into account the effect of people's environmental knowledge on their perceived health risk and vice versa. The analysis is based on a survey conducted in the Jinchuan mining area. It includes information on respondents' socio-demographic characteristics, their environmental knowledge and perceived health risk.

The paper is organized as follows. Section 2.2 presents the conceptual model. It defines the endogenous variables perceived health risk and environmental knowledge and specifies the relationships among the endogenous variables mutually and among the exogenous and endogenous variables. Section 2.3 describes the methodology (SEM), section 2.4 the survey, the data and the empirical results. Section 2.5 concludes.

2.2 CONCEPTUAL MODEL

The perceived health risk-environmental knowledge (PHR-EK) conceptual model is presented in Figure 2.1. Below, the variables in the PHR-EK model, their relationships and the expected signs of their impacts will be briefly discussed. First, we pay attention to the endogenous variables: perceived health risk (PHR) and environmental knowledge (EK). Next, we discuss the exogenous variables of PHR and EK, i.e. ability, age, family size, family health experience, proximity to the pollution source, and work environment, and their expected impacts.

2.2.1 Endogenous variables

Perceived health risk (PHR)

The main dependent variable of the PHR-EK model is perceived health risk. Menon et al.(2008) defines it as the subjective likelihood of the occurrence of a negative event related to health for a person or a group of people over a specified time period. In other words, perceived health risk is the subjective assessment of the probability of suffering from an illness and the concern about the consequences (Sjöberg, 2004;Sutton, 1999). In this paper, perceived health risk is measured as follows.[1] First, respondent's perception of the likelihood of occurrence of air pollution in Jinchuan was measured by the question: "what do you think is the average number of days per week Jinchuan's air was heavily polluted during the past year?". Second, to measure perception of the consequences, four major types of health problems were presented to the respondents. They were asked to what extent they believed that Jinchuan's airpollution increases the possibility of suffering from each of them. The four major health problems include: respiratory diseases, cardiovascular diseases, lung cancer and death. (See Figure 2.3 for details).

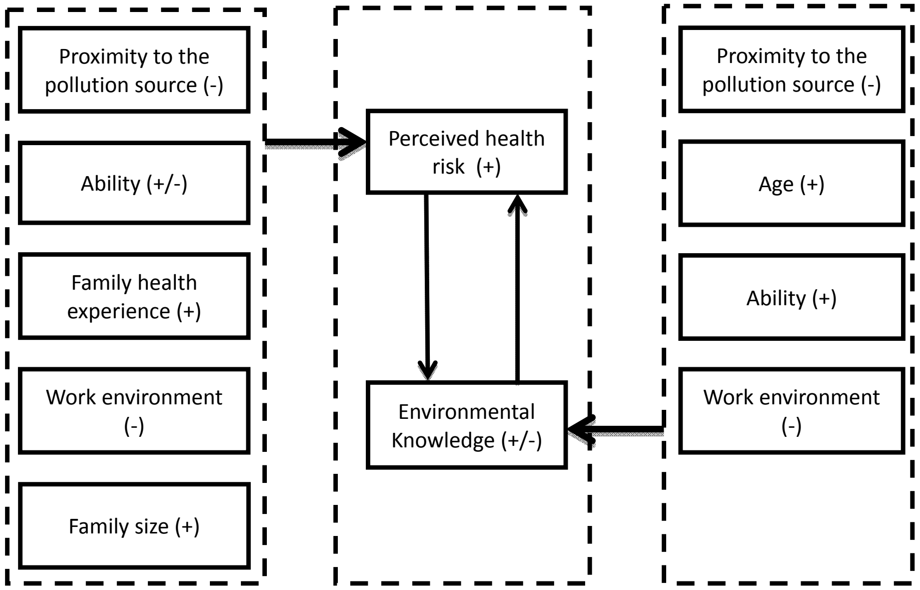

Figure 2.1 The Perceived Health Risk - Environmental Knowledge (PHR-EK) model
Note: within brackets: expected sign

Environmental knowledge (EK)

Following Berkes et al. (2000), we define environmental knowledge as the cumulative body of knowledge of the interdependency between human society and its natural environment. Hence, the more people know about an environmental problem, its nature and causes, the better they are able to predict its consequences and to take preventive actions or safety measures to avoid or reduce its negative impacts. We measure Jinchuan residents' environmental knowledge by means of eight items. The first four relate to general environmental issues and their causes, the remainder to the main air pollutants in the Jinchuan area (Figure 2.2).

From the above it follows that the distinguishing feature between perceived health risk and knowledge is that the former refers to the evaluation and assessment ofan environmental problem, whereas the latter refers to the understanding of it. We assume that perceived health risk and environmental knowledge interact. First of all, environmental knowledge is an important determinant of perceived health risk (Raghubir and Menon, 1998), although there exists uncertainty about the sign of the relationship in the literature. That is, environmental knowledge may positively or negatively impact on perceived health risk. Wallquist et al. (2010) studied how knowledge of Carbon Dioxide Capture and Storage (CCS) impacts on perceived risk and found a negative relationship between knowledge and people's concerns. On the other hand, in a study of farmworkers' risk perception of pesticides in Carolina, Arcury et al.(2002) found a positive relationship: better knowledge of a pesticide increased the perception of the risk due to the exposure to it. A positive effect was also found by Bernardi (2002) who investigated the determinants of risk perception of getting infected by HIV/AIDS with data from the Kenya Diffusion and Ideational Change (KDIC) Project. For this study, the sign is an empirical matter.

We also assume a reverse effect: perceived health risk influences people's environmental knowledge. In a study on the fiscal implications of climate change, Osberghaus and Reif (2010) noted that risk perception works as a motivation to collect more information about the risk. Davies (1996) conducted a research on tuberculosis in the UK and found that risk perception of tuberculosis induces people to look for information. We assume that the stronger a Jinchuan resident's risk perception, the more environmental knowledge they have. We now turn to the exogenous variables.

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[1] Like environmental knowledge and ability, perceived health risk is a latent variable or theoretical construct that cannot be directly observed. However, it can be measured (indirectly observed) via indicators (Folmer and Oud, 2008). For further details, see section 3.

2.2.2 Exogenous Variables

Age (AGE)

We assume that age positively influences environmental knowledge. The rationale is that older people have lived in Jinchuan for a longer spell of time and thus have more life experience and better knowledge about Jinchuan's mining and smelting industries than younger generations. This assumption is supported by Aminrad et al. (2011) who studied the influence of age on environmental knowledge of students (Bs, Ms and PhD) at Malaysian universities. They divided students into three group based on their age (17-25, 26-40, >40) and found a positive impact of age on environmental knowledge. Khamees (2009) comes to a similar conclusion in a studyon people's knowledge of indoor air pollution in Kuwaiti. Regarding perceived health risk, we do not hypothesize a direct age impact but rather, an indirect effect via environmental knowledge. We distinguish 7 age classes (see Table 2.1 for details).

Proximity to the pollution source (PPS)

The number of studies on the relationship between proximity to a pollution source and environmental knowledge is very limited. One of the few exceptions is Mirzaei et al. (2012), who studied noise pollution in Zahedan, Iran. The authors did not find evidence of differences in peoples' knowledge based on distance from the pollution source. We nevertheless assume that proximity to the pollution source negatively influences environmental knowledge. The rationale is that the closer one lives to the pollution source (smelting plant), the stronger exposure to air pollution and the stronger the motivation to pay attention to it and to collect information on it.

We also assume that proximity to the pollution source negatively influences perceived risks. The rationale is that respondents who live further away from the smelting plants are less exposed to air pollution than those who live nearby. Bickerstaff and Walker (2001) conducted research on how residents of Birmingham, UK, thought about urban air pollution. They found that air quality perception is spatially bounded and follows a source-directed distance-decay relationship. Using data from a survey addressing mortality risks related to transporting high-level radioactive waste to a Yucca Mountain storage facility in Nye County, Nevada, Riddel (2009) found that perceived mortality risk falls as the distance from the transport route increases.Similar results were also found by Combest-Friedman et al. (2012). We distinguish three distance categories: (1) SAP(Nearby smelting plants, serious air pollution area), (2) MAP (medium polluted area) and (3) LAP (far away from pollution source, light air pollution area).

Work environment (WE)

We expect people working in the Jinchuan mining company (JMC) to have better knowledge of Jinchuan's environmental issues than non-JMC employees because JMC is the source of Jinchuan's environmental issues. The reason is that JMC employees, especially miners and smelter workers, know more about the input and output of the smelting process than non-JMC employees. This hypothesis is supported by Juang et al. (2010), who investigated the effects of noise pollution on medical staff.They found that people's work environment has a significant effect on their knowledge of itincluding pollution issues. Similar results were found by Arcury et al. (2002).

We also assume that one's work environment negatively influences one's perceived health risk. That is, a better work environment is associated with lower perceived health risk. The work environment of JMC's employees, especially of the miners and smelter workers, is harsh. Their work places are located in the plant or mine where the most serious air pollution problems are generated. Thus, the JMC employees, especially the ones who work in the mine or smelter, are more at risk than non-JMC employees. The assumption is supported by Rundmo (1995), who conducted a study in Norway on oil workers' perceived risk correlated with offshore installations in the North Sea. The author found that oil workers assigned to offshore installations with high incident records had higher risk perception and were more concerned about safety than their peers at installations with lower incident records. We distinguish 3 work environment classes: (1)MS (miners and smelter workers of JMC), (2) NMS (people who are the employees of JMC, but not miners or smelter workers) and (3) NMC (non-JMC staff).

Ability (AB)

We define ability as the intellectual capacity to adequately understand problems and to act according to one's skills or talents (Benshoff and Griffin, 2009). It is a latent variable that needs to be measured via indicators. A large variety of observable variables of ability have been developed, including income and education that are used in this study (see Chamorro-Premuzic and Furnam, (2002); Mackay (2007); and Finnie and Mueller (2008) for overviews). Smedley and Syme (2001) point out that people with higher ability commonly achieve higher education levels and earn more than individuals with lower ability. We assume that ability positively impacts on environmental knowledge. That is, people with higher ability are more interested and more actively involved in environmental issues. Therefore, they commonly know more about this kind of problems (Diamantopoulos et al., 2003). George et al.(2013) conducted a study on people's awareness of arsenic in well water in Singair, Bangladesh, and found that people's ability is positively correlated with their knowledge. The hypothesis is also supported by Ogunbode and Arnold (2012) who examined knowledge, awareness and attitudes in Ibadan, south-western Nigeria across socio-demographics categories. They found that people with higher income and education have more environmental knowledge.

We also assume a direct impact of ability on perception of health risk. The literature is ambiguous about the sign of the impact. Khan (2013) studied people's concern about the health effects of pesticide use in Pakistan and found that income and education are positively correlated with people's perception of health risk. Similar results were found by Ndunda and Mungatana (2013) who analyzed the determinants of farmers' perception of health risks of wastewater irrigation in Nairobi, Kenya. On the other hand, Lee et al. (2008) analyzed datafrom a national survey in Canadaand found that ability is negatively correlated with perception of health risk. Education is measured as the highest degree obtained and income as after tax income (see Table 2.1 for details).

Family size (FS)

We assume that family size positively impacts on perceived health risk because in larger families more people are at risk than in smaller families. This assumption is supported by Njagi (2013) who found that family size is positively correlated with perceived health risk related to the proximity of a dump sitein Nairob, Kenya. Ndunda and Mungatana (2013) also found that family size is a positive predictor of perceived health risk.We do not assume a direct impact of family size on environmental knowledge. In this paper we define family size as the number of family members who live in the same house.

Family health experience (FHE)

We assume that family health experience positively impacts on perceived health risk. This assumption is supported by Howell et al. (2003) who found a positive relationship between people's perceived risk of air pollution and their health experiences in Northeast England. Similar results were found by Bickerstaff and Walker (1999) and Krueger (1999). We do not hypothesize a direct impact of family health experience on environmental knowledge but rather an indirect effect via perceived health risk. We measure family health experience by means of a dichotomous variable which takes the value 1, if the respondent, or one or more of his or her family members, have been hospitalized for cardiovascular diseases or respiratory diseases, and 0 otherwise (see Table 2.1).

2.3. METHODOLOGY (SEM)

The PHR-EK model contains both observed variables (e.g. age and family size) and latent variables (ability, perceived risk and environmental knowledge). To handle both types of variables within one model framework, we apply structural equation modeling (SEM). A SEM is made up of three sub-models: the structural model and two measurement models (Jöreskog and Sörbom, 1996).[2] Equation (2.1) is the structural model which specifies the relationships among the latent variables:

$$\boldsymbol{\eta} = \boldsymbol{B}\boldsymbol{\eta} + \boldsymbol{\Gamma}\boldsymbol{\xi} + \boldsymbol{\zeta} \tag{2.1}$$

where $\boldsymbol{\eta}$ and $\boldsymbol{\zeta}$ are the m×1 and n×1 vectors of latent endogenous and exogenous variables, respectively. The (m×m) matrix $\boldsymbol{B}$ contains the structural relationships among the latent endogenous variables. The impacts of the exogenous latent variables on the endogenous latent variables are given by $\boldsymbol{\Gamma}$ which is an (m×n) matrix. ζ is a random (m×1) vector of errors with covariance matrix $\boldsymbol{\Psi}$ (m×m).The covariance matrix of ζ is $\boldsymbol{\Phi}$ (n×n).

Equation (2.2) and equation (2.3) are the measurement modelsthat present the relationship between the latent variables and their indicators:

$$\mathbf{y} = \boldsymbol{\Lambda}_y\boldsymbol{\eta} + \boldsymbol{\varepsilon} \tag{2.2}$$
$$\mathbf{x} = \boldsymbol{\Lambda}_x\boldsymbol{\xi} + \boldsymbol{\delta} \tag{2.3}$$

where $\mathbf{y}$ and $\mathbf{x}$ are the p×1 and q×1vectors of observed endogenous and exogenous variables, respectively. The (p×m) and (q×n) matrices $\boldsymbol{\Lambda}_y$ and $\boldsymbol{\Lambda}_x$, specify the relationships (loadings) between y and x and their corresponding latent variables $\boldsymbol{\eta}$ and ξ, respectively $\boldsymbol{\varepsilon}$ and $\boldsymbol{\delta}$ are the measurement errors with covariance matrices $\boldsymbol{\Theta}_\varepsilon$ (p×p) and $\boldsymbol{\Theta}_\delta$ (q×q), respectively.[3]

Estimation of a SEM comes down to the minimization of thedistance between the sample covariance matrix, $\boldsymbol{S}$, and the theoretical covariance matrix $\Sigma = \Sigma(\boldsymbol{\theta})$ with θ the vector of unknown parameters of model (1)-(3). The methods that can be used to estimate a SEMinclude Generalized Least Squares (GLS), Two-Stage Least Squares (TSLS). Unweighted Least Squares (ULS), Instrumental Variables (IV), Maximum Likelihood(ML) and Weighted Least Squares (WLS) (Jöreskog and Sörbom, 1996). ML, which is most

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[2] It is possible to combine the two measurement models (Oud and Folmer, 2008). Furthermore, means and intercepts can be included in the system. However, we delete them here because in the application we standardize all variables

[3] Note that a directly observed variable can be straightforwardly handled in the SEM framework by defining it identical to its corresponding latent variable and accordingly specifying an identity relationship in the measurement model.

widely used, assumes that the observed variables are continuous and follow a multivariate normal distribution. However, when the data is highly non-normal, as in the present paper, ML will give biased standard errors and inflated test statistic of the overall model fit (West et al., 1995). In that case weighted least squares (WLS) can be applied (Browne, 1984; Jöreskog and Sörbom, 1989, 1993, 1996).

Estimation can be done by means of the software packages Lisrel 8, OpenMX (in R), AMOS and Mplus. Lisrel 8, which will be applied in this paper , is probably best known (for details, see Jöreskog and Sörbom, 1996). Lisrel 8 also provides information on identification and various test statistics, for instance, of the overall goodness of fit, z-statistics for each parameter and s for the measurement models and the structural model. Moreover, it provides modification indices which can be used to improve the model fit by freeing constrained or fixed parameters.

2.4. EMPIRICAL RESULTS

2.4.1 Survey and data collection

A survey was conducted in August 2012 in the Jinchuan mining area, Gansu province, China, via face to face interviews. A stratified-random sample of 800 respondents was selected. Stratification was based on the degree of pollution: severely, moderately and lightly polluted areas. Selection within the districts was random. The questionnaire contains questions about a respondent's environmental knowledge, perceived risks and socio-demographic characteristics.

2.4.2 Descriptive statistics

The total number of questionnaires that were available for analysis was 759. The dropout due to incompleteness was 5.12 percent (41). There was no evidence of non-random drop out.

Descriptive statistics are presented in Table 2.1, Figure 2.2 and Figure 2.3.

The distribution of the socioeconomic characteristics in Table 2.1 is in line with the population distribution of Jinchuan (see Statistical Yearbook 2010).

In order to examine how knowledgeable the respondents are about Jinchuan's environment, eight statements were presented to them (Figure 2.2). For each statement a five-point scale ranging from 1 (strongly disagree) to 5 (strongly agree) was used. The first three statements (EK1-EK3) measure knowledge of general environmental issuesin Jinchuan. As can be seen from Figure 2.2, the vast majority of the residents strongly agrees or agrees that air pollution, industrial solid waste, and water pollution are serious environmental issues. Regarding the causes (measured by EK4), almost all of the respondents (93.2%) knowthat local industries are the main source of Jinchuan's environmental problems. The last four statements (EK5-EK8) test people's knowledge of the main air pollutants. The results show that chlorine gas is known as the main pollutant (85.5%), followed by sulfur dioxide (82.3%), suspended particles (76%) and carbon dioxide (57.9%).

Table 2.1 Descriptive statistics for the observed exogenous variables

Variables	Min	Max	Mean	S.D
Age (AGE)	21	78	44.11	11.4
Family Size (FS)	1	6	2.95	0.78
Family health experience (FHE)	0	1	0.33	0.48

Education (EDU)	%	**Household Net Income (CNY per month) (IN)**	%
Primary school	6.30%	1000-2000	4.70%
Middle school	23.60%	2000-3000	15.30%
High school	25.30%	3000-4000	18.30%
Vocational school,	25.30%	4000-5000	19.10%
Bachelor's degree	19.10%	5000-6000	20.90%
Master's degree	0.40%	6000-7000	13.00%
Proximity to the pollution source (DPS)	%	7000-8000	3.70%
Nearby smelting plants, severe air pollution (SAP)	29.60%	8000-9000 9000-10000	1.80% 1.10%
Medium air pollution (MAP)	29.80%	More than 10000	2.00%
Far away from smelting plants, light air pollution (LAP, reference case)	40.60%		
Work environment(WE)	%		
Non-JMC employee (reference case)	59.55%		
Miners and smelter workers of JMC (MS)	18.18%		
JMC employee, but not miner or smelter worker (NMS)	22.27%		

Note: ***Family size:*** number of family members living in the same house. ***Current health condition:*** respondent's self -evaluation of his/her own current health condition. (5=very good, 4=good, 3= no good, no bad, 2=bad, 1=very bad).***Family Health experience***: 1 if the respondent or one or more of his/her family members have been hospitalized for cardiovascular diseases(e.g., hypertension, heart attack, chest pain, arrhythmia and miocardial infraction) or respiratory diseases (e.g., upper respiratory tract infection, bronchitis, pneumonia, asthma, and lung cancer), 0 otherwise.
Source: Author's survey

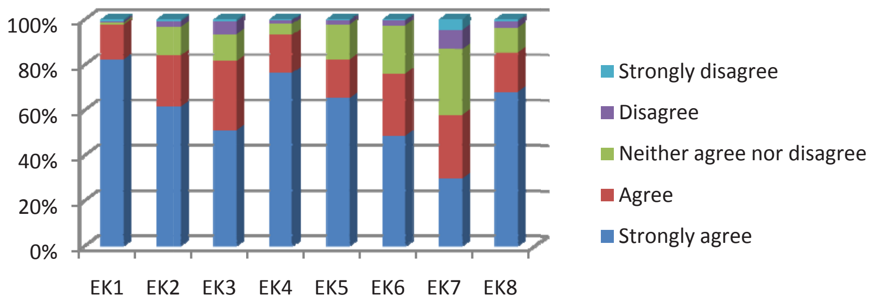

Figure 2.2 Frequency distribution of the indicators of environmental knowledge
Note: **EK1**: Jinchuan suffers from air pollution. **EK2**: Jinchuan suffers from industrial solid waste.**EK3**: Jinchuan suffers from water pollution. **EK4**: Environmental issues in Jinchuan are mainly caused by local industrial activities. **EK5**: Sulfur dioxide is one of the main air pollutants of Jinchuan. **EK6**: Suspended particles is one of the main air pollutants of Jinchuan. **EK7**: Carbon dioxideis one of the main air pollutants of Jinchuan. **EK8**: Chlorine gasis one of the main air pollutants of Jinchuan.
Source: Author's survey

Sjöberg et al. (2004) distinguishes two dimensions ofenvironmental risk perception: (i) subjective assessment of intensity of exposure to pollution, and(ii) subjective assessment of the consequences of exposure. We measurethe first dimension with the question: "How many days a week do you think the air in Jinchuan city was heavily polluted last year?". Figure 2.3 shows that the majority (62.1%) answered '2 or 3' days a week(medium exposure), 18.3% '4 or more days a week' (heavy exposure), and the rest (19.6%) 0 or 1 days a week (light exposure). The other indicators in Figure 2.3 measure people's perception of specific health risks, such as respiratory or cardiovascular illnesses (PHR2-PHR5). A five-point scale was used with 1 indicating strong disagreement and 5 strong agreement. Figure 2.3 shows that the vast majority (over 70 %)of the respondents either strongly believe or believe that air pollution increases the possibility of suffering from respiratory illnesses, lung cancer, cardiovascular illnesses and death.

2.*4.3 The estimated SEM*

In terms of equations(2.1)-(2.3), the conceptual model presented in Figure 2.1 reads as follows[4]:

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[4] To make the model identified and parameters interpretable, we fixed variances of latent variables as 1 to assign measurement scales to the latent variable. See Jöreskog and Sörbom (1996) for details.

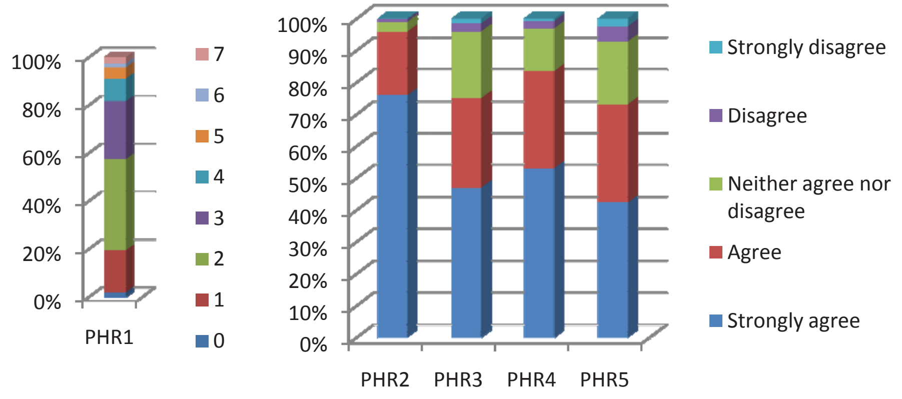

Figure 2.3 Frequency distribution of the indicators of perceived health risk
Note: **PHR1**: How many days a week do youthink the air in Jinchuan city was heavily polluted last year? **PHR2**: Jinchuan's air pollution increases the possibility of suffering from respiratory illnesses. **PHR3**: Jinchuan's air pollution increases the possibility of suffering from cardiovascular illnesses. **PHR4**: Jinchuan's air pollution increases the possibility of suffering from lung cancer. **PHR5:** Jinchuan's air pollution increases the possibility of suffering from death.
Source: Author's survey

The structural model reads

$$\begin{bmatrix} PHR \\ EK \end{bmatrix} = \begin{bmatrix} 0 & \beta_{12} \\ \beta_{21} & 0 \end{bmatrix} \times \begin{bmatrix} PHR \\ EK \end{bmatrix} + \begin{bmatrix} \gamma_{11} & \gamma_{12} & 0 & \gamma_{14} & \gamma_{15} & \gamma_{16} & \gamma_{17} & \gamma_{18} \\ \gamma_{21} & 0 & \gamma_{23} & 0 & \gamma_{25} & \gamma_{26} & \gamma_{27} & \gamma_{28} \end{bmatrix} \times \begin{bmatrix} AB \\ FS \\ AGE \\ FHE \\ MAP \\ SAP \\ NMS \\ MS \end{bmatrix} + \begin{bmatrix} \zeta_1 \\ \zeta_2 \end{bmatrix} \tag{2.4}$$

Measurement models

$$\begin{bmatrix} PHR1 \\ \vdots \\ PHR5 \\ EK1 \\ \vdots \\ WK8 \end{bmatrix} = \begin{bmatrix} \lambda^{y}_{11} & 0 \\ \lambda^{y}_{21} & 0 \\ \vdots & 0 \\ \lambda^{y}_{51} & 0 \\ 0 & \lambda^{y}_{62} \\ 0 & \lambda^{y}_{72} \\ \vdots & \vdots \\ 0 & \lambda^{y}_{13\,2} \end{bmatrix} \times \begin{bmatrix} PHR \\ EK \end{bmatrix} + \begin{bmatrix} \varepsilon_1 \\ \vdots \\ \varepsilon_5 \\ \varepsilon_6 \\ \vdots \\ \varepsilon_{13} \end{bmatrix} \tag{2.5}$$

$$\begin{bmatrix} EDU \\ IN \\ FS \\ AGE \\ FHE \\ MAP \\ SAP \\ NMS \\ MS \end{bmatrix} = \begin{bmatrix} \lambda^{x}_{11} & 000000 \\ \lambda^{x}_{21} & 000000 \\ 0 & 100000 \\ 0 & 010000 \\ 0 & 001000 \\ 0 & 000100 \\ 0 & 000010 \\ 0 & 000001 \end{bmatrix} \times \begin{bmatrix} AB \\ FS \\ AGE \\ FHE \\ MAP \\ SAP \\ NMS \\ MS \end{bmatrix} + \begin{bmatrix} \delta_1 \\ \delta_2 \\ 0 \\ 0 \\ 0 \\ 0 \\ 0 \\ 0 \end{bmatrix} \tag{2.6}$$

The data set contains several ordinal anddichotomous variables, particularly the indicators of perceived risk and environmental knowledge. Moreover, the distributions of these indicators are highly skewed and non-normal (see Figures 2.2 and 2.3). For these reasons, we estimate the PHR-EK model by WLS based on polychoric correlations.

As a first step, we estimatedthe complete conceptual model, as specified in equations (2.4)-(2.6) (denoted baseline model below). The baseline model contained several insignificant coefficients. We deleted the corresponding variables stepwise starting each step with the variable with the coefficient with the highest p-value. The resulting (final) model is presented in Tables 2.3 (measurement model) and 2.4 (structural model).

Comparison of the overall goodness of fit statistics of the baseline and the final model indicates whether the variables with insignificant coefficients were correctly deleted or not. The goodness of fit statistics presented in Table 2.2 are the Goodness-of-Fit Index (GFI), the $\chi2$/DF (DF denoting degrees of freedom), the Comparative Fit Index (CFI), the Incremental Fit Index (IFI), the Adjusted goodness-of-Fit Index (AGFI) and the Root Mean Square Error of Approximation (RMSEA) (see Bentler and Bonnet, 1980; Jöreskog and Sörbom, 1993; Byrne, 1998; Schreiber 2006; Tabachnick and Fidell, 2007; Ouyang, 2009 for details). The almost negligible differences between the baseline and final model goodness of fit statistics support the deletion of the insignificant variables. Particularly, GFI and AGFI are equal in the baseline and final models while the $\chi2$/DF has slightly deteriorated and the RMSEA, IFI and CFI have slightly improved.

Table 2.2 Overall goodness of fit indices

Fit index	Baseline model	Final model	Cut off value
Goodness-of-fit index (GFI)	0.98	0.98	>0.90
χ^2/DF	2.53	2.47	<3
Comparative fit index (CFI)	0.91	0.93	>0.90
Incremental fit index (IFI)	0.92	0.93	>0.90
Adjusted goodness-of-fit index (AGFI)	0.97	0.97	>0.80
Root mean square error of approximation (RMSEA)	0.045	0.041	<0.05

Before turning to the estimated models, we observe that to facilitate comparison of effects, we present standardized coefficients (beta coefficient). A standardized coefficient represents the standard deviation change in the dependent variable for a one standard deviation change in the corresponding explanatory variable. Below we first discuss the estimated measurement models and next the structural model.

The measurement models are shown in Table2.3. It presents the standardized coefficients (loadings), standard errors and reliability (R^2s). The reliability of each indicator is the proportion of variation of the indicator that is explained by its corresponding latent variables. Table 2.3 indicates that the indicators of the four latent variables(perceived risk due to intensity of exposure, perceived health risk due to hazard pollutants, environmental knowledge and ability) in final model allsignificantly load on their corresponding latent variables.

Table 2.4 shows the structural model. It presents the standardized coefficients, standard errors, and R^2s. As hypothesized in the conceptual model, environmental knowledge has a positive and significant impact on perceived risk due to intensity of exposure (PRL1) and perceived health risk due to hazard pollutants (PRL2). However, the reverse effect is highly insignificant in initial model. Therefore, this relationship is not included in the final model. A possible explanation is that the suffocating and pungent odor of sulfur dioxide and chlorine gas, which are the main observable air pollutants in the Jinchuan mining area, is sufficient evidence of the health risks that one runs. The persistence of the odor renders further knowledgeacquisitionredundant.

We now turn to the exogenous variables. We first discuss the exogenous variables of environmental knowledge (EK) and next those of perceived risk due to intensity of exposure (PRL1) and to hazard pollutants (PRL2). The final model shows that in line with its definition as the intellectual capacity to acquire and process information, ability positively and significantly influences environmental knowledge. Age also has a positive and significant impact on environmental knowledge, as postulated in the conceptual model. This result indicates that longer life experience in the Jinchuan mining area increases people’s knowledge about its mining and smelting industries and related environmental issues.Working environment is also an important determinant of environmental knowledge. Miners and smelter works of the mining company have more knowledge about Jinchuan’s environmental issues than the non-JMC employees.

We now turn to perceived risk. In addition to its indirect effect via environmental knowledge, ability also directly and significantly impacts on perceived health risk due to hazard pollutants (PHRL2). Its direct impact on perceived risk due to intensity of exposure (PHRL1) is positive, though marginally significant.The difference in impacts on PHRL2

Table 2.3 Measurement models (standardized coefficient)

Final model					Baseline model				
latent variables	**Indicators**	**Coefficient**	**Standard errors**	**R²**	**latent variables**	**Indicators**	**Coefficient**	**Standard errors**	**R²**
Perceived risk due to intensity of exposure (PHRL1)	PHR1	1.00	--	1.00	Perceived health risk(PHR)	PHR1	0.16	0.05	0.03
Perceived health risk due to hazard pollutants(PHRL2)	PHR2	0.59	0.03	0.35		PHR2	0.60	---	0.35
	PHR3	0.53	0.03	0.28		PHR3	0.53	0.05	0.28
	PHR4	0.62	0.03	0.38		PHR4	0.62	0.04	0.38
	PHR5	0.55	0.03	0.30		PHR5	0.55	0.05	0.30
Environmental knowledge (EK)	EK1	0.49	---	0.24	Environmental knowledge (EK)	EK1	0.49	---	0.24
	EK2	0.43	0.04	0.19		EK2	0.43	0.06	0.19
	EK3	0.43	0.04	0.19		EK3	0.43	0.07	0.19
	EK4	0.51	0.03	0.25		EK4	0.5	0.07	0.25
	EK5	0.57	0.04	0.32		EK5	0.57	0.07	0.32
	EK5	0.51	0.03	0.26		EK5	0.51	0.07	0.26
	EK7	0.36	0.03	0.13		EK7	0.36	0.07	0.13
	EK8	0.44	0.03	0.19		EK8	0.44	0.07	0.19
Ability (AB)	Education	0.48	0.05	0.23	Ability (AB)	Education	0.45	0.18	0.21
	Income	0.46	0.04	0.21		Income	0.46	---	0.21

Table 2.4 The structural model

	Final model			Initial model	
Variables	**EK**	**PHRL1**	**PHRL2**	**EK**	**PHR**
Perceived health risk (PHR)				0.22	
				(0.23)	
Environmental knowledge(EK)`		0.13***	0.66***		0.50***
		(0.04)	(0.08)		(0.30)
Ability (AB)	0.33	0.06***	0.14***	0.22***	0.29***
	(0.07)	(0.05)	(0.08)	(0.11)	(0.10)
Age(AGE)	0.09***	`		0.08**	
	0.03			(0.03)	
Family size (FS)			-0.08***		-0.09***
			(0.03)		(0.03)
Family health experience (FHE)			0.05*		0.06**
			(0.03)		(0.03)
Medium air pollution (MAP)		0.09***	0.06	-0.02	0.08*
		(0.03)	(0.04)	(0.04)	(0.04)
Serious air pollution (SAP)		0.19***	0.06	0.05	0.09**
		(0.03)	(0.04)	(0.04)	(0.04)
JMC employee, but not miner or smelter worker (NMS)	0.08			0.06	-0.03
	(0.05)			(0.05)	(0.05)
Miners and smelter workers of JMC (MS)	0.16***			0.12**	0.02
	(0.04)			(0.05)	(0.06)
R^2	0.13	0.05	0.51	0.19	0.37

Note: Standard errors in parenthesis. *, **and ***:10%, 5% and 1%

and PHRL1 is probably due to the fact that intensity of exposure is directly observable while perception of risk due to hazard pollution requires acquisition and processing of information. Family size has a negative impact on PHRL2 which is in contrast to the conceptual model. A possible explanation is that in larger families there is dampening of risk perception. For instance, in bigger families vital family tasks and duties can be shared by a larger number of family members when a family member is hit by a disease. In other words, bigger family implies larger capacity to absorb risks (Ajetombobi and Binuomote,2006; Amaefula et al.,2012)Family health experience has a positive impact on PHRL2, as hypothesized in the conceptual model. Finally, as expected, exposure to pollution due to living in severely and moderately polluted areas increases both PHRL1 and PHRL2, though the latter impact is marginally significant.

Table 2.5 presents the standardized total and indirect effects of all variables on all endogenous variables of the model. An indirect effect represents the effect of one variable on another through intervening endogenous variables (Jöreskog and Sörbom,1996).The total effect is the sum of the direct and indirect effects. Table 2.5 shows that serious air pollution (SAP), environmental knowledge, ability, and medium air pollution (MAP) are the four most important predictors of PHRL1 with total effects of 0.19, 0.13, 0.10, and 0.09, respectively. Age, miners and smelter workers (MS) and other JMC workers (NMS) also positively influence PHRL1 with total effects of 0.01, 0.01 and 0.02, respectively. The effect of NMS, however, is not significant.

Table 2.5 Standardized total and indirect effects of the final model

	Indirect effect			Total effect		
Variables	**EK**	**PHRL1**	**PHRL2**	**EK**	**PHRL1**	**PHRL2**
Environmental knowledge (EK)					0.13***	0.66***
					(0.04)	(0.08)
Family size (FS)						-0.08***
						(0.03)
Age (AGE)		0.01**	0.06***	0.09***	0.01**	0.06***
		(0.01)	(0.02)	(0.01)	(0.02)	(0.03)
Ability (AB)		0.04***	0.02***	0.33***	0.10***	0.35***
		(0.02)	(0.06)	(0.07)	(0.05)	(0.09)
Family health experience (FHE)						0.05*
						(0.03)
Medium air pollution (MAP)					0.09***	0.06
					(0.03)	(0.04)
Serious air pollution (SAP)					0.19***	0.06
					(0.03)	(0.04)
JMC employee, but not miner or smelter worker (NMS)		0.01	0.05	0.08	0.01	0.05
		(0.01)	(0.04)	(0.05)	(0.01)	(0.04)
Miners and smelter workers of JMC (MS)		0.02**	0.10***	0.16***	0.02**	0.10***
		(0.01)	(0.03)	(0.04)	(0.01)	(0.04)

Note: Standard errors in parenthesis. *, **and ***:10%, 5% and 1%

Table 2.5 shows that environmental knowledge has the largest positive total effect (0.66) on PHRL2, followed by ability with a total effect of0.35. Age and family health experience also positively and significantly influence PHRL2 with total effects of 0.06 and 0.05, respectively. Family size negatively and significantly influences PHRL2 with total effect -0.08. Although they have no direct effect on PHRL2, NMS and MS positively influence PHRL2 through environmental knowledge with total effects of0.05 and 0.10, respectively. The effect of NMS, however, is not significant

Ability is the most important determinants of environmental knowledgewith a total effect of 0.33. NMS and MS positively impact on environmental knowledge, but only MS is significant with a total effect of 0.16. Next is age (0.09).

2.5 CONCLUSION

In this paper we have analyzed health risk perception and environmental knowledge among residents of the Jinchuan mining area, Gansu Province, China, based on a cross-sectional dataset of 759 respondents. Structural equation modeling has been employed to estimate the simultaneous equations perceived health risk- environmental knowledge model.

The main finding is that Jinchuan residents are strongly aware of the gravity of air pollution in their city. Almost all of the respondents (97.8%) know that Jinchuan's air is heavily polluted and consequently more than 70% perceive health risks in that they believe that air pollution increases the possibility of suffering from cancer, cardiovascular illness, respiratory illnesses and death. Moreover, we have found that knowledge of the gravity of air pollution is the most important determinant of perceived health risk caused by air pollutants, followed by ability, proximity to the pollution source, family size, and family health experience. Another important finding is that environmental knowledge is influenced by ability, work environment and age.

Since environmental knowledge positively impacts on people's perceived health risk, information on air quality should be widely disclosed to allow Jinchuan's residents to take risk reducing actions. For instance, in combination with the weather forecast, information on local air quality conditions could be communicated and risk mitigating actions like reducing or abandoning outdoor activities could be recommended. The positive effect of age on environmental knowledge is also important from a policy perspective because it indicates that environmental knowledge among older age groups is better than among younger people. Therefore, more attention should be paid to young people's environmental education, e.g. in middle school.

To the best of our knowledge, the present study is the first on environmental knowledge and perceived health risk due to air pollution in China. Consequently, no prior information on measurement of these latent variables was available. Hence, the indicators derived and tested here have not been tested before. Therefore, further development and testing of indicators of environmental knowledge and perceived health risk is urgently needed, especially in the light of the alarming state of the environment in many Chinese cities. However, knowledge thus developed has substantially wider application because many cities in most developing countries are suffering from similar problems.

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Chapter 3

Valuing acute health risks of air pollution in the Jinchuan mining area, China: A choice experiment with environmental knowledge and perceived health risk as co-determinants

ABSTRACT

This paper analyzes the choice of illness-cure combinations to estimate the willingness to pay (WTP) for the reduction of acute health risks correlated with air pollution caused by mining and smelting in the Jinchuan mining area, China. Illness attributes are type, duration and activity restriction while price is the main cure characteristic. In addition to the characteristics of the illness-cure combination, and the conventional socio-demographic characteristics education, household net income, family size, family health experience, age, work environment and proximity to the pollution source, we also take into account the latent variables environmental knowledge and perceived risk due to (i) intensity of exposure to polluted air and (ii) hazardousness of pollutants as determinants of the choice.We extend previous methodological research by merging random parameter logit models (RPL) with structural equation modeling with latent variables (SEM). On the basis of the estimated RPL we calculate the mean WTP for avoiding the different kinds of acute illnesses. The WTP varies by activity restrictionand, to a less extent, by duration. Taking allillnesses investigated together, the mean household WTP is 94.87 CNY per year (0.18% of average yearly household income). Another important finding is that both kinds of perceived health risk indicate that residents may also use other mechanisms than medicines to reduce health risk. The outcomes of this study are instrumental to the development of long and short run air pollution reduction policies.

3.1 INTRODUCTION

Since its nickel resource and output are the largest in the nation, Jinchuan has been called the nickel capital of China. Mining and smelting industries dominate its economy and make a substantial contribution to its development. Nearly 55% of the workforce is employed in these industries and 70% of the government receipts of the city of Jinchuan derive from them (Statistical Yearbook, 2011). However, the two industries also cause serious air pollution (Xiao, 2003; Wei, 2008; Li and Zhao, 2004; Huang 2009) and thus health problems such as eye irritation, asthma, bronchitis, and lung cancer (Pope III and Dockery, 2006; Kampa and Castanas, 2008; Bernstein et al., 2004; Zhao et al.,2006; Chen et al.,2004). Although the local government has initiated considerable efforts to improve the situation, Jinchuan is still one of the ten most air polluted cities in China (Wei, 2008). To assist the government in developing and implementing (further) reduction policies, insight into the residents'valuation of the health impacts of air pollution is instrumental.
A method that has been applied to model people's preferences for avoiding health risks correlated with environmental degradation including air pollutionis choice experiment (CE). Itanalyzes typical health status attributes such as type of illness, duration, and price of cure to estimate the willingness to pay (WTP) for improving the environmental conditions (Rodriguez and Leon, 2004; Banfi et al., 2007; Yoo et al., 2008). The main advantage of using CE is that it mimics consumers' purchase situationsby presenting a set of predetermined choices to them. It is a suitable method for valuing environmental goods that typically are multi-attributes goods (Baarsma, 2003) in that it focuses on changing attribute levels rather than on losing (or gaining) the environmental bad (good) as a whole (Hanley et al., 1998).

CE has been widely used to value people's preference for recreational activities (Boxall et al.,1996; Hanley, 2000; Christie, 2007), water quality (Eggert and Olsson, 2004; Abou-Ali and Carlsson,2004), wetland management (Morrison et al.,1998; Birol,2006), landscape and wildlifeprotection (Scarpaet al., 2007; Campbell et al., 2007; Hanley et al., 1998; Adamowicz et al., 1998; Bullock et al., 1998), improving river ecology (Hanley et al. 2006), and acid deposition damages to cultural resources (Morey, 2000).

CE has also been used to value people's preference for reducing health risks. Tsuge et al. (2005) developed an integratedevaluation framework for the reduction of several types of mortality risks due to accidents, cancer, and heart disease in Tokyo using a CE approach. The author found that the average individual WTP for a 1/1000 overall risk reduction is 35335 Japanese Yen, which was 0.5% of average household income of the Tokyo residents in 2002. Johnson et al. (2000) used the attributes symptom, duration, and daily activity restriction to describe episodes of acute respiratory and cardiovascular disease in a CE case study related to Toronto, Canada. The author found that that the WTP for reducing these diseases is particularly sensitive to activity restriction and thus strongly varies across this attribute. Dickie and Messman (2003) analyzed parents' preferences to relieve their own and their children's acute illnesses[1] in Hattiesburyg and Mississippi. They found that the WTP increases with household income and declines with fertility. It also increases, though at a decreasing rate, with the duration and number of symptoms. Parents'WTP to avoid all symptoms is about 6.25 % of yearly household income for their children and 3.22% of household income per year for adults.

The number of CE studies to value health risk caused by air pollution is very limited. Rodriguez and Leon (2004) studied the health effects caused by emissions from a large power plant in Las Palmas de Gran Canaria (Spain) and found that people's preferences are significantly influenced by the magnitude of the reduction of the risk of becoming ill, the duration of illness episodes, and the limitations imposed by the illness.Banfi et al. (2007) studied the impact of air pollution externalities on human welfare in Zurich and Lugano by way of CE and found that the WTP is positively and significantly related to the reduction level.[2] The mean household WTP for air quality improvement from bad to good in Zurich is 198 CHF and 151 CHF in Lugano. Yoo et al. (2008) conducted a CE to quantify the environmental costs of air pollution impactson mortality, morbidity and poor visibility in Seoul. The author found that an individual's average monthly WTP is approximately 5494 Korean won (USD4.6) for a 10% reduction of the concentrations of the major pollutants in Seoul's air (0.23% of per capita monthly income).

The CE studies mentioned above commonly explain choice behaviors in terms of illness characteristicslike type of illness, duration, and price of cure, and socio-demographic characteristics such as age, income, education, and so on. However, they tend to ignore the role of psychological factors in preference formation (notably perception and knowledge) which may lead to inadequate explanation of behavior (Ajzen, 1991; Menon et al., 2008; Folmer, 2009; Folmer and Johansson-Stenman,2012). In fact, Abdalla et al. (1992) and Um et al.(2002),amongst others, have confirmed that perceived health risk and environmental knowledge are important predictors of behaviors aimed at reducing health risks caused by environmental degradation. Furthermore, research in other areas, especially transportation research, has shown that incorporating psychological factors into choice modeling cansignificantly improve the explanatory power of traditional choice model (e.g. Johansson et al., 2006; Ashok et al., 2002; Morikawa, et al., 2002; Temme et al., 2008). However, to the best of our knowledge, psychological factors are not routinely incorporated in CEs of health risk related to environmental issues including air pollution. Therefore, in a bid to reduce possible under-specification, we also include these latent psychological variables[3] in this CE study, in addition to the conventional explanatory variables, notably illness characteristics and socioeconomic characteristics.

In this study we focus on acute health risks, for instance, acute upper respiratory tract infection, since these symptoms are common and clearly discernible risks of air pollution. This feature facilitates respondents' understanding of the health problem at hand, and thus of making a choice. See amongst others Bresnahan(1997) who points out that people are more sensitive to take actions against acute health problems than to chronic health impairments. The illnesses considered in this paper are acute upper respiratory tract infection, acute bronchitis and acute pneumonia.

The paper is organized as follows. In section 3.2 we present the conceptual model on the basis of a literature review. Section 3.3 describes the methodology (Structural Equations Model (SEM) and Random Parameter logit Model (RPL)). Section 3.4 presents the empirical results, and section 3.5 concludes.

3.2. CONCEPTUAL FRAMEWORK

In a CE,the researcher presents two or more hypothetical commodities (a choice set) to the respondents,and asks them to choose the most preferredone.The commodities are described in terms of bundles of attributes. Table 3.1, based on Johnson et al. (2000) and consultation with local doctors, presents several attributes and levels of acute health risks that are typically correlated with air pollution in Jinchuan. The four attributes are: "illness", "activityrestriction", "episode duration" and "price of cure". The first three attributes are symptoms, while the fourth attribute "price", is the amount of money that a respondentis willing to spend per time period onthe cure to reducea combination of symptoms, i.e.on medicines or seeing doctor.

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[1] The illnesses considered were cough with phlegm, shortness ofbreath with wheezing, chest pain on deep inspiration, and/or fever with muscle pain and fatigue.

[2] Three levels of air quality were considered: bad, medium and good.

[3] Oud and Folmer (2008) define latent variables as phenomena that are supposed to exist but cannot be directly observed. However, they can be measured with indicators (observed or manifest variables). See section 3.3 for further details

Table 3.1 Attributes and attribute levels

Attribute	Levels of Attributes	Description
Illness		
(1) Acute upper respiratory tract infection[4]		Sneezing, a runny nose, cough and fever
(2) Acute Bronchitis[5]		Cough, fever, burning, or dull pain in the chest, wheezing
(3) Acute Pneumonia[6]		Chest pain, fever, and difficulty breathing
Episodes Duration (days)		
(1) 5	(2) 9	(3)15
Activity Restriction		
(1) No Limitation		No physical limitations nor restrictions of activities
(2) At home		You have to stay in your house, without social or recreational activities
(3)In Hospital		You are in hospital and need help to take care of yourself
Priceof cure (annual)		
(1) 100 ￥	(2) 300￥	(3) 500 ￥

Source: (Johnson et al., 2000) and consultation with local doctors.

In Table 3.1, for the four attributes with three levels, there are 3^4=81 alternatives. Since it is impossible to ask each individual in the sample to evaluate, and respond to, all 81 combinations, we apply an experimental design to reduce the number of alternatives. Sandor et al. (2002) describes a search procedure to identify a nearly optimal CE design. We applied their algorithm which gave 12 choice sets. In a next step, implausible or uninformative combinations were eliminated which gave 6 choice sets (Appendix B).

Table 3.2 illustrates a typical choice set derived from Table 3.1.Alternatives A and B are two hypothetical goods a respondent could choose. Specifically, alternative A is a scenario of 5 days of acute pneumonia which restricts a subject's activities in that they cannot leave their home. If the subject spends 300￥ per year to purchase medicines and to see a doctor, they can avoid acute pneumonia. Similarly for acute bronchitis. Note that subjects can also choose alternative C "I don't want to purchase either" and instead take the risk.

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[4] Arbex et al. (2011) showed that exposure to air pollutants in general, and to PM_{10} in particular, can increase the number of emergency health department visits due to upper respiratory tract infections.

[5] Lawther et al. (1970) used a simple 'diary' technique in London and in other large towns in the UK to examine the relationship between the condition ofbronchitis patients and their environment. Their research showed that the changes in the condition are closely related to air pollution, as indicated by the concentrations of smoke or sulfur dioxide.

[6] Cheng (2009) showed that for patients with comorbid upper respiratory infections the risk of hospital admissions for pneumonia in relation to air pollutant levels may increase.

Table 3.2 A typical choice set

Alternative	A	B	C
Disease	Acute Pneumonia	Acute Bronchitis	I don't want to purchase either
Duration	5-day episode	9-day episode	
Daily activity	At home	At home	
Price of cure (annual)	300 ￥	500 ￥	
which alternative do you prefer to purchase			

Analysis of preferences for reducing acute health risk with CE is based on expected utility maximization. Respondents face several alternative courses (choice sets) and choose the one with highest utility. As mentioned in section 3.1, in standard CE, choices are assumed to be functionallyrelated to socio-demographic characteristics such as income, age, etc., and to attributes and their levels, such as the ones in Table 3.1 and 3.2. However, as discussed above, we hypothesize that the latent psychological factors environmental knowledge and perceived health risk are also important determinants of people's behaviors aimed at reducing health effects. Hence, our conceptual model (Figure 3.1) contains the following three categories of variables:

1. **Respondent's socio-demographic characteristics** including age, family size, income, education, family health experience, work environment and proximity to the pollution source.
2. **Respondent's socio-psychological characteristics,** i.e. environmental knowledge and perceived health risk
3. **Illness characteristics, i.e.** type of illness, duration, activity restriction, and price of prevention (cure).

Following inter alia Walker and Ben-Akiva(2002), Dillon and Yuan (2002), Johnsson et al. (2006) and Temme et al. (2008),we assume that the alternative specific attributes, respondents' socio-demographic characteristics and their perceived health risk directly influence their choice while their environmental knowledge indirectly influences their choice via perceived health risk. Moreover, respondents' environmental knowledge and perceived health risk are functionally correlated with their socio-demographic characteristics (See Figure 3.1). Below we discuss the main variables in the CE model presented in Figure 3.1.

Choice

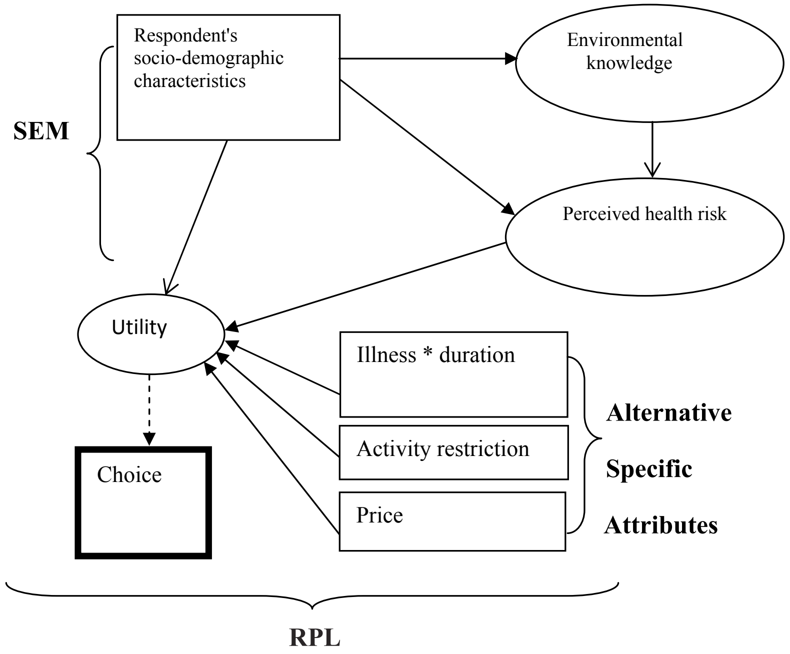

Figure 3.1 The Conceptual CE Model
Source: Johansson et al. (2006); Temme et al. (2008)

We sequentially present 6 choice sets to each respondent. Each choice set consists of 3 alternatives. See table 3.2 for one set. Alternative A portrays a relatively mild illness situation with low price to avoid it; alternative B describes a relative severe condition with higher price while alternative C is the status quo: accept the situation, no purchase of medicines or visits to doctor. Respondents are asked to select the most preferred alternative in each choice set. For each choice set, one alternative is chosen.

Illness characteristics

We assume that the three attributes illness, duration and activity restrictions are the important determinants of choice. Suffering from an illness will not only influence a patient’s own life, but also the lives of their family members. Hence, it will lead to disutility. Thus, respondents have an incentive to choose alternative A or B.We follow Dickie and andMessman (2003) and Johnson et al. (2000) and facilitate comparison of alternatives by combining the attributes type of illness and duration. In addition, we take the natural log of duration to give the variable illness*ln(duration). The activity-restriction

levels have a natural ordering with no limitation representing the best and in hospitalthe worst. Price is the amount of money which people are willing to pay to reduce the acute health risk for a year by purchasing thecure. Price is an important determinant of choice because purchasing the cure comes at a cost. Hence, there is a tradeoff between price and avoiding the illness. For further details, see Dickie and and Messman (2003) and Johnson et al. (2000).

Socio-psychological variables

Perceived health risk (PHR)

Following Menon et al.(2008), we define PHR as the subjective judgement of the occurrence of a negative outcome for one’s health for a specified time period. The impact of PHR on people’s choice mode is ambiguous. On the one hand, people who have higher perceived health risk commonly will take actions to protect themselves (Nauges et al., 1999; Um et al., 2002). Hence, PHR increases the likelihood of purchasing alternative A or B. On the other hand, a negative sign may occur if perceived risk induces people to turn to alternatives to medicine to avoid health risks. In that case they tend to choose alternative C (Johnson et al., 2000; Tsuge et al.,2005). Alternative mechanisms to avoid health risk correlated with air pollution include installing air filters at home, growing air filtering plants at home, reducing outdoor activities and spending more time indoors. PHR is a latent variable that will be measured by 5 indicators (see Figure 3.3).

Environmental knowledge (EK)

Environmental knowledge (EK) is the cumulative body of knowledge concerning the natural environment and its impacts on human society (Fryxell and Lo, 2003). We assume that environmental knowledge is also an important predictor of people’s choice mode. That is, knowledge of environmental issues and their causes can help people take more adequate and efficient actions to reduce their negative impacts. This assumption is supported by Abdalla et al.(1992) who valued the economic costs of ground water degradation to households and found that households’ knowledge of contamination significantly impacts their averting activities. We present the items used to measure EK in Figure 3.2.

Socio-demographic characteristics

Following the CE literature (see e.g. Carlsson et al., 2003; Blamey et al., 1999; Yoo et al., 2008; Tsuge et al., 2005; Johnson et al., 2000; Dickie and Messman, 2003), we assume that socio-demographic characteristics impact on choice behavior. In this paper, age, income, education, family size, family health experience, work environment and proximity to the pollution source are included in the analysis because each has been shown to be a valid predictor of choice behavior aimed at reducing negative health effects caused by environmentaldegradation (Abdalla 1990; Abdalla et al. 1992; Harrington et al. 1989; Laughland et al., 1996; Um et al., 2002; Bresnahan et al., 1999, Murty et al., 2003). Moreover, Li et al. (2013) shows that environmental knowledge and perceived health risk are endogenous. Particularly, family health experience, family size and proximity to the pollution source are important determinants of perceived health risk while environmental knowledge is influenced by age, work environment and ability.

3.3. METHODOLOGY

3.3.1. Structural Equation Models (SEM)

The latent choice model presented above contains observed variables (e.g. age and family size) and environmental knowledge and perceived health risk that are latent, i.e. not directly observable, However, latent variables can be indirectly observed and measured via observed indicators. Latent variables and their indicators can be simultaneously handled by means of Structural Equation Models (SEM).

A SEMis made up of three sub-models: two measurement models and a structural model (Jöreskog and Sörbom, 1996)[7]. Specifically:

$$\boldsymbol{y} = \Lambda_y \boldsymbol{\eta} + \boldsymbol{\varepsilon} \tag{3.1}$$

$$\boldsymbol{x} = \Lambda_x \boldsymbol{\xi} + \boldsymbol{\delta} \tag{3.2}$$

$$\boldsymbol{\eta} = \mathbf{B}\boldsymbol{\eta} + \boldsymbol{\Gamma}\boldsymbol{\xi} + \boldsymbol{\zeta} \tag{3.3}$$

Equations (3.1) and(3.2) are the measurement models that present the relationship between the latent variables and their indicators. Equation (3.3) is the structural model that specifies the relationships among the latent variables $\boldsymbol{\eta}$ and $\boldsymbol{\xi}$ are the m×1 and n×1 vectors of latent endogenous and exogenous variables, respectively; **y** and **x** are the p×1 and q×1 vectors of observed endogenous and exogenous variables, respectively; $\boldsymbol{\zeta}$, $\boldsymbol{\varepsilon}$ and $\boldsymbol{\delta}$ are the vectors of measurement errors with covariance matrices $\boldsymbol{\Psi}$ (m×m), $\boldsymbol{\Theta}_{\varepsilon}$ (p×p) and $\boldsymbol{\Theta}_{\delta}$ (q×q) respectively.[8] The covariance matrix of $\boldsymbol{\xi}$ is $\boldsymbol{\Phi}$ (n×n).

The m×m matrix $\boldsymbol{B}$ contains the structural relationships among the latent endogenous variables. The impacts of the exogenous latent variables on the endogenous latent variables are given by $\boldsymbol{\Gamma}$ which is an m×n matrix. The (p×m) and (q×n) matrices $\boldsymbol{\Lambda}_y$ and $\boldsymbol{\Lambda}_x$, specify the relationships (loadings) between **y** and **x** and their corresponding latent variables $\boldsymbol{\eta}$ and $\boldsymbol{\xi}$, respectively. For identification, estimation, testing and modification indices, see Jöreskog and Sörbom, (1996).

3.3.2 The Random Parameter logit Model (RPL)

The random utility model is the standard approach to analyze choice experiment responses (Train, 1998; McFadden and Train, 2000). In the random utility framework individual i's (i=1, …,N) utility associated with alternative j (j=1, …,J) in choice set m (m=1, …,M) is given by

$$U_{ijm} = \mathbf{b}\mathbf{s}_{ijm} + \boldsymbol{\gamma}\mathbf{z}_i + \mathbf{c}\boldsymbol{\eta}_i + \nu_{ijm} \tag{3.4}$$

$$d_{ijm} = \begin{cases} 1 \text{ if } U_{ijm} \geq U_{ikm} & j,k \in \mathbf{c}_m \\ 0 & \text{otherwise} \end{cases} \tag{3.5}$$

where for respondent i $\mathbf{s}_{\mathbf{ijm}}$ is an (s×1) attribute vector (in the present study $\mathbf{s}_{\mathbf{ijm}}$ consists of the elements illness*ln(duration), activity restriction, price) of alternative j, z_i a (g×1) vector of observable socio-demographic characteristics (e.g. age, family size, etc.), $\boldsymbol{\eta}_{\mathbf{i}}$ an (m×1) vector of latent variables (e.g. perceived health risks), ν_{ijm} an error term that follows an extreme-value (Weibull) distribution. **b**, **c** and $\boldsymbol{\gamma}$ are (1×s), (1×m) and (1×g) row vectors of unknown coefficients of $\mathbf{s}_{\mathbf{ijm}}$, $\mathbf{z}_{\mathbf{i}}$ and $\boldsymbol{\eta}_{\mathbf{i}}$, respectively.

The standard approach to estimate model (3.4)-(3.5) assumes that the error terms ν_{ijm} of the alternatives in a choice set are distributed independently from each other, i.e. the Independence of Irrelevant Alternatives (IIA) assumption (McFadden, 1973; Hanley et al., 2001). Specifically, the IIA implies that the ratio of choice probabilities between two alternatives in a choice set is unaffected by changes in that choice set. This strong assumption is likely to be violated in practice. The problem can be resolved by applying the random parameters logit model (RPL), which allows the parameters associated with alternative-specific attributes to vary randomly across individuals (Revelt and Train, 1998). Specifically:

$$\mathbf{b} = \boldsymbol{\beta} + \boldsymbol{\omega}_{\mathbf{i}} \tag{3.6}$$

Combining equation (3.4) and (3.6) gives:

$$\mathrm{U}_{ijm} = (\boldsymbol{\beta} + \boldsymbol{\omega}_i)\, \mathbf{s}_{ijm} + \boldsymbol{\gamma}\mathbf{z}_i + \mathbf{c}\boldsymbol{\eta}_i + \nu_{ijm} = \boldsymbol{\beta}\mathbf{s}_{ijm} + \boldsymbol{\gamma}\mathbf{z}_i + \mathbf{c}\boldsymbol{\eta}_i + \boldsymbol{\omega}_i\, \mathbf{s}_{ijm} + \nu_{ijm} \tag{3.7}$$

where $\boldsymbol{\beta}$ is the population mean, and $\boldsymbol{\omega}_i$ the stochastic deviation that represents individual

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[7] It is possible to combine the two measurement models (Oud and Folmer, 2008). Furthermore, means and intercepts can be included in the system. However, we delete them here because in the application we standardize all variables

[8] Note that a directly observed variable can be straightforwardly handled in the SEM framework by defining it identical to its corresponding latent variable and accordingly specifying an identity relationship in the measurement model.

taste relative to the average taste in the population. From (3.7) it follows that the error term $\boldsymbol{\omega}_i\, \mathbf{s}_{ijm} + \nu_{ijm}$ iscorrelated over the attributes of the alternative because of the presence of $\boldsymbol{\omega}_\mathrm{i}$.

Note that we take the coefficient of price fixed for the following reasons. First, as pointed out by Revelt and Train (1998) and Ruud (1996), allowing all coefficients of alternative specific attributes to vary tends to render the RPL model unstable and identification of the model empirically difficult. Specifically, when the stochastic part of utility $\nu'_{\mathrm{ijm}} = \boldsymbol{\omega}_\mathbf{i}\mathbf{S}_\mathbf{ijm} + \nu_{\mathrm{ijm}}$ in equation (3.7) is dominated by $\boldsymbol{\omega}_\mathbf{i}\mathbf{s}_\mathbf{ijm}$, the error term ν_{ijm} will have little influence on utility. At the extreme, the error term ν_{ijm} has no influence on utility (variance of ν_{ijm} is zero). Consequently, the scaling of utility by the variance of ν_{ijm} will become unstable and additional scaling is need. Secondly, the marginal willingness to pay (WTP) for an attribute is the ratio of the attribute's coefficient and the price coefficient. When the price coefficient is fixed, the distribution of the marginal WTP simply follows the distribution of the attribute's coefficient. If the price coefficient also varies, the distribution of the marginal WTP becomes complicated. Therefore, Train (2000) suggests to keep the coefficient of price fixed. For further details we refer to Lusk and Schroeder (2004), Bhat (1997), Revelt and Train (1998).

Following Train et al. (1986), Morikawa et al. (1996), Johansson et al. (2006), Yánez et al. (2009), we estimate the SEM-RPL model in two steps. We first estimate the SEM by means of the software package LISREL8 (Jöreskog and Sörbom, 1996). Because the latent variables: environmental knowledge and perceived health risk are measured by ordinal variables (see section 3.4), we estimate the SEM model by Weighted Least Squares (WLS) based on the matrix of polychoric correlations. The predictions of the latent variables based on the estimated SEM, together with the socio-economic and illness characteristics are used to estimate the RPL (by means of the mlogit package in R).

The WTP of individual i for the reduction of a specific illness can be obtained from the estimated parameters as follows (McFadden, 1973; Hanley et al., 2001):

$$WTP_i = b_{price}^{-1} \ln \left\{ \frac{\exp(\mu V_i^1)}{\exp(\mu V_i^0)} \right\} \tag{3.8}$$

where b_{price} is the coefficient of the price attribute indicating the marginal utility of money and μ is a scale parameter which isinversely proportional to the standard deviation of the error distribution. In addition, V is the deterministic component[9] of utility function with V_i^0 the utility of the initial state and V_i^1 the utility of the alternative state.[10]

3.4.EMPIRICAL RESULTS

3.4.1 Survey and Descriptive Statistics

Data was collected using a face-to-face survey in the city of Jinchuan, Gansu province, China, in August 2012. A sample of 800 respondents aged between 20 and 80 were randomly selected and interviewed at home. The questionnaire contained questions about the respondents' socio-demographic characteristics, their environmental knowledge and perceived health risks, and their choice modes of reducing acute health risks. The questions are presented in notes to Table 3.3 and Figures 3.2, 3.3 and 3.4.

Of the 800 questionnaires filled out, 41 (5.12%) were rejected because they were incomplete. There was no evidence of non-random drop out. Descriptive statistics are presented in Table 3.3, Figures 3.2 and 3.3.

The distribution of the socio-economic characteristics in Table 3.1 is in line with the population distribution of Jinchuan (see Jinchuan Statistical Yearbook, 2010).

Environmental knowledge was tested using eight indicators. Each indicator is measured on a five points scale ranging from 1 (strongly disagree) to 5 (strongly agree). The first three indicators (EK1-EK3) refer to knowledge on Jinchuan's general environmental issues. Figure 3.2 indicates that a vast majority of the respondents (over 80%) believe or strongly believe that air pollution, industrial solid waste, and water pollution are important environmental issues in Jinchuan Moreover, 93.2% think that local industrial activities are the culprits of the environmental problems (EK4). Respondents' specific knowledge about local air pollution is measured with the final four indicators (EK5-EK8). Figure 3.2 shows that over 55.0 % of the respondents think that chlorine gas, sulfur dioxide, suspended particles and carbon dioxide are important pollutants of Jinchuan's air.

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[9] In terms of (3.7) $V = \boldsymbol{\beta}\mathbf{s}_{ijm} + \boldsymbol{\gamma}\mathbf{z}_i + \mathbf{c}\boldsymbol{\eta}_i$

[10] After estimating the parameters of the utility function ($\boldsymbol{\beta}$,$\boldsymbol{\gamma}$ and $\mathbf{c}$), V_i^0 and V_i^1 can be calculated as follow: $V_i^0 = \boldsymbol{\beta}\mathbf{s}^0_{ijm} + \boldsymbol{\gamma}\mathbf{z}_\mathrm{i} + \mathbf{c}\boldsymbol{\eta}_\mathrm{i}$, $\mathrm{V}_\mathrm{i}^1 = \boldsymbol{\beta} \times \mathbf{s}^1_{ijm} + \boldsymbol{\gamma}\mathbf{z}_i + \mathbf{c}\boldsymbol{\eta}_i$ where $\mathbf{s}^0_{ijm}$ and $\mathbf{s}^1_{ijm}$ indicate the initial and alternative state vectors of attribute levels, respectively.

Table 3.3 Descriptive statistics for the observed exogenous variables

Variables	Min	Max	Mean	S.D
Age (AGE)	21	78	44.11	11.4
Family Size (FS)	1	6	3	0.78
Family health experience (FHE)	0	1	0.33	0.48

Education (EDU)	%	**Household Income (CNY per month) (IN)**	%
Primary school	6.30%	1000-2000	4.70%
Middle school	23.60%	2000-3000	15.30%
High school	25.30%	3000-4000	18.30%
Vocational school,	25.30%	4000-5000	19.10%
Bachelor’s degree	19.10%	5000-6000	20.90%
Master’s degree	0.40%	6000-7000	13.00%
Proximity topollution source (PPS)	%	7000-8000	3.70%
Nearby smelting plants, severe air pollution (SAP)	29.60%	8000-9000	1.80%
		9000-10000	1.10%
Medium air pollution (MAP)	29.80%	More than 10000	2.00%
Far away from smelting plants, light air pollution (LAP, reference case)	40.60%		
Work environment (WE)	%		
Non-JMC employee (reference case)	59.55%		
Miners and smelter workers of JMC (MS)	18.18%		
JMC employee, but not miner or smelter worker (NMS)	22.27%		

Note: **Family size:** number of family members living in the same house. **Family Health experience**: 1 if the respondent or one or more of his/her family members have been hospitalized for cardiovascular diseases (e.g., hypertension, heart attack, chest pain, arrhythmia and miocardial infraction) or respiratory diseases (e.g., upper respiratory tract infection, bronchitis, pneumonia, asthma, and lung cancer), 0 otherwise.
Source: Author survey

Sjöberg et al. (2004) and Egondi et al. (2013) point out that perceived health risk correlated with air pollution is multidimensional. Li et al. (2013a,b) identified two different, though related dimensions: perceived risk due to(i) intensity of exposure, and (ii) hazardousnessof pollutants, respectively. The first dimension is measured with the qustion (PHR1) “what do you perceive as the average number of days per week Jinchuan’s air was heavily polluted during the past year?”. Figure 3.3 shows that 18.3% answered 4 or more days (‘heavy exposure’), 62.1% 2 or 3 days (medium exposure’’) and 19.6% 0 or 1 days (‘light exposure’). The second dimension was measured by questions about the perceived

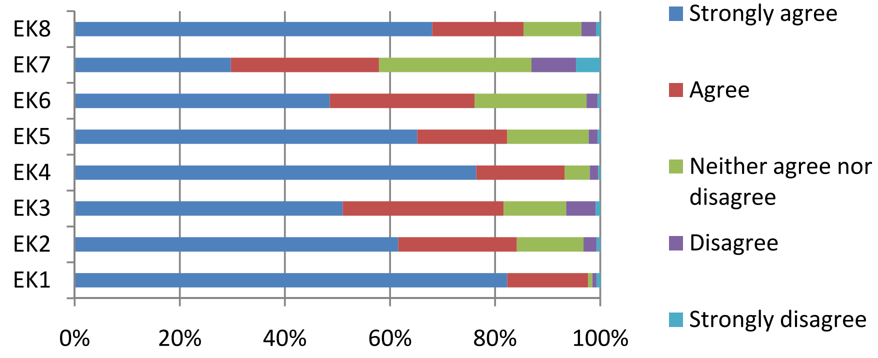

Figure 3.2 Frequency distribution of the indicators of environmental knowledge
Note: **EK1**: Jinchuan suffers from air pollution. **EK2**: Jinchuan suffers from industrial solid waste. **EK3**: Jinchuan suffers from water pollution. **EK4**: Environmental issues in Jinchuan are mainly caused by local industrial activities. **EK5**:Sulfur dioxide is one of the main air pollutants of Jinchuan. **EK6**: Suspended particles is one of the main air pollutants of Jinchuan. **EK7**: Carbon dioxide is one of the main air pollutants of Jinchuan. **EK8**: Chlorine gasis one of the main air pollutants of Jinchuan.
Source: Author survey

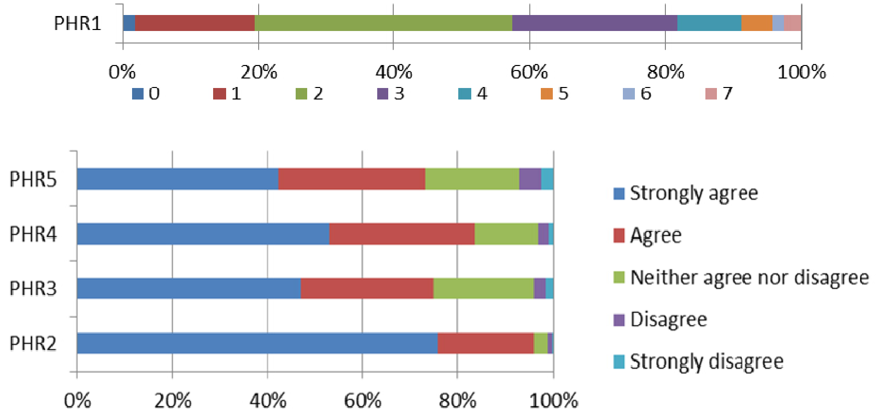

Figure 3.3 Frequency distribution of the indicators of perceived health risk
Note: **PHR1**: what do you perceive as the average number of days per week Jinchuan’s air was heavily polluted during the past year? **PHR2**: Jinchuan’s air pollution increases the likelihood of suffering from respiratory illnesses. **PHR3**: Jinchuan’s air pollution increases the likelihood of suffering from cardiovascular illnesses. **PHR4**: Jinchuan’s air pollution increases the likelihood of suffering from lung cancer. **PHR5:** Jinchuan’s air pollution increases the likelihood of suffering from death.
Source: Author survey

likelihood of suffering from illnesses. A five-points scale was used with 1 indicating strong disagreement (zero or weak perception) and 5 strong agreement (strong perception). Figure 3.3 indicates that more than 70 % agree or strongly agree that Jinchuan's air pollution increases the likelihood of suffering from respiratory illnesses, lung cancer, cardiovascular illnesses and death.

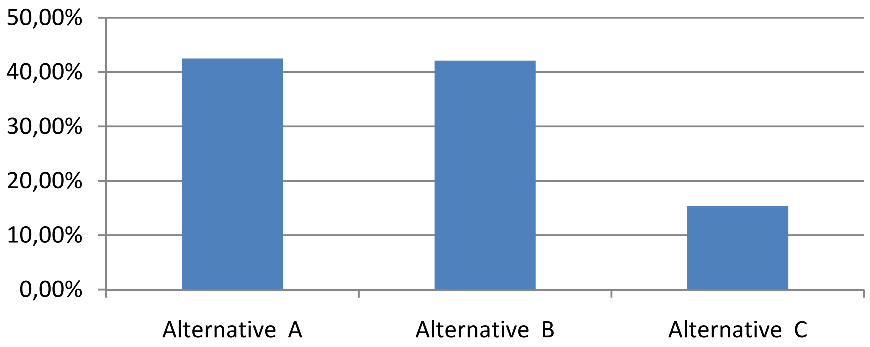

Figure 3.4 Frequency distribution of mode choice
Source: Author survey

Figure 3.4 shows the frequency distribution of choice mode. 15.4% of respondents chose the alternative C (status quo) for the six choice sets, 42.5% alternative A and 42.1% alternative B, respectively.

3.4.2 SEM

Appendix A presents the conceptual SEM in terms of equations (3.1)- (3.3). The estimated SEM is presented in Tables 3.4-3.6. It is the same as in Li et al. (2013) to which we refer for details. Below we summarize the main results. Table 3.4 shows that all goodness of fit indices meet their critical values. The measurement models, Table 3.5, indicate that all loadings are highly significant and that there are no indicators with extremely low reliability. The structural model, Table 3.6, shows that perception of intensity of expsoure (PHRL1) is a function of environmental knowledge, ability and proximity to pollution source. Family size, ability, family health experience, proximity to the pollution sourceand environmental knowledge are all important determinants of perceived risk of hazardousness of the pollutants (PHRL2). Environmental knowledge is impacted by age, work environment and ability. The averages of the latent variables are presented in Table 3.7.

Table 3.4 Overall goodness of fit indices of the SEM

Fit index	SEM model	Cut off value
χ^2/DF	2.47	<3
Goodness-of-fit index(GFI)	0.98	>0.90
Incremental fit index (IFI)	0.93	>0.90
Comparative fit index (CFI)	0.93	>0.90
Adjusted goodness-of-fit index (AGFI)	0.97	>0.80
Root mean square error of approximation (RMSEA)	0.041	<0.05

Table 3.5 Measurement models(standardized coefficient)

latent variables	Indicators	Coefficient	Standard errors	R^2
Perceived risk due to intensity of exposure (PHRL1)	PHR1	1.00	---	1.00
Perceived risk due to hazardousness ofpollutants (PHRL2)	PHR2	0.59	0.03	0.35
	PHR3	0.53	0.03	0.28
	PHR4	0.62	0.03	0.38
	PHR5	0.55	0.03	0.30
Environmental knowledge (EK)	EK1	0.49	---	0.24
	EK2	0.43	0.04	0.19
	EK3	0.43	0.04	0.19
	EK4	0.50	0.03	0.25
	EK5	0.57	0.03	0.32
	EK5	0.51	0.03	0.26
	EK7	0.36	0.03	0.13
	EK8	0.44	0.03	0.19
Ability (AB)	Education	0.48	0.05	0.23
	Income	0.46	0.04	0.21

Table 3.6 The structural model

Variables	EK	PHRL1	PHRL2
Environmental knowledge (EK)		0.13***	0.66***
		(0.04)	(0.15)
Ability (AB)	0.33***	0.06	0.14***
	(0.09)	(0.05)	(0.08)
Age (AGE)	0.09**		
	(0.02)		
Family size (FS)			-0.08**
			(0.02)
Family health experience (FHE)			0.05*
			(0.02)
Medium air pollution (MAP)		0.09***	0.06
		(0.03)	(0.04)
Serious air pollution (SAP)		0.19***	0.06
		(0.03)	(0.04)
JMC employee, but not miner or smelter worker (NMS)	0.08		
	(0.05)		
Miners and smelter workers of JMC (MS)	0.16**		
	(0.04)		
R^2	0.13	0.05	0.51

Note: Standard errors in parenthesis. *, **and *** :10%, 5% and 1%

Table 3.7 Descriptive statistics for averages of latent variables

Variables	Min	Max	Mean	S.D
Environmental knowledge (EK)	3.32	7.01	5.88	0.66
Perceived risk due to hazard pollutant (PHRL2)	2.84	8.56	7.06	0.92
Ability	1.32	9.85	4.93	1.69

3.4.3 RPL Model

Before going into detail, we make the following remark. Following Johnson et al. (2000) and Bech and Gyrd-Hansen (2005), we effect-coded[11] the attributes illness* ln(duration) and activity restrictions. Acute upper respiratory tract infection (AI)*ln(duration) and no limitation (NL) are the omitted categories.[12] Consequently, in terms of equation (3.7), the choice RPL model presented in Figure 3.1 reads as follows:

$$U_{ijm} = (\beta_{AB*LD} + \omega_{AB*LD\text{-}i})\, AB * LD_{ijm} + (\beta_{AP*LD} + \omega_{AP*LD\text{-}i})\, AP * LD_{ijm} + (\beta_{\mathrm{AH}} + \omega_{AH\text{-}i})\, AH_{ijm} + (\beta_{IH} + \omega_{IH\text{-}i})\, IH_{ijm} + b_{\mathrm{price}}\, \mathrm{Price}_{ijm} + c_1\, PHRL1_i + c_2 PHRL2_i + \gamma_1 FS_i + \gamma_2 AB_i + \gamma_3 AGE_i + \gamma_4 MAP_i + \gamma 5SAP_i + \gamma_6 NMS_i + \gamma_7 MS_i + \gamma_8 FHE_i + \nu_{ijm} \tag{3.9}$$

where i refers to individual i, AB*LD= Acute Bronchitis * ln(duration), AP*LD = Acute Pneumonia * ln(duration), AH=at home, IH=in hospital. PHRL1=perceived health risk due to intensity of exposure, PHRL2=perceived health risk due to hazardousness of pollutants. Note that proximity to the pollution source has been incorporated into the model as two dummy variables: serious air pollution area (SAP) and medium air pollution area (MAP), with lightly polluted area as the base case. Work environment is also modeled by means of two dummy variables: Jianchuan Mining Company (JMC) employees, but not miners and smelter workers (NMS), and JMC miners and smelters workers (MS). Non-JMC employee is the base case.

The estimated coefficients and their t-values are displayed in Table 3.8. To facilitate comparison of their marginal utility, we also present normalized coefficients across attributes by rescaling the coefficients from 0 to 1 (Johnson et al., 2000), with the IH coefficient equal to 0 (most disutility) and the NL coefficient equal to 1 (least disutility). Below, we first discuss the illness characteristics, next perceived health risk, and finally the socio-demographic characteristics.

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[11] Similar to dummy coding, effect coding transforms attributes with, say, L qualitative levels into L-1 dummy variables. Unlike dummy coding, however, effect coding assigns a value -1 rather than 0 to each category for the reference level. For example, ineffect coding, a three-level attribute is coded (1 0, 0 1, -1 -1), the third level being the reference level. The coefficients of effect-coded dummy variablesrepresent the deviation of the category's mean from the overall or "grand mean" across categories (Pedhazur, 1997). For example, the coefficient of in hospital represents the deviation of the mean disutility of in hospital from the mean disutility of activity restrictions(mean disutility across levels including no limitation, at home and in hospital).

[12] There are no guidelines for choosing the omitted category in effect coding (Pedhazur, 1997).

The negative coefficients of AB*LD and AP*LD indicate that compared to acute upper respiratory tract infection*ln(duration)(AI*LD)[13], acute bronchitis* ln(duration) and acute pneumonia*ln(duration) as the relatively serious and long lasting illnesses have substantially more disutility than the mild base case acute upper respiratory tract infection*ln(duration). The coefficients of activity restriction monotonically decrease and indicate that higher levels of activity restriction lead to higher utility losses. The coefficient of at home(AH) is insignificant, indicating that it is not different from the overall mean of activity restriction. The coefficient of price is significant and positive, indicating that purchasing medicines can improve people's utility. The standard deviation of AP*LD and IH are significant, indicating that there is preference heterogeneity across the respondents. Moreover, these standard deviations are larger than the corresponding means indicating that there is considerable variation across observations that is not well explained in the model (Johnson, 2000).

The estimated coefficients of the psychological and socio-demographic characteristics indicate the effects of these variables on the likelihood of choosing alternative A or B relative to the alternative C[14] (Gabriel and Rosenthal, 1989).Table 3.8 shows that perceived risk due to intensity of exposure (PHRL1) decreases the propernsity to purchase alternatives A and alternative B, although the significance level of the former is a border case. Likewise, perceived risk due to hazardousness ofthe air pollutants (PHRL2) also decreases the likelyhood of choosing alternative A over C, and alternative B over C, although the later effect is not significant.As mentioned above, their negative impacts on the propensity to buy alternatives A and B, do not mean that PHRL1 and PHRL2 are not important determinants of people's preferences for avoiding health risks in general. People with higher levels of PHRL1 and PHRL2 may opt for other preventive actions than buying medicine, for example, installing air filters or spending more time indoor. See also Johnson et al. (2000) and Tsuge et al. (2005).

We now turn to the socio-demographic characteristics. The impacts of ability onthe decision of purchasing alternative A or B are positive and statistically highly significant. This outcome indicates that people with higher ability prefer to take actions to avoid negative effects of air pollution by purchasing alternative A or alternative B. Family health experience also positively influencesthe decisions of purchasing alternative A and alternative B. However, the former is insignificant. These results suggest that family members' health experience of suffering respiratory or cardiovascular illnesses correlated with air pollution will increase the concern about air pollution and increase the possibility of choosing the more expensive alternative B which corresponds to a relatively serious illness. The coefficients of age are negative and highly significant, indicating that elderly people are more likely to choosing alternative C.

Table 3.8 also indicates that people who live in an area with medium air pollution are more likely to choose alternative A or alternative B, compared to those who live in lightly polluted areas. Note that $\textit{Serious air pollution}_A$ is positive, though insignificant whereas $\textit{Serious air pollution}_B$ is negative and significant. The latter result indicates that compared to those who lives in lightly polluted areas, people in seriously polluted areas prefer to choose alternative C. A possible explanation for this finding is that people who live in heavily polluted areas opt for other preventive behaviors like installing air filters and restricting outdoor activities. Table 3.8 also shows that compared to non-JMC employees, people working in the JMC prefer to purchase alternative B. For alternative A, the effects of both NMS and MS are insignificant. Finally, the coefficients of family size are negative and insignificant, indicating that family size is not an important determinant of people's choice mode for avoiding acute health risk correlated with air pollution. A possible explanation for the negative sign is that in bigger families vital family tasks and duties can be shared by a larger number of family members when a family member is hit by a disease. In other words, bigger family implies larger capacity to absorb risks. Thus, family members of larger family prefer to choose alternative

3.4.4 Willingness To Pay (WTP)

Based on the above results, we estimate Jinchuan residents' mean WTP for reducing acute health risk correlated with air pollution by means of equation (3.8). For example, the average WTP for avoiding 5 days of acute pneumonia which confines respondents to their home is:

$$\begin{aligned}
&\mathbf{WTP}_{\text{for avoiding acute pneumonia,5 days,at home}} \\
&= \frac{\text{Utility of avoiding (acute pneumonia, 5 days, at home)} - \text{Utility of keeping status quo}}{\text{marginal uility of money}} \\
&= \frac{-(\ln(5)\times\beta_{AP*LD}+\beta_{\text{at home}}) - 0}{b_{\text{price}}} \\
&= \frac{-(1.609\times(-0.049)+(-0.039))}{0.037} = 3.19\ \text{CNY}
\end{aligned}$$

We estimated 95% confidence intervals for the average WTP for the three illness* ln(duration) combinations. The results are presented in Table 3.9. The first column shows

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[13] AI*LD is the omitted category and its coefficient is the negative sum of the included categories (Bech and Gyrd-Hansen 2005).

[14] Alternative C (Status quo) is used as the reference alternative.

zero WTP in the caseof no limitation for all durations. This outcome implies that the implied health problems areseen as so minor that spending money on avoiding them does not increase utility. The third column shows the WTP estimates for the inhospital restriction. First, note that there is no WTP estimate for the combination acute upper respiratory tract infection and in hospital because hospitalization for this kind of illness is rare. Secondly, for the other diseases the results show that average WTP increases by duration.

Comparison of the the second and third activity restriction columns shows that the WTP for avoiding hospitalization is substantially larger than for the activity restriction at home. This result is consistent with Johnson et al. (2000)who also found that the differences in average WTP due to activity restriction are substantially larger than for duration.

Finally, taking the WTPs for all illnesses investigated together gives the mean total household WTP to avoid all illnesses. The outcome is 94.87 CNY per year (0.18% of average yearly household income). Note that this outcome only reflects three acute illnesses and choices of related cures. Other illnesses related to air pollution in Jinchuan and other types of averting behavior are not included.

Table 3.8 The RPL model

Variables	Coefficient	Normalized	T-value
Acute upper respiratory tract infection * ln(duration) (AI*LD)	0.105	0.633	---
S.D	---		---
Acute Bronchitis * ln(duration) (AB*LD)	-0.059 **	0.378	2.11
SD	0.0003		0.0002
Acute Pneumonia * ln(duration) (AP*LD)	-0.049 *	0.394	-1.71
S.D	0.485 ***		13.66
No Limitation (NL)	0.341	1.000	---
S.D	---		--
At home (AH)	-0.039	0.409	-0.76
S.D	0.0005		0.0002
In hospital (IH)	-0.302 ***	0.000	-3.46
S.D	1.030 ***		7.49
Price	0.037 ***		6.83
Perceived risk due to intensity of exposure(PHRL1) $_{A}$	-0.040		-1.62
Perceived risk due to intensity of exposure(PHRL1) $_{B}$	-0.037 *		-1.74
Perceived risk due to intensity of exposure(PHRL1) $_{B}$	-0.172***		-2.79
Perceived risk due to intensity of exposure(PHRL1) $_{B}$	-0.041		-0.72
Ability (AB) $_{A}$	0.311 ***		5.90
Ability (AB) $_{B}$	0.596 ***		11.66
Family health experience(FHE) $_{A}$	0.062		0.60
Family health experience(FHE) $_{B}$	0.474 ***		4.82
Age(AGE) $_{A}$	-0.121 ***		-2.75
Age (AGE) $_{B}$	-0.229 ***		-5.51
Medium air pollution(MAP) $_{A}$	0.345 **		2.38
Medium air pollution(MAP) $_{B}$	0.299 ***		2.96
Serious air pollution(SAP) $_{A}$	0.146		1.13
Serious air pollution(SAP) $_{B}$	-0.308 ***		-2.46
JMC employee,but not miners or smleter worker(NMS) $_{A}$	0.090		0.72
JMC employee,but not miners or smleter worker(NMS) $_{B}$	0.388 ***		3.10
Miners or smelter worker(MS) $_{A}$	-0.023		-0.18
Miners or smelter worker(MS) $_{B}$	0.383 ***		3.11
Family size(FS) $_{A}$	-0.001		-0.02
Family size(FS) $_{B}$	-0.063		-1.11
Alternative-specific constants			
Alternative specific constant (ASC) of Alternative-A	0.816		1.61
Alternative specific constant (ASC) of Alternative-B	-1.590***		-2.76
N		759	
log-likelihood		-4203.3	
Likelihood ration test		$\chi^2 = 850.37$	
		2.22E-16	

Note: variable subscripts denote choice mode. A= alternative A: relatively mild illness with low prevention price. B= alternative B: relatively sever illness with high prevention price.
S.D.: standard deviation
Significance levels: *, ** and ***: 10%, 5% and 1%.

Table 3.9 Average WTP estimates by disease, activity restriction and duration (CNY per year)

Disease	Duration	Activity restriction level		
		No limitation	**At home**	**In hospital**
Acute upper respiratory tract infection (AI)	5	0	0	---
		----	(-2.002/-2.000)	
	9	0	0	---
		---	(-2.732/-2.731)	
	15	0	0	---
		---	(-3.366/-3.367)	
Acute Bronchitis (AB)	5	0	3.621	10.728
		(-6.649/-6.650)	(3.619/3.622)	(8.709/12.748)
	9	0	4.558	11.666
		(-5.713/-5.711)	(4.557/4.559)	(9.647/13.685)
	15	0	5.372	12.481
		(-4.898-4.897)	(5.370/5.374)	(10.461/14.500)
Acute pneumonia (AP)	5	0	3.186	10.294
		(-8.035/-.6.134)	(2.234/4.137)	(7.324/13.263)
	9	0	3.964	11.072
		(-7.257/-5.356)	(3.012/4.916)	(8.102/14.041)
	15	0	4.640	11.749
		(-6.581/-4.679)	(3.689/5.912)	(8.779/14.718)

3.5 CONCLUSIONS

This paper analyzes the choice of illness-cure combinations to estimate the willingness to pay (WTP) for the reduction of acute health risks correlated with air pollution caused by mining and smelting in the Jinchuan mining area, China. Ilness attributes are type, duration and activity restriction while price is the main cure characteristic. The illnesses considered are acute upper respiratory tract infection, acute bronchitis and acute pneumonia.In addition to the attributes of the illness-cure combination and the conventional socio-demographic characteristics education, household net income, family size, family health experience, age, work environment and proximity to the pollution source, we also take into account environmental knowledge and perceived risk due to (i) intensity of exposure to polluted air and (ii) hazardousness of pollutants asdeterminants of the choice. The latter two variables are latent in that they are not directly observable and measurable. However, they can be measured by means of observed indicators. We apply structural equations modeling (SEM) to handle the latent variables and their indicators within one model framework. On the basis of the estimated SEM, we obtain predictions of environmental knowledge and both perceived risk variables, which together with the illness attributes, the cure price and the socio-demographic characteristics are used to analyze the choice mode by means of a random parameter logit model.

Based on a cross-sectional data set of 759 households in the Jinchuan mining area, we found that the illness attributes, and the socio-demographic characteristics ability, age, family health experience, work environment and proximity to pollution source are the main determinants of choice mode. On the basis of the estimated random parameter logit model, we estimated the WTP for each type of illness and its attributes. The WTP was found to vary by activity restriction and, to a less extent, by duration. Particularly,the more serious the activity restriction, the larger the WTP. Taking allillnesses investigated together, the mean household WTP is 94.87 CNY per year (0.18% of average yearly household income). Another important finding is that both kinds of perceived health risk indicate that residents may also use other mechanisms than medicines to reduce health risk. Alternative mechanisms to avoid health risk correlated with air pollution include installing air filters or growing air filtering plants at home, reducing outdoor activities and spending more time indoors. Further research is needed on this issue.

Understanding the choice illness-cure combination is useful information for policy makers in the Jinchuan mining area for the development of environmental policies in the long run. The results indicate that health concerns are major drivers of people’s behavior. Therefore, improving air quality ought to be a major long run policy objective. As it takes time to implement air quality improving policies, a short run disclosure policy should be installed to provide the inhabitants information to take the right actions, particularly medicines, to reduce health risks.

In addition to further analysis of averting behavior mechanisms, this study can be extended in several additional ways. Our study just focuses on acute health risks correlated with air pollution. However, apart from acute health risk, CE can also be used to value people’s preference for avoiding chronic health risk and premature mortality correlated with air pollution.

Another area for further research is developing, refining and further testing of the indicators of environmental knowledge and perceived health risk to improve explaining environmental behavior including choice mode. Note that the impact of people’s latent characteristics on their environmental behaviors is of topical interest in environmental psychology (e.g., Cottrell,2003; Kaiser ,1999; Byrka, 2009). In other areas of environmental research, however, the interest in this topic is still very limited.

APPENDIX A

In terms of model (3.1)-(3.3), the latent variable model presented in Figure 3.1 reads as follows:

Measurement models

$$\begin{bmatrix} PR1 \\ \vdots \\ PR5 \\ EK1 \\ \vdots \\ WK8 \end{bmatrix} = \begin{bmatrix} \lambda^y_{11} & 0 & 0 \\ 0 & \lambda^y_{2\,2} & 0 \\ \vdots & \vdots & 0 \\ 0 & \lambda^y_{5\,2} & 0 \\ 0 & 0 & \lambda^y_{6\,3} \\ 0 & 0 & \lambda^y_{7\,3} \\ \vdots & \vdots & \vdots \\ 0 & 0 & \lambda^y_{13\,3} \end{bmatrix} \times \begin{bmatrix} PHRL1 \\ PHRL2 \\ EK \end{bmatrix} + \begin{bmatrix} \varepsilon_1 \\ \vdots \\ \varepsilon_5 \\ \varepsilon_6 \\ \vdots \\ \varepsilon_{13} \end{bmatrix} \qquad \text{(A.3.1)}$$

$$\begin{bmatrix} EDU \\ IN \\ FS \\ AGE \\ FHE \\ MAP \\ SAP \\ NMS \\ MS \end{bmatrix} = \begin{bmatrix} \lambda^x_{11}000000 \\ \lambda^x_{21}000000 \\ 0\ 100000 \\ 0\ 010000 \\ 0\ 001000 \\ 0\ 000100 \\ 0\ 000010 \\ 0\ 000001 \end{bmatrix} \times \begin{bmatrix} AB \\ FS \\ AGE \\ FHE \\ MAP \\ SAP \\ NMS \\ MS \end{bmatrix} + \begin{bmatrix} \delta_1 \\ \delta_2 \\ 0 \\ 0 \\ 0 \\ 0 \\ 0 \\ 0 \end{bmatrix} \qquad \text{(A.3.2)}$$

The structural model reads

$$\begin{bmatrix} PHRL1 \\ PHRL2 \\ EK \end{bmatrix} = \begin{bmatrix} 0 & 0 & \beta_{1\,2} \\ 0 & 0 & \beta_{1\,3} \\ 0 & 0 & 0 \end{bmatrix} \times \begin{bmatrix} PHRL1 \\ PHRL2 \\ \mathrm{EK} \end{bmatrix} + \begin{bmatrix} \gamma_{1\,1} & 0 & 0 & 0 & \gamma_{1\,5} & \gamma_{1\,6} & 0 & 0 \\ \gamma_{2\,1} & \gamma_{2\,2} & 0 & \gamma_{2\,4} & \gamma_{2\,5} & \gamma_{2\,6} & 0 & 0 \\ \gamma_{3\,1} & 0 & \gamma_{3\,3} & 0 & 0 & 0 & \gamma_{3\,7} & \gamma_{3\,8} \end{bmatrix} \times \begin{bmatrix} AB \\ FS \\ AGE \\ FHE \\ MAP \\ SAP \\ NMS \\ MS \end{bmatrix} + \begin{bmatrix} \zeta_1 \\ \zeta_2 \end{bmatrix} \qquad \text{(A.3.3)}$$

APPENDIX B

Choice sets

Please consider how much your household would prefer to spend money to prevent the risks of having the acute illnesses. When you make your selection please consider the disposable income of your household after necessary expenses (such as food, rent, and so on)

Choice set 1

Alternative	**A**	**B**	**C**
Disease	Acute Pneumonia	Acute Pneumonia	I don't want to purchase either
Duration	9-day episode	15-day episode	
Daily activity	No Limitation	No Limitation	
Price	300 ¥	500 ¥	
which alternative do you prefer to purchase			

Choice set 2

Alternative	**A**	**B**	**C**
Disease	Acute Bronchitis	Acute Bronchitis	I don't want to purchase either
Duration	5-day episode	5-day episode	
Daily activity	At home	In Hospital	
Price	300 ¥	500 ¥	
which alternative do you prefer to purchase			

Choice set 3

Alternative	A	B	C
Disease	Acute Pneumonia	Acute upper respiratory tract infection	I don't want to purchase either
Duration	5-day episode	9-day episode	
Daily activity	No Limitation	At home	
Price	100 ¥	300 ¥	
which alternative do you prefer to purchase			

Choice set 4

Alternative	**A**	**B**	**C**
Disease	Acute upper respiratory tract infection	Acute Bronchitis	I don’t want to purchase either
Duration	5-day episode	15-day episode	
Daily activity	At home	In Hospital	
Price	300 ￥	500 ￥	
which alternative do you prefer to purchase			

Choice set 5

Alternative	**A**	**B**	**C**
Disease	Acute Pneumonia	Acute Bronchitis	I don’t want to purchase either
Duration	9-day episode	15-day episode	
Daily activity	No Limitation	No Limitation	
Price	100 ￥	300 ￥	
which alternative do you prefer to purchase			

Choice set 6

Alternative	**A**	**B**	**C**
Disease	Acute Pneumonia	Acute Bronchitis	I don’t want to purchase either
Duration	5-day episode	9-day episode	
Daily activity	At home	At home	
Price	300 ￥	500 ￥	
which alternative do you prefer to purchase			

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Chapter 4

Air pollution and perception-based avertingbehavior: the case of the Jinchuan mining area, China

ABSTRACT

This paper presents a simultaneous equations, perception-based averting behavior model (PABM) of the response to health risks caused by air pollution, with application to the Jinchuan mining area, China. We develop and test indicators of the latent variables averting behavior and risk perception. This leads to three types of averting behavior: investment in purifying equipment and plants; purchase of preventive and curing medication and food; and adjustment of daily activities. For perceived health risk, we identify two kinds: perceived risk due to intensity of exposure, and risk of the pollutants. The estimation results show thatthe two perceived risk variables and ability are the most important determinants of the three types of averting behavior. To get insight into their driving mechanisms, the perceived health risk variables are endogenized. We find that environmental knowledge, family health experience, proximity to pollution source.proximity to pollution source, and family size systematically influence perceived risk due to exposure while environmental knowledge and proximity to the pollution source are the main determinants of perceived risk of the pollutants. Environmental knowledge is also taken as an endogenous variable to capture possible interaction with perceived health risk. The estimations show that it is only systematically influenced by the exogenous variables age, work environment and ability. An increase in risk perception due to an increase of intensity of exposure, measured as the number of days per week of heavy air pollution, leads to a restriction of outdoor activities by 45 minutes per week. The responses to an increase in the perception of risk associated with the main pollutants varies by level and type of type of risk, and by the kind of averting behavior. For the purchase of purifying equipment and plants expenditure increases on average by 2.14% for a one level increase in the perceived likelihood of suffering from lung cancer to 3.48% for the perceived likelihood of cardiovascular illnesses. For expenditure on curative and preventive medicine the corresponding percentages are 1.03% and 1.67%, respectively. On the basis of our findings, we conclude that improving air quality decreasesrisk averting cost (both financially and in terms of adjustment of daily activities). An important short or medium term policy handle that follows from this study is the introduction of disclosure of air quality, since it may help residents to take the right kind and level of risk reducing actions.

4.1 INTRODUCTION

During the last three decades, China has experienced very rapid economic growth and has become an engine of the global economy. However, its rapid growth has also resulted in a substantial increase in energy consumption and serious air pollution. For instance, suspended particulate matter (PM) and sulfur dioxide (SO_2), are far above the World Health Organization's Air Quality Guidelines in most Chinese cities (WHO, 2005; China State Environmental Protection Agency, 2005;Chan and Yao, 2008; He et al.,2002). Based on 2003 data, the World Bank (2007) estimated that the total health cost associated with outdoor air pollution in urban China was between 157 and 520 billion￥(20.65 and 68.39 billion 2007US$).

As a typical mining city, Jinchuan's economy is dominated by mining and smelting industries which make a substantial contribution to its local economic development. However, these industries also lead to serious environmental issues, especially air pollution. Jinchuan is one of the ten most seriously air polluted cities in China (Wei, 2008). Suspended particles, sulfur dioxide, chlorine gas and carbon dioxide are the main pollutants (Xiao, 2003; Wei, 2008; Li and Zhao, 2004; Huang et al, 2009). The first three pollutants increase the probabilities of respiratory and cardiovascular illnesses, lung cancer and even death (Pope III and Dockery, 2006; Kampa and Castanas, 2008; Bernstein et al., 2004). Carbon dioxide (CO2) is a toxic gas that at high concentration(>2%) can lead to irritation of the eyes and nose,increased heart rate, headaches, shortness of breath, loss of consciousness and possibly death (Baxter, 2000; Faivre-Pierret and Le Guern, 1983).

In order to mitigate negative health effects caused by air pollution, Brenham et al.(1997) distinguishes the following three types of averting behavior:

- Investments that improve quality of the air inhaled, for example, installation of air filters.
- Taking preventive and curing medication.
- Adjusting activities, particularly spending more time indoors, by limiting, rescheduling, or otherwise changing planned outdoor leisure activities.

Traditionally, the costs of averting actions and socio-economic characteristics (e.g. age and education) are considered to explain averting behaviors. However, various researchers have pointed out that socio-psychological factors, such as knowledge, perception, attitude and expectations may also have substantial impacts on (environmental) behavior (Ajzen, 1991; Menon et al., 2008; Cottrell, 2003; Folmer, 2009; Folmer and Johansson-Stenman, 2011; Duerden and Witt, 2010; Shogren and Taylor, 2008; Hammitt,2013; Tang et al., 2013). For instance, Cottrell (2003) found that environmental attitudes explain 23.8% of the total variance in people's environmental behavior whereas Tang et al. (2013) shows that perception is the most important determinant of irrigation water use efficiency in the Guangzhong Plain, China. Therefore, extending averting behavior research with psychological factors – particularly perceived health risk and environmental knowledge –may lead to a better understanding of decision processes (Temme, 2008). Hence, averting behavior research should not only consider socio-economic characteristics (e.g. income, age), but also knowledge of environmental issues and perception of health risks.

The main objective of this paper is to obtain insight into the various types of averting behavior by the residents of Jinchuan to reduce perceived health risk correlated with air pollution. In addition, we intend to estimate their willingness to pay (WTP) for health risk reduction. The data set analyzed includes expenditures on averting actions, socio-economic and demographic variables, and information on the psychological factors knowledge about local environmental issues and perception of health risks caused by air pollution.

The paper is organized as follows. Section 4.2 outlines the perceived averting behavior model (PABM). Section 4.3 describes the methodology (structural equation model with latent variables, SEM) and Section 4.4 the survey, the data and the empirical results. Section 4.5 presents the conclusion and policy recommendations.

4.2. THE PERCEPTION-BASED AVERTING BEHAVIOR MODEL

The averting behavior model (ABM) is a cost-based model. That is, the costs of commodities used to avoid negative health effects from pollution, are taken as indications of the valuation of environmental quality. The model is based on the assumption that when people expect negative impacts of pollution on their well-being, they will adapt their behaviors to avert or reduce these negative effects. Therefore, information on what individuals do to protect themselves against environmental and other risks can be used to infer individuals' preference for reducing these risks. Based on the above assumption, the averting behavior model was first introduced by Grossman (1972) and has since then been widely applied (see e.g. Bartik, 1988; Courant and Porter, 1981;Gerking and Stanley, 1986; Bresnahan, 1999; Olmstead, 2009).

The averting behavior model assumes that individuals maximize their utility or well-being, made up of a composite good and health status, subject to a budget constraint. The latter is the outcome of a health production function with pollution level and averting behavior as arguments (Um et al., 2002). The outcome of this constrained utility maximization exercise is that optimal averting behavior is a function of, *inter alia*, the level of pollution, the price of the composite good, the price of averting behavior, and the individual's socio-economic and demographic characteristics.

The ABM has been used to estimate inter alia the benefits and costs of changes in drinking water quality (Abdalla, 1990; Abdalla et al., 1992; Harrington et al., 1989; Laughland et al., 1996; Um et al., 2002) and air quality (Bresnahan et al., 1999, Murty et al., 2003). Bresnahan et al. (1999) analyzed people's defensive responses to air pollution with an averting behavior model based on objective air pollution data, and found that people will spend significantly less time outdoors when ozone concentrations exceed the national standard. Murty et al. (2003) measured economic benefits from reducing air pollution in Delhi and Kolkata, India, with an averting behavior model. They found that if the current level of suspended particulate matter (PM) were reduced to a safe level, the annual benefits to all the households in those cities would be Rs. 4897 million and Rs. 3000 million, respectively.

Averting behavior studies are likely to fail to accurately predict averting behaviors when they are solely based on expert or objective risks and ignore perception of risk (Cai, 2008; Nauges, 2009; Um et al., 2002). Laboratory experiments have frequently indicated that individuals tend to underestimate objective high-risk events and overestimate objective small-risk events so that their perceived risk often strongly differs from objective risk (Allais, 1953; Ellsberg, 1961; Riddel and Shaw, 2006; Shaw and Woodward, 2008). The laboratory outcomes have been confirmed by recent surveys on averting behavior in the fields of drinking water and air pollution (e.g. Poe and Bishop, 1999; Shaw et al., 2005; Um et al., 2002; Cai, 2008; Richardson, 2011). For instance, Richardson (2011) analyzed the economic health cost of exposure to wildfire smoke in the USA by means of an averting behavior model and found that perceived pollution levels have a positive and significant effect on households' averting activities.

In this paper, we develop a perception-based averting behavior model by using perceived risk next to objective risk. Moreover, we also consider respondents' environmental knowledge as a determinant of averting behavior. The inclusion of the latter is supported by Abdalla et al. (1992) who valued the economic costs of groundwater degradation to households with the averting behavior method in a south-eastern Pennsylvania community. The author found that households' knowledge of contamination significantly influences their averting actions.

Note that an individual's WTP can be calculated from an averting behavior model by maintaining constant utility and analyzing how income varies with a change in perceived health risk caused by pollution (Um et al., 2002):

Before discussing the PABM in detail, we present an overview in Figure 4.1.

Below we present the definitions of the variables in the conceptual model and discuss their expected impacts. We restrict ourselves to the averting behavior component of the model. For the environmental knowledge - perceived health risk sub-model, we refer to Li et al. (2013).

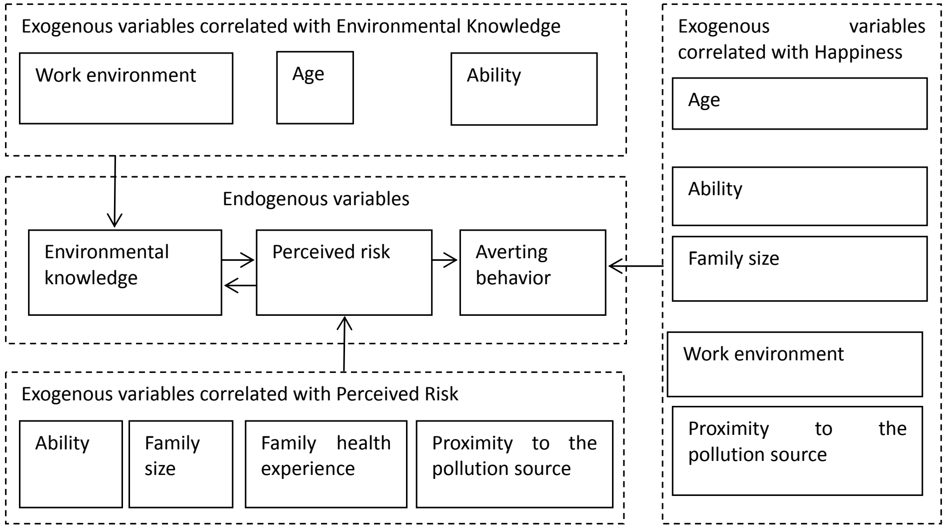

Figure 4.1 Conceptual Framework of the Perception-based Averting BehaviorModel (PABM)
Note: within brackets: expected sign

Averting behaviors (AVB)

We measure the three types of averting behavior specified in section 4.1 by means of the following indicators: (1) annual household expenditure on installing and maintaining air filters[1] and growing houseplants[2] at home, (2) household expenditures (per year)on special foods and medicines, and seeing doctors, (3) reduction of exposure to polluted air by reducing outdoor activities (hours per week). See Table 4.1 for further details. Note that we expect the impacts of the explanatory variables on the three types of averting behavior to have the same sign. The unknown magnitudes, however, may differ. Hence, we do not discuss each type separately below.

Perceived health risk (PHR)

Perceived health risk is defined as the subjective likelihood of the occurrence of a negative event related to the health of a person, or a group of persons, over a specified spell of time (Menon et al., 2008). Perceived health risk is assumed to have a positive impact on averting behaviors. Support for this hypothesis is given by Nauges et al. (1999) who analyzed household data from surveys in Sri Lanka and found that perceived health risk induced households to treat water carefully. i.e.to boil or filter it before drinking. Um et al. (2002) added perception of health risk to their conventional averting behavior model and found that it had a significant impact on citizens' aversion to use tap water in Korea. Perceived health risk, which is a latent variable[3], cannot be directly observed and will be measured by five indicators (See Figure 4.3).

Environmental knowledge (EK)

Environmental knowledge is defined as an individual's cumulative body of knowledge of the interdependency between human society and its natural environment (Berkes et al., 2000). We assume that environmental knowledge positively, but indirectly, impacts on averting behavior via perceived health risk. That is, knowledge of environmental issues and their causes can help people predict their consequences (health risks) and take preventive actions or safety measures to avoid or reduce their negative impacts. We also assume a reverse effect: perceived health risk of air pollution positively impacts on people's environmental knowledge (Li et al., 2013). We measure environmental knowledge by means of eight items. See Figure 4.2.

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[1] Annual householdexpenditure on an air filter is the total acquisition cost divided by its life span (years).

[2] Wolverton (1997) and Kobayashi et al.(2007) pointout that growing house plants can effectively purify indoors air.

[3] Oud and Folmer (2008) define latent variables as phenomena that are supposed to exist but cannot be directly observed. However, they can be measured by indicators (observed or manifest variables)

Exogenous variables

The exogenous variables hypothesized to affect averting behaviors include age, family size, education, income and proximity to the pollution source.

Age (AGE)

We assume that age positively impacts on averting behavior because resistance deteriorates with age which implies that one gets more prone to illnesses. Empirical support for this assumption is given by Eiswerth et al. (2006) who studied how activity schedules responded to ozone pollution in Los Angeles. They found that age positively influences averting behaviors. Atreya (2007) investigated acute health impacts associated with pesticide exposure in rural Nepal and also found a positive relationship between age and averting behavior. We distinguish seven age classes (see Table 4.1 for details).

Family size (FS)

We expect that family size positively influences averting behavior because the larger a family, the more people are exposed and thus at risk. This assumption is supported by Ndiritu (2013) who conducted a study on the treatment of drinking water in four Kenyan towns. The author found that people's averting behaviors (treating and filtering water) increases with family size. In this paper we define family size as the number of family members who live in the same house.

Ability (AB)

Following Cropley and Dehn (1996), we define ability as the capacity to adequately understand problems and to act accordingly. Ability, which is taken as a latent variable, can be measured via indicators such as income and education (see inter alia Chamorro-Premuzic and Furnam, 2002; Mackay, 2007; Finnie and Mueller, 2008for over views and details). Smedley and Syme (2001) point out that people with higher ability commonly achieve higher education levels and earn more than individuals with lower ability. We assume that ability has a positive impact on averting behavior to mitigate the negative effects of air pollution on themselves and their family members. This assumption is supported by Neidell (2004) who conducted a study on the effect of outdoor air quality on childhood asthma in California. The author found that poorer and less educated households were underrepresented in clean areas. As a result their children's health suffered. Using data from Delhi, India andEspírito Santo, Brazil, McConnell and Rosado (2000) found that education of the household head positively and significantlyinfluences a household's decision to purify drinking water to avoid health risks. Similar results were obtained by Abrahms et al. (2000). Education is measured as the highest degree obtained and income by classes (See Table 4.1 for details).

Proximity to pollution source (PPS)

We assume that the closer one lives to the air pollution source (smelting plants), the higher the level of concentration of air pollutants will be. Therefore, people who live close to the smelting plants are more susceptible to illnesses correlated with air pollution and may be more likely to take actions. This assumption is supported by Devi (2010) who conducted a study in the Karur district of Tamil Nadu, India, on farmers' WTP to avert the negative externalities of pollution. The author found that proximity to the pollution source is negatively correlated with expenditure on averting actions. We distinguish three distance categories: (1) SAP (close to the smelting plants, serious air pollution), (2) MAP (medium air pollution) and (3) LAP (far away from the source, light air pollution).

Family health experience (FHE)

People who have had adverse health experiences from air pollution are likely to be strongly concerned about air pollution and likely to take precautions. Moreover, patients commonly need extensive care from their family members. This will not only influence family members' daily life routines, but also negatively impact on their emotions (Northouse et al.,2002). Therefore, we expect that individuals who themselves or whose family members have experienced health problems related to air pollution are likely to take averting behaviors. Lichtenberg et al. (1999) analyzed the relationship between farmers' health experience and preventive behavior in Maryland, New York, and Pennsylvania, and found that farmers who had experienced adverse health effects from pesticides were likely to take precautions. We measure family health experience by means of a dichotomous variable which takes the value 1, if the respondent, or one or more of his or her family members, have been hospitalized for cardiovascular diseases or respiratory diseases, and 0 otherwise (See Table 4.1).

4.3. METHODOLOGY (SEM)

The conceptual PABM contains both latent variables (e.g. perceived health risk and environmental knowledge) and observed variables (e.g. age and family size).In oder to simultaneously handle latent and observed variables in one framework, astructural equation model with latent variables (SEM)will be applied.[4] A SEM is made up of three

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[4] The use of SEM has several advantages including reduction of multicollinearity (Folmer and Oud, 2008) and of bias due to measurement error (Bollen, 1989; Suparman et al., 2013).

sub-models: two measurement models and the structural model (Jöreskog and Sörbom, 1996). Specifically:

$$\mathbf{y} = \Lambda_y \eta + \varepsilon \textbf{ with } \mathbf{cov}(\varepsilon) = \Theta_\varepsilon \tag{4.1}$$

$$\mathbf{x} = \Lambda_x \xi + \delta \textbf{ with } \mathbf{cov}(\delta) = \Theta_\delta \tag{4.2}$$

$$\eta = \mathrm{B}\eta + \Gamma\xi + \zeta \textbf{ with } \mathbf{cov}(\xi) = \Phi\mathbf{cov}(\zeta) = \Psi \tag{4.3}$$

Equations (4.1) and (4.2) are the measurement models which describe the relations between latent variables and their corresponding indicators. Specifically, **y** and **x** are the p×1 and q×1vectors of observed endogenous and exogenous variables, respectively, and $\boldsymbol{\eta}$ and $\boldsymbol{\xi}$ the m×1 and n×1 vectors of latent endogenous and latent exogenous variables, respectively. $\boldsymbol{\Lambda}_y$ is the (p×m) matrix of loadings of **y** on $\boldsymbol{\eta}$ while $\boldsymbol{\Lambda}_x$ is the (q×n) matrixwith the loadings of **x** on $\boldsymbol{\xi}$.$\boldsymbol{\Theta}_\varepsilon$ (p×p) and $\boldsymbol{\Theta}_\delta$ (q×q) are covariance matrices of $\boldsymbol{\varepsilon}$ and $\boldsymbol{\delta}$ which are the measurement errors of **y** and **x**, respectively.

Equation (4.4) is the structural model which specifies the relationships among the latent variables. $\boldsymbol{B}$ is an m×m matrix that presents the structural relationships among the latent endogenous variables, $\boldsymbol{\Gamma}$ an m×n matrix of the impacts of the exogenous latent variables on the endogenous latent variables, and $\boldsymbol{\zeta}$ a random (p×1) vector of errors with covariance matrix $\boldsymbol{\Psi}$ (p×p). The covariance matrix of $\boldsymbol{\xi}$ is $\boldsymbol{\Phi}$ (n×n).[5]

A SEM is estimated by minimizing the fit function $\mathbf{F}(\mathbf{S},\sum(\theta))$ where $\boldsymbol{S}$ and $\sum(\boldsymbol{\theta})$) are the sample and theoretical covariance matrix, respectively, and $\boldsymbol{\theta}$ is the vector of unknown model parameters in equations (4.1)-(4.3). The methods that can be used to estimate a SEMinclude Generalized Least Squares (GLS), Two-Stage Least Squares (TSLS), Unweighted Least Squares (ULS), Instrumental Variables (IV), Maximum Likelihood(ML) and Weighted Least Squares (WLS) (Jöreskog and Sörbom, 1996). ML, which is most widely used, is based on the assumption of multivariate normality of the observed variables. When the data is not continuous or does not follow a multivariate normal distribution, ML willlead to biased standard errors and an inflated χ^2 test statistic of the overall model fit(West et al., 1995). In those cases weighted least squares (WLS) can be applied (Browne, 1984; Jöreskog and Sörbom, 1989, 1993, 1996), as is done in the present paper. The WLS fit function reads:

$$\mathbf{F}_{\mathbf{WLS}} = [\boldsymbol{\rho} - \boldsymbol{\rho}(\boldsymbol{\theta})]'\ \mathbf{W}^{-1}\ [\boldsymbol{\rho} - \boldsymbol{\rho}(\boldsymbol{\theta})] \tag{4.4}$$

where $\boldsymbol{\rho}$ is the vector of the elements in the lower (or upper) half of the matrix of polychoric correlations including the diagonal $\boldsymbol{\rho(\theta)}$ denotes the restrictions imposed on the population polychoric correlation matrix as specified in equations (4.1)-(4.3). W^{-1} is a positive-definite weight matrix.[6]

Several software packages are available to estimate a SEM including Lisrel 8, OpenMX (in R), AMOS and Mplus. The Lisrel software package, which is probably best known, provides information on identification and various test statistics. Moreover, it also contains modification indices which can be used to respecify the model, notably to free fixed or constrained model parameters (for details, see Jöreskog and Sörbom,1996).

4.4 EMPIRICAL RESULTS

4.4.1 Survey and data collection

A survey among Jinchuan residents was conducted inAugust 2012. A stratified random sample of 800 respondents, aged between 20 and 79, was drawn. The face-to-face interviews were carried out atthe respondents' homes. Apart from questions on socio-economic and demographic characteristics, interviewees were questioned about their environmental knowledge, perceived health risk, and averting behaviorsFigures 4.2 and 4.3 for details)

4.4.2 Descriptive statistics

Of our initialsample of 800 filled out questionnaires, 41 (5.12%) were rejected because they were incomplete. There was no evidence of non-random drop out. Descriptive statistics are presented in Table 4.1, Figures4.2 and 4.3.

The distribution of the socio-economic characteristics in Table 4.1 is in line with the population distribution of Jinchuan (see Jinchuan Statistical Yearbook, 2011).

We examined the respondents' knowledge of environmental issues by means of eight indicators (Figure 4.2). Each indicator is measured on a five-points scale ranging from 1 (strongly disagree) to 5 (strongly agree). The first four indicators (EK1-EK4) are used to

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[5] Note that it is possible to include intercepts in the measurement models and in the structural model. However, below we standardize the variables. We furthermore observe that directly observed variables can be included in the structural model by specifying an identity relationship between a latent variable and its indicator in its measurement model.

[6] Browne (1982, 1984) shows that if W^{-1} is the correct weight matrix, F_{WLS} is an asymptotically efficient estimator of the parameters, standard errors and chi-square overall test statistic.

Table 4.1 Descriptive Statistics

Variables	Min	Max	Mean	S.D
Age (AGE)	21	78	44.11	11.4
Family Size (FS)	1	6	2.95	0.78
Family health experience (FHE)	0	1	0.33	0.48
AVBE1 (￥per year)	0	2100	177.59	241.79
AVBE2 (￥per year)	0	18000	344.83	1468.8
AVBE3 (hoursper week)	0	27	8.97	7.54

Education (EDU)	**%**	**Household Income (￥permonth) (IN)**	**%**
Primary school	6.30%	1000-2000(￥)	4.70%
Middle school	23.60%	2000-3000(￥)	15.30%
High school	25.30%	3000-4000(￥)	18.30%
Vocational school,	25.30%	4000-5000(￥)	19.10%
Bachelor’s degree	19.10%	5000-6000(￥)	20.90%
Master’s degree	0.40%	6000-7000(￥)	13.00%
Proximity to pollution source.(PPS)	**%**	7000-8000(￥)	3.70%
Nearby smelting plants, severe air pollution (SAP)	29.60%	8000-9000(￥)	1.80%
Medium air pollution (MAP)	29.80%	More than 10000(￥)	2.00%
Far away from smelting plants, light air pollution (LAP, reference case)	40.60%		
Work environment (WE)	**%**		
Non-JMC employee (reference case)	59.55%		
Miners and smelter workers of JMC (MS)	18.18%		
JMC employee, but not miner or smelter worker (NMS)	22.27%		

Note: **AVBE1**: annual household expenditure on air filters and houseplants at home. **AVBE2**: households expenditures (per year) on special foods and medicines, and seeing doctors. **AVBE3**:respondent’s average adjusting behaviors to reduce the impacts of exposure to polluted air (hoursper week) including limited, rescheduled, or otherwise postponed planned leisuretime. **Family size:**number of family members living in the same house. **Family Health experience**: 1 if the respondent or one or more of his/her family members have been hospitalized for cardiovascular diseases (e.g., hypertension, heart attack, chest pain, arrhythmia and miocardial infraction) or respiratory diseases (e.g., upper respiratory tract infection, bronchitis, pneumonia, asthma, and lung cancer), 0 otherwise.

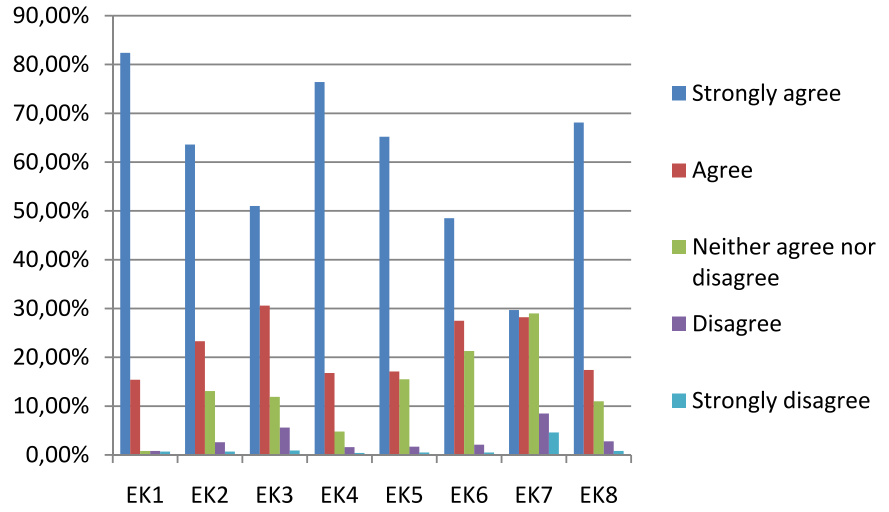

Figure 4.2 Frequency distribution of the indicators of environmental knowledge

Note: EK1:Jinchuan suffers from air pollution.**EK2**:Jinchuan suffers from industrial solid waste. **EK3**:Jinchuan suffers from water pollution.**EK4**: Environmental issues in Jinchuan are mainly caused by local industrial activities. **EK5**:Sulfur dioxide is one of the main air pollutants of Jinchuan. **EK6**: Suspended particle matter is one of the main air pollutants of Jinchuan. **EK7**: Carbon dioxideis one of the main air pollutants of Jinchuan. **EK8**:Chlorine gasis one of the main air pollutants of Jinchuan.

test respondents’ knowledge of Jinchuan’s general environmental issues and their causes. Figure4.2 shows that over 80% of the respondents strongly agree or agree that air pollution, industrial solid waste, and water pollution are environmental issues in Jinchuan. Moreover, 93.2 % are of the opinion that Jinchuan’s environmental problems are mainly caused by local industrial activities (EK4). The final four indicators (EK5-EK8) specify the main air pollutants. Figure 4.2 shows that the majority (over 55.0 %) of the respondents either strongly agree or agree that chlorine gas, sulfur dioxide, suspended particles and carbon dioxide are the main pollutants.

Five indicators (relating to two domains) were used to measure perceived health risks caused by air pollution. For the first domain, respondents were asked to answer the question (PHR1): what is the average number of days per week Jinchuan’s air was heavily polluted during the past year? Figure 4.3 shows that the percentages of respondents who answered ‘heavily polluted’ (4 or more days a week) and ‘lightly polluted’ (0 or 1 day a week) were 18.3% and 19.6%, respectively. The majority (62.1%) answered ‘medium polluted’ (2 or 3 days a week). Regarding the second domain, four major types of health problems were presented to the respondents. They were asked to what extent they agreed that Jinchuan’s air pollution increased the probability of suffering from each of them. A five-points scale was used with 1 indicating strong disagreement and 5 strong agreement. The results show that respiratory illnesses (95.9%) are considered to have the most serious impacts, followed by lung cancer (83.6%), cardiovascular illnesses (75%) and death (73.1%).

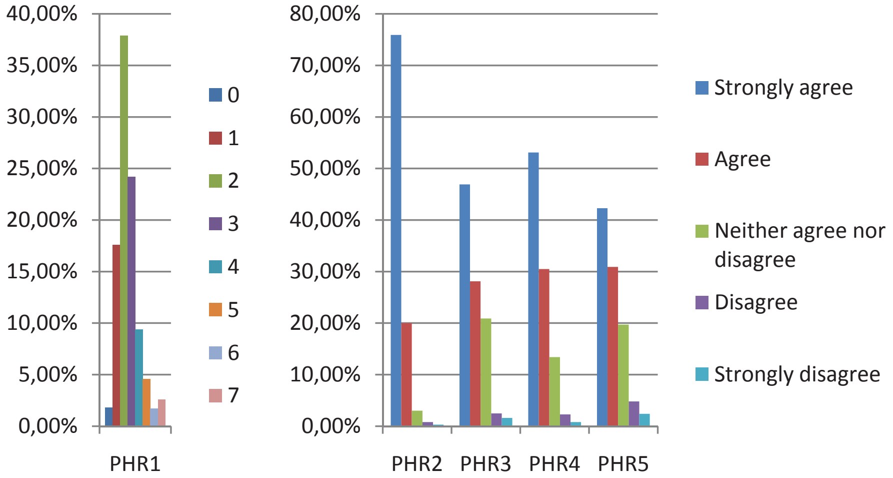

Figure 4.3 Frequency distribution of the indicators of perceived health risk

Note: PHR1:What is the average number of days per week Jinchuan's air was heavily polluted during the past year?**PHR2**: Jinchuan's air pollution increases the possibility of suffering from respiratory illnesses. **PHR3**:Jinchuan's air pollution increases the possibility of suffering from cardiovascular illnesses. **PHR4**: Jinchuan's air pollution increases the possibility of suffering from lung cancer. **PHR5:** Jinchuan's air pollution increases the possibility of suffering from death.

4.4.3 The estimated SEM

Before going into detail, we note that we present the SEM estimates as standardized or beta coefficients which are the standard deviation changes in the dependent variable due to a standard deviation change of an explanatory variable. Standardized coefficients are directly comparable, as the scales of the explanatory variables are irrelevant. As mentioned above, averting behavior is taken as a latent variable measured by three indicators: AVBE1, AVBE2 and AVBE3 (See Table 4.1 for definitions). (To distinguish between the latent variables and their indicators, we add 'L' to the former. For example, AVBL denotes the latent variable and AVB1 one of its indicators.) To obtain percentage changes of the first two indicators, we take natural logarithms of their scores. We re-label them as AVB1 and AVB2, respectively. Since some outcomes of ABVE1 and ABVE2 are equal to zero, we increase all scores by 1. Hence, note that we also re-label AVBE3 as AVB3 but do not apply a log transformation.Before turning to the estimates, we present the conceptual model in Figure 4.1 in the notation of equation (4.5)-(4.6):[7]

Measurement models

$$\begin{bmatrix} AVB1 \\ \vdots \\ AVB3 \\ PHR1 \\ \vdots \\ PHR5 \\ EK1 \\ \vdots \\ EK8 \end{bmatrix} = \begin{bmatrix} \lambda^y_{1\,1} & 0 & 0 \\ \lambda^y_{2\,1} & \vdots & \vdots \\ \lambda^y_{3\,1} & 0 & 0 \\ 0 & \lambda^y_{4\,2} & 0 \\ 0 & \lambda^y_{5\,2} & 0 \\ \vdots & \vdots & \vdots \\ 0 & \lambda^y_{8\,2} & 0 \\ 0 & 0 & \lambda^y_{9\,3} \\ 0 & 0 & \lambda^y_{10\,3} \\ \vdots & \vdots & \vdots \\ 0 & 0 & \lambda^y_{16\,3} \end{bmatrix} \times \begin{bmatrix} AVBL \\ PHRL \\ EKL \end{bmatrix} + \begin{bmatrix} \varepsilon_1 \\ \vdots \\ \varepsilon_3 \\ \varepsilon_4 \\ \vdots \\ \varepsilon_8 \\ \varepsilon_9 \\ \vdots \\ \varepsilon_{16} \end{bmatrix} \tag{4.5}$$

$$\begin{bmatrix} EDU \\ IN \\ FS \\ AGE \\ FHE \\ MAP \\ SAP \\ NMS \\ MS \end{bmatrix} = \begin{bmatrix} \lambda^x_{11}000000 \\ \lambda^x_{21}000000 \\ 0\ 100000 \\ 0\ 010000 \\ 0\ 001000 \\ 0\ 000100 \\ 0\ 000010 \\ 0\ 000001 \end{bmatrix} \times \begin{bmatrix} ABL \\ FS \\ AGE \\ FHE \\ MAP \\ SAP \\ NMS \\ MS \end{bmatrix} + \begin{bmatrix} \delta_1 \\ \delta_2 \\ 0 \\ 0 \\ 0 \\ 0 \\ 0 \\ 0 \end{bmatrix} \tag{4.6}$$

The structural model

$$\begin{bmatrix} AVBL \\ PHRL \\ EKL \end{bmatrix} = \begin{bmatrix} 0 & \beta_{1\,2} & 0 \\ 0 & 0 & \beta_{2\,3} \\ 0 & \beta_{3\,2} & 0 \end{bmatrix} \times \begin{bmatrix} AVBL \\ PHRL \\ EKL \end{bmatrix} + \begin{bmatrix} \gamma_{1\,1} & \gamma_{1\,2} & \gamma_{1\,3} & \gamma_{1\,4} & \gamma_{1\,5} & \gamma_{1\,6} & 0 & 0 \\ \gamma_{2\,1} & \gamma_{2\,2} & 0 & \gamma_{2\,4} & \gamma_{2\,5} & \gamma_{2\,6} & 0 & 0 \\ \gamma_{3\,1} & 0 & \gamma_{3\,3} & 0 & 0 & 0 & \gamma_{3\,7} & \gamma_{3\,8} \end{bmatrix} \times \begin{bmatrix} ABL \\ FS \\ AGE \\ FHE \\ MAP \\ SAP \\ NMS \\ MS \end{bmatrix} + \begin{bmatrix} \zeta_1 \\ \zeta_2 \\ \zeta_3 \end{bmatrix} \tag{4.7}$$

As described in the previous section, several observed variables, notably the indicators of perceived health risk and environmental knowledge, are ordinal or dichotomous. Moreover, the indicators of environmental knowledge are highly skewed and non-normally distributed because the vast majority of respondents expressed agreement or strong agreement to the statements on Jinchuan's environmental issues.Therefore, and as explained in section 4.3,

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[7] Note that latent variables are unobservable and thus have no definite scale. To render the model identified and to make the parameters interpretable, we assign measurement scales to the latent variable by fixing their variances (at 1). See Jöreskog and Sörbom (1996) for details.

WLS based on the matrix of polychoric correlations,was employed to estimate model (4.5)-(4.7).

As a first step, we estimatedthe full conceptual model (denoted initial model), presented in (4.5)-(4.7). The estimated measurement models showed that ABV1 and ABV2 on the one hand and ABV3 on the other, measured different dimensions of averting behavior.[8] Therefore, we split the latent variable AVBL into 2 different latent variables AVBL1, measured by the indicators AVB1 and AVB2, and AVBL2 measured by AVB3. AVBL1 relates to expenditures on purifying equipment and plants, and food and medicine, and AVBL2 to restrictions on behavior.

PHR1 was found to measure a different dimension of the latent variable perceived health risk than the other indicators. Therefore, it was split into PHRL1, measured by PHR1, and PHRL2, measured by the remaining indicators. PHRL1 denotes people's perceived risk due to intensity of exposure, i.e. frequency of occurrence of serious air pollution in Jinchuan while PHRL2 is people's judgments of the risk associated with the main pollutants. PHRL1 is measured by PHR1 and PHRL2 by PHR2-5

Another outcome of the estimated initial model was that several explanatory variablesin the AVBL1 and AVBL2 equationshad the wrong sign or were highly insignificant. We deleted the variables with insignificant coefficients one by one starting with the one with the largest *p*-value (stepwise backward elimination). In the thus reduced (i.e. final) model, all the exogenous variables are significant(see table 4.4). Below we discuss the final model. Note that all the loadings and structural coefficients are standardized or beta coefficients.

The overall goodness-of-fitindices of the final model are presented in Table 4.2, i.e. the χ2/DF (DF denoting degrees of freedom), the Goodness-of-Fit statistic (GFI), the Adjusted Goodness-of-Fit statistic (AGFI), the Standardized Root Mean Square Residual (SRMR) and the Root Mean Square Error of Approximation (RMSEA) (See Bentler and Bonnet,1980; Jöreskog and Sörbom, 1993; Byrne, 1998; Schreiber, 2006; Tabachnick and Fidell, 2007; Ouyang, 2009for details.) All the indicesmeet their critical values indicating that the final model has a good fit.

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[8] The different dimensions were indicated by the extremely low reliability of AVB3 compared to the reliabilities of AVB1 and AVB2. Note that the reliability of AVB2 is a border case. (For details on this issue, seeBollen, 1989.) In addition to the reliabilities, there are substantive arguments that the indicators measure different dimensions. Specifically, whereas AVB 1 and AVB2 relate to expenditures, AVB3 measures activities. Similar substantive arguments apply to splitting PHRL into 2 dimensions.

Table 4.2 Overall goodness-of-fit indices

Fit index	Value	Cut off value
χ2/DF	2.22	<3
Goodness-of-fit index(GFI)	0.98	>0.90
Adjusted goodness-of-fit index (AGFI)	0.97	>0.90
Standardized root mean square residual(SRMR)	0.027	<0.08
Root mean square error of approximation (RMSEA)	0.040	<0.05

The estimated measurement models are presented in Table 4.3 which contains for each indicator its loadings, standard error and reliability (*R^2*), respectively. Table 4.3 indicates that the loadings of all indicators are significant at 1% or less.

Table 4.3 Measurement models

latent variables	Indicators	Coefficient	Standard errors	R^2
Averting behavior 1 (AVBL1)	AVB1	0.36	0.12	0.13
	AVB2	0.28	0.09	0.08
Averting behavior 2 (AVBL2)	AVB3	1.00	---	1.00
Perceived health risk 1 (PHRL1)	PHR1	1.00	---	1.00
Perceived health risk 2 (PHRL2)	PHR2	0.60	0.03	0.36
	PHR3	0.52	0.03	0.28
	PHR4	0.62	0.03	0.38
	PHR5	0.55	0.03	0.30
Environmental knowledge (EKL)	EK1	0.51	0.04	0.26
	EK2	0.46	0.03	0.22
	EK3	0.39	0.03	0.15
	EK4	0.48	0.07	0.23
	EK5	0.56	0.04	0.31
	EK5	0.47	0.03	0.22
	EK7	0.31	0.03	0.10
	EK8	0.44	0.04	0.19
Ability(ABL)	Education	0.50	0.05	0.25
	Income	0.45	0.04	0.20

The structural model including estimated standardized structural coefficients, standard errors, and is presented in Table 4.4 The results show that perceived health risk,as measured by days of exposure (PHRL1), positively and significantly induces reduction of exposure to polluted airby reducing outdoor activities (AVBL2). That is, the more days a week one thinks that the air is heavily polluted, the more one restricts outdoor activities. The impact of PHRL1 on expenses on air purification equipment and food and medicine (AVBL2) was highly insignificant and deleted from the initial model. Furthermore, perceived health risk as measured by types of illnesses that one may incur due to exposure to polluted air (PHRL2) impacts positively on ABVL1, although the impact is not significant at conventional levels (p value: 0.072). The impact of PHRL2 on ABVL2 is highly insignificant. A possible explanation is that reduction of outdoor activities is seen as a more flexible, effective and cheaper type of averting behavior to air pollution than the purchase of equipment, food and medicine. Specifically, reducing outdoor activities induces an immediate reduction in health risks whereas possible effects of purification equipment, food and medicine materialize with delays. Furthermore, there is a difference in the nature of the effects of the two kinds of averting behavior. Whereas restricting outdoor activities reduces direct exposure to outdoor pollution, purification equipment purifies indoor air which is likely to be less polluted than outdoor air. Finally, whereas medicine and food are expected to mitigate the effects of exposure, reduction of outdoor activities reduces the cause (exposure) rather than its effects.

In line with the conceptual model, ability substantially, positively and significantly influences purchases of equipment, food and medicine (AVBL1) while its impact on outdoor activities (AVBL2) is positive, though marginally significant. This difference in outcome is probably related to the fact that the purchase of purification equipment, special food and medicine require substantial outlays whereas restricting, outdoor activities does not have financial implications.

Consistent with Li et al (2013), environmental knowledge positively and significantly influences both types of perceived risk. The reverse effect, however,was highly insignificant and not included in the final model. Moreover - apart from environmental knowledge – ability and family size significantly impact on people's judgments of the risk of the various pollutants (PHRL2) whereas family health experience and proximity to the pollution source have marginally significant impacts. Proximity to the pollution source, however, is a highly significant determinant of perception of the risk to exposure (PHRL1). Finally, environmental knowledge is significantly associated with ability, age and work environment, as hypothesized in the conceptual model. For further details we refer to Li et al. (2013).

Table 4.5 presents the standardized indirect and total effects of all variables on all endogenous variables. (An indirect effect is the effectsofan endogenous or exogenous variable on an endogenous variable through intervening endogenous variables (Jöreskog and Sörbom, 1996)). The total effect is the sum of the direct and indirect effects). Table 4.5 indicates that ability has the largest positive total effect (0.69) on AVBL1, followed by perceived health risk 2 (PHRL2), though the latter impact is marginally significant. The total effects of the other variables are insignificant. PHRL1 is the most important determinant of AVBL2 with a total effect of 0.20. Next is ability (0.05). Although they have no direct effect on AVBL2, environmental knowledge, age, proximity to the pollution source and work environment also positively and significantly influence AVBL2. Environmental knowledge, ability, and proximity to the pollution source are the most important determinants of perceived health risk (PHRL1). Age and work environmental also significantly and positively impact on PHRL1, but their total effects are small. The most important determinant of PHRL2 is environmental knowledge with a total effect of 0.69. Next is ability (0.35). Age and work environment indirectly and significantly influence PHRL2 via environmental knowledge. SAP and MAP positively influence PHRL2 with total effects of 0.06 and 0.05, respectively, though they are marginally significant. Family size and family health experience impact on with PHRL2 total effects of -0.08 and 0.05, respectively, though family health experience is marginally significant.Ability is the most important determinant of environmental knowledge with a total effect of 0.36. NMS and MS positively influence environmental knowledge with total effects of 0.08 and 0.17, respectively. The total effect of NMS, however, is insignificant. The total effect of age is 0.09.

We now turn to the calculation of the averting behavior costs (WTP) due to risk perception as measured by the indicators of PHRL1 and PHRL2. As a first step, we present in Table 4.6 the total effects of PHRL1 and PHRL2 on the observed indicators AVB1-AVB3. From table 4.6 it follows that an increase of perceived risk due to intensity of exposure by 1 standard deviation, i.e. 2.02 days (or 1 day) a week of severe air pollution, reduces outdoor activities by a fifth of standard deviations of AVB3 (1.508 hours per week).For 1 day a week this implies a reduction of 45 minutes. If we value this at the average hourly wage rate in Jinchuan (26.01 ￥ per hour in 2011)[9] , we arrive at a WTP of 19.42￥ per week for reducing perceived risk due to an increase of one day a week of severely polluted (See table 4.7).

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[9] See Jinchuan Statistical Yearbook (2011)

Table 4.4 The structural model

Variables	AVBL1	AVBL2	PHRL1	PHRL2	EKL
Perceived health Risk 1 (PHRL1)		0.20***			
		(0.06)			
Perceived health Risk 2 (PHRL2)	0.15				
	(0.11)				
Environmental knowledge (EKL)			0.13***	0.69***	
			(0.03)	(0.09)	
Ability(ABL)	0.69***	0.03	0.05	0.10*	0.36***
	(0.49)	(0.03)	(0.05)	(0.08)	(0.07)
Age (AGE)					0.09***
					(0.03)
Family size (FS)				-0.08***	
				(0.03)	
Family health experience (FHE)				0.05	
				(0.03)	
Medium air pollution (MAP)			0.09***	0.06	
			(0.03)	(0.04)	
Serious air pollution (SAP)			0.19***	0.05	
			(0.03)	(0.04)	
JMC employee, but not miner or smelter worker (NMS)					0.08
					(0.05)
Miners and smelter workers of JMC (MS)					0.17***
					(0.04)
	0.56	0.04	0.05	0.53	0.16

Note: Standard errors in parenthesis. *, **and *** :10%, 5% and 1%, respectively.

Table 4.6 Total effects of PHRL1 and PHRL2 on AVB1-AVB3 (standardized coefficients)

Variables	AVB1	AVB2	AVB3
PHRL1 (exposure)			0.20***
			(0.08)
PHRL2 (risk judgment)	0.05*	0.04	
	(0.03)	(0.03)	

Note: Standard errors in parenthesis. *, **and *** :10%, 5% and 1%

Table 4.5 Total and indirect effects

	Total effects					Indirect effects				
Variables	AVBL1	AVBL2	PHRL1	PHRL2	EKL	AVBL1	AVBL2	PHRL1	PHRL2	EKL
Perceived health Risk 1 (PHRL1)		0.20***								
		(0.06)								
Perceived health Risk 2 (PHRL2)	0.15									
	(0.11)									
Environmental knowledge (EKL)	0.10	0.03**	0.13***	0.69***		0.10	0.03**			
	(0.10)	(0.02)	(0.05)	(0.09)		(0.10)	(0.02)			
Ability(ABL)	0.74***	0.05*	0.10***	0.35***	0.36***	0.05	0.02**	0.05***	0.25***	
	(0.41)	(0.04)	(0.05)	(0.09)	(0.07)	(0.05)	(0.01)	(0.02)	(0.07)	
Age (AGE)	0.01	0.00*	0.01**	0.06***	0.09***	0.01	0.00*	0.01**	0.06***	
	(0.01)	0.00	(0.01)	(0.03)	(0.03)	(0.01)	(0.00)	(0.01)	(0.03)	
Family size (FS)	-0.01			-0.08***		-0.01				
	(0.01)			(0.03)		(0.01)				
Family health experience (FHE)	0.01			0.05		0.01				
	(0.01)			(0.03)		(0.01)				
Medium air pollution (MAP)	0.01	0.02**	0.09***	0.06		0.01	0.02**			
	(0.01)	(0.01)	(0.03)	(0.04)		(0.01)	(0.01)			
Serious air pollution (SAP)	0.01	0.04**	0.19***	0.05		0.01	0.04***			
	(0.01)	(0.01)	(0.03)	(0.04)		(0.01)	(0.01)			
JMC employee, but not miner or smelter worker (NMS)	0.01	0.00	0.01	0.06	0.08	0.01	0.00	0.01	0.06	
	(0.01)	(0.00)	(0.01)	(0.04)	(0.05)	(0.01)	(0.00)	(0.01)	(0.04)	
Miners and smelter workers of JMC (MS)	0.02	0.00*	0.02***	0.12***	0.17***	0.02	0.00*	0.02**	0.12***	
	(0.01)	(0.00)	(0.01)	(0.04)	(0.04)	(0.01)	(0.00)	(0.01)	(0.04)	

Note: Standard errors in parenthesis. *, **and *** :10%, 5% and 1%

For the calculations of the impacts of PHRL2 on AVB1 and AVB2 as measured by their ordinal indicators PHR2-PHR5 we need to transform them into their underlying unobservable continuous variables and to transform the standardized coefficients into the corresponding un-standardized coefficients. The various steps are summarized in Appendix C and the results are presented in Table 4.7. The table shows that the WTP for averting the common impairments of cardiovascular (PHR3) and respiratory (PHR2) illnesses is larger than for the more rare impairment of lung cancer (PHR4) and death.. This applies to both purifying equipment and plants and curative and preventing food and medicine. These results are in line with Bresnahan et al.(1997) who points out that people prefer to take more actions against common health problems than to less familiar impairments. Note that the WTP for filters and plants is systematically larger than that for curative and preventive food and medicine.

Table 4.7 The impacts of perceived health risks on AVB1- AVB3 (un-standardized coefficients)

	AVB1	AVB2	AVB3
PHR1	0	0	45 minutes
PHR2	2.91%	1.61%	0
PHR3	3.48%	1.67%	0
PHR4	2.14%	1.03%	0
PHR5	2.86%	1.46%	0

4.5 SUMMARY AND CONCLUSION

Based on a cross-sectional data set of 759 households in the Jinchuan mining area, China, we analyzed and measured perception of health risk correlated with air pollution and its impact on household's averting behavior. By means of structural equation modeling, particularly the measurement models, we identified two related, though different dimensions of each concept. For averting behavior the dimensions are curative and preventive expenditures on the one hand, and restricting outdoor activities on the other; for the latter perceived health risk due to intensity of exposure and risk of the main pollutants. Distinguishing and modeling each of the dimensions is required to develop a comprehensive understanding of the impacts of perception-based risk on averting behavior. Lumping the dimensions together will lead to a distorted picture of averting behavior and its causes.

As regards contents, we found that higher perceived risk commonly drives people to take more action to mitigate the negative effects caused by air pollution. These results support the arguments by Um et al.(2008) and Richardson et al. (2011) thatrisk perception positively and significantly influences people's averting behavior. Apart from perceived risk, we found that ability, as measured by income and education, is an important determinant of averting behavior.

To develop an understanding of its main characteristics, we conceptualized and treated the perceived risk variables as endogenous variables and estimated their determinants. Based on a brief literature review, we identified inter alia environmental knowledge as a driving force. We also took environmental knowledge as an endogenous variable based on the assumption that it is influenced by perceived risk and socioeconomic characteristics. As in the case of averting behavior and perceived risk, we developed a set of test items to measure the latent variable environmental knowledge. As regards contents, we found that environmental knowledge is associated with age, ability and work environment.

Li et al. (2013) shows that air pollution is one of the main driving forces of happiness in the Jinchuan mining area. The results in this paper are in line with this finding in that the average WTP for improved air quality as derived from averting behavior expenses amounts to 2 % of average household net income. In addition, perceived risk due to intensity of exposure leads to a reduction of outdoor activities by 45 minutes per week for another day of heavy air pollution per week. It follows that reducing air pollution generated by the mining and smelting industries ought to be a top policy priority. However, realization of this policy goal requires time. For the short and medium term and in anticipation of reductions, intermediate policy measures aimed at assisting the inhabitants to take appropriate averting behaviors, could be implemented. Because environmental knowledge is one of its major indirect driving forces, disclosing information on air quality is an important policy handle. For instance, information on local air quality conditions could be announced daily, possibly in combination with the weather forecast. Suggestions about averting behaviors - for example, spending more time indoors - could be also made.

This study needs to be extended in several ways. First, the definitions of the latent variables averting behavior, perceived health risk and environmental knowledge need to be refined. In this paper we identified two different dimensions of the former two. It is important to investigate if there are other dimensions. Secondly, the set of test items need to re-tested and, possibly, revised and expanded. Thirdly, in this paper we emphasized that perceived risk should be used to analyze averting behavior. It is important to analyze the correspondence between objective risk and perceived risk. Fourthly, this paper relates to a specific mining area in China. It is of great scientific importance to understand the universality of the concepts analyzed here and the applicability of their measurements in other geographical settings. Finally, this study has solely focused on the relationship between air pollution and averting behavior. However - apart from air - water and soil are also heavily polluted by mining and smelting in the Jinchuan area. It is important to investigate how each of these types of environmental degradation affects people's averting behaviors

APPENDIX C

Calculation of the impacts on averting behavior expenditure of perceived health risk of pollutants measured by their ordinal indicators

1. Calulate for each category of the ordinal variable its proportion of scores.
2. The ordinal variable is considered a measurement of an underlying unobserved continuous variable that is (usually) assumed to follow a normal distribution. The categories of the ordinal variable are taken to correspond to intervals of the continuous variable. The endpoints of the intervals are the treshold values of the continuous variable which can be obtained by PRELIS 2, a subroutine of LISREL 8 (Jöreskog and Sörbom, 1996)
3. For each endpoint determine its cumulative probability based on the normal distribution underlying the ordinal variable. The mean and standard deviation of the normal distribution are given by PRELIS 2.
4. From the cumulative probability of the endpoints, calculate the probability of each category under the normal distribution as the difference between the cumulative probability of the upper and lower endpoint.
5. Calculate the midpoint for each interval as the normal distribution quintile corresponding to the lower endpoint cumulative distribution +0.5 times the probability of the corresponding category calculated under 4.
6. Calculate the distance between successive midpoints.
7. Calculate the unstandardized structural and measurement coefficients. The unstandardized coefficient β'_1 of, say X_i on Y, is $\beta'_1 = \beta_1 \frac{S_y}{S_{x_1}}$ where S_y and S_{x_1} are standard deviations of Y and explanatory variable X_1, respectively, and β_1 is the standardized coefficient.
8. The effect of a shift between successive categories is obtained by multiplying the unstandardized coefficients with the distance between their midpoints.

The expected effect of a shift effect between successive categories is obtained as the weighted average of the one shift effects, i.e. each shift effect is multiplied by its proportion of scores, divided by the sum of the proportions.

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Chapter 5

To What Extent Does Air Pollution Affect Happiness? The Case of the Jinchuan Mining Area, China

ABSTRACT

This paper presents a structural equation model of happiness, as influenced by *inter alia* perceived risk due to (i) intensity of exposure to polluted air, and (ii) hazard of pollutants. In addition, objective risk measured as proximity to the pollution source, is considered. The main finding is that both types of perceived risk negatively and significantly influence people's happiness, although in absolute terms, the total perceived risk effect is less than the (positive) effect of ability, measured by income and education. Other important determinants of happiness are family size, age, proximity to the pollution source, work environment and current health condition. Perceived risk due to intensity of exposure is influenced by environmental knowledge and proximity to the pollution source; perceived risk of hazard by ability, environmental knowledge, family size, family health experience and proximity to the pollution source. Environmental knowledge is found to be a function of age, ability and workenvironment. On the basis of the findings, we conclude that reducing air pollution is an important policy measure to ameliorate happiness. As environmental knowledge is an important determinant of perceived risk, reduction policies should be accompanied by disclosure of the state of air quality

5.1. INTRODUCTION

As a result of its rapid economic development, China has become the second largest economy in the world and an engine ofglobal economic growth. However, the rapid growth has also resulted in unprecedented increases in energy consumption and emissions of air pollutantswith wide ranging global, national and local effects (Brunekreefand Holgate, 2002; Wei, 2008; Hao et al., 2002).

This paper focuses on local impacts of air pollution - a topic that has increasingly attracted public and private attention. The main reason is that polluted air not only affects people's health (Peters et al., 2001; Brunekreef and Holgate, 2002), but also has detrimental effects on residential property values (Foell and Green, 1991), and on agricultural production (Unsworth and Ormrod, 1980). Generally speaking, poor local air conditions tend to make people less happy. This also applies to theJinchuan mining area, Gansu province, China. The Jinchuan area has the largest nickel resources in China. Mining and smelting industries dominate the local economy and substantially contribute to the economic development of the city. However, the two industries also produce serious environmental problems, especially air pollution. The main pollutants of Jinchuan's air include suspended particles, sulfur dioxide, chlorine gas and carbon dioxide. The first three pollutants contribute to illnesses such as cancer, asthma, bronchitis, and less serious health problems like eye irritation (Xiao,1997; Wei, 2008; Li and Zhao, 2004; Huang, 2009).

Since the 1970s, happiness has been used to measure well-being. It denotes an individual's evaluation of her or his overall quality of life (Veenhoven, 1999). The term is used interchangeably with "life satisfaction" (Haybron, 2007). In 1967, the psychologist Warner Wilson (1967) introduced the notion of happiness and presented a broad review of its meaning. Since Wilson's review, happiness has been widely studied by psychologists (Argyle, 1987; Sarason and Pierce, 1990; Schkade and Kahneman, 1997; Diener et al., 1999; Haybron, 2007). This literature deals with individual valuation and subjective views of the quality of life (Diener et al., 1999).

In economics, the concept of happiness was introduced by Easterlin (1974) who analyzed US data and found that people with higher incomes are more likely to report being happy than people with lower incomes. He, and subsequent authors such as Welsch (2002, 2006, 2007, 2009), have argued that individual well-being can be measured directly with happiness data. Operationally, happiness is measured by the answers given by people to questions such as "On a scale from one to ten, where one is 'worst conceivable' and ten is ‘best conceivable’, how satisfied are you nowadays with your life?” (Van Praag and Baarsma, 2005).

The traditional economic yardsticks to the measurement of well-being, such as equivalent and compensating variation,are money measures derived from the notion that individuals maximize utility under a budget constraint (Varian, 1992; Suzanne and Lynne, 2005). Despite their widespread use, there is consensus among a growing group of economists that the traditional money measures of well-being are subject to fallacies (see e.g. Gowdy, 2004; Rehdanz and Madison, 2008; Welsch, 2009). Specifically, they ignore the fact that individuals are not merely acting to maximize utility under an income constraint (Folmer, 2009, and the references therein); nor do they fully cover the relevant dimensions of well-being (Sumner, 2006; Folmer, 2009).In particular, they fail to account for psychological and sociological aspects (see, amongst others,Welsch, 2006, 2007, 2009; McGillivray, 2007; Ferre-i-Carbonell and Gowdy, 2007; Kaheneman and Sugden, 2005;Folmer and Johansson, 2012). To fill the gap between the narrowly defined money measures and a more comprehensive notion of well-being, the notion of happiness has been introduced into the environmental economics literature (see inter alia Welsch, 2002, 2006, 2007, 2009).

The happiness economics literature does not purport to replace money measures of welfare but,rather, to complement them with broader notions of well-being (Graham, 2005). Measurements of happiness are based on surveys in which respondents are invited to value their welfare in terms of its various dimensions including income, family relationships, own and family health condition, public goods such as the quality of schools, health care, safety and accessibility, and environmental quality. Happiness analysis thus relies on a more comprehensive notion of well-being than conventional economic money measures. Consequently, it allows estimating and comparing the importance and weights of the various dimensions of well-being, rather than the mere tradeoff between environmental quality and income, as is typical in conventional valuation studies. It thus directly highlights the role of non-income factors that affect well-being (Ferrer-i-Carbonell and Gowdy, 2007; Luechinger and Raschky, 2009; Van Praag and Baarsma, 2005).

Although the happiness approach is relatively new in environmental economics, a number of studies have been conducted to explain the difference in people’s happiness as a function of ambient environmental quality. Van Praag and Baarsma (2005) conducted a postal survey among the population living within a radius of fifty kilometers around Amsterdam Schiphol Airport to analyze how people’s happiness was influenced by aircraft noise. They found that noise has a significant and negative influence on happiness. Rehdanz and Maddison (2005) analyzed a panel of sixty-seven countries in a bid to explain differences in happiness as a result of temperature and precipitation. Their study indicates that climate variables have a highly significant effect on country-wide happiness.Brereton et al. (2008) analyzed Irish data disaggregated at the individual and local level to show that amenities such as climate, environmental and urban conditions, have a direct impact on happiness. Luechinger and Raschky (2009) applied the happiness approach to estimate and monetize utility losses caused by floods in seventeen OECD countries between 1973 and 2004. Their resultsshow anegative and significant impact of floods on happiness.

There is also a literature on the relationship between air pollution and happiness. Levinson (2012) used the General Social Survey (GSS), which asked respondents in various U.S. locations how happy they were. Subsequently, he matched the happiness data with the Environmental Protection Agency’s Air Quality System (AQS) data. He found that people, who were interviewed on days when air pollution was worse than the local seasonal average, reported relatively low levels of happiness. Ferreira et al.(2013) analyzed the relationship between air quality and subjective well-being in Europe. They found a robust negative impact of SO2 concentrations on self-reported life satisfaction. Welsch (2002, 2006, 2007) also explored the relationship between air pollution and happiness among European countries and found that air pollution has a statistically significant negative impact on happiness. Rehdanz and Maddison (2008) analyzed differences in happiness in terms ofenvironmental quality with data drawn from the German Socio-Economic Panel (GSEP) and found that severe local air pollution significantly reduces people’s happiness. Using a similar approach, Luechinger (2010) and Luechinger and Raschky (2009) also found a negative effect of air pollutionon happiness.

The happiness studies mentioned above are commonly based on expert or objective risks. However, analyses that are solely based on objective risk may fail to accurately capture its impact on happiness. One reason is that objective risk is a measure that does not account for socio-psychological conditions – in particular, perception. In fact, all objective measures of risk (and of other states of one’s environment including the natural environment) are processed and transformed by perception. Consequently, it is the latter that impacts on mental conditions such as happiness (Davis, 2000; Menon et al., 2008; Braman et al., 2005; Elias and Shiftan, 2012). Specifically, individuals with different backgrounds are likely to perceive the same objective level of air pollution differently. For example, people who have suffered from an illness related to air pollution are likely to have a different perceived risk level, compared with those who have not suffered such an illness. In a similar vein, environmental knowledge is likely to affect perception and thus happiness. Hence, although perceived risk is affected by objective risk, both kinds of risk are likely to differ because of personal experiences but also because of such issues as imperfect information or lack of confidence in official information sources. Note that in this paper we do not only consider subjective risk as a determinant of happiness but also objective risk, as (crudely) measured by air quality in one's residential area and by work environment. These latter two variables are also used as determinants of perceived risk (see Sections 5.3 and 5.5).

Laboratory experiments have frequently indicated that individuals tend to under-estimate high-risk events and over-estimate small-risk events, which is an illustration of the fact that perceived risk differs from objective risk (Ellsberg, 1961; Riddel and Shaw, 2006; Shaw and Woodward, 2008). The laboratory outcomes have been confirmed by Van Praag and Baarsma (2005). They found that perceived noise is more adequate in predicting individual happiness than objective measures. A similar result was obtained by Rehdanz and Maddison (2008) who estimated the differences in happiness in terms of perceived air pollution in residential areas. Ferrer-i-Carbonell and Gowdy (2007) examined the relationship between happiness and attitudes regarding ozone pollution with data from the British Household Panel Survey. They found that concern about ozone pollution significantly and negatively its impacts on an individual's happiness.

This paper examines the impact of perceived health risk due to air pollution on happiness which is furthermore modeled as a function of socio-economic variables such as age and income, and of environmental knowledge. It also takes into account that environmental knowledge and perceived risk are endogenous and may interact.

The paper is organized as follows. Section 5.2 outlines the conceptual model and Section 5.3 describes the methodology. Section 5.4 presents the empirical results and Section 5.5 the main conclusions and policy recommendations.

5.2. CONCEPTUAL MODEL

We assume that individual *i*'s happiness can be represented by the following happiness function:

$$HAP_i = HAP\,(X_i\,,\,PR_i) \tag{5.1}$$

where HAP_i denotes happiness, X_i is a set of individual characteristics (specified below) and PR_i is perceived air pollution risk. Furthermore, we assume that PR_i is a function of X_i, HAP_i and environmental knowledge (EK_i) which in its turn, is a function of X_i and PR_i.

Formally:

$$PR_i = PR\,(EK_i, X_i, HAP_i) \tag{5.2}$$

$$EK_i = EK\,(PR_i, X_i) \tag{5.3}$$

The above Happiness –Perceived Risk –Environmental Knowledge (H-P-E) model is presented in Figure 5.1. The expected signs of the impacts are presented in Table 5.1.

Several of the relationships in Figure 5.1 and Table 5.1 are well-known or intuitively clear. We therefore only present a brief discussion of the less familiar aspects of the conceptual model.

The main dependent variable is happiness (abbreviated HAP). It is measured as follows. First, following Baarsma and van Praag (2005), respondents are asked how satisfied they currently are with their lives as a whole. Second, a list of various dimensions of life is presented to them and they are asked how much pleasure and joy they get from each of them. The dimensions include financial situation, work situation, living in Jinchuan and interpersonal relationships. The respondents are asked to answer the questions on 10 points scales, where 1 is 'worst conceivable' and 10 is 'best conceivable'. The questions used to measure HAP are presented in Table 5.3.

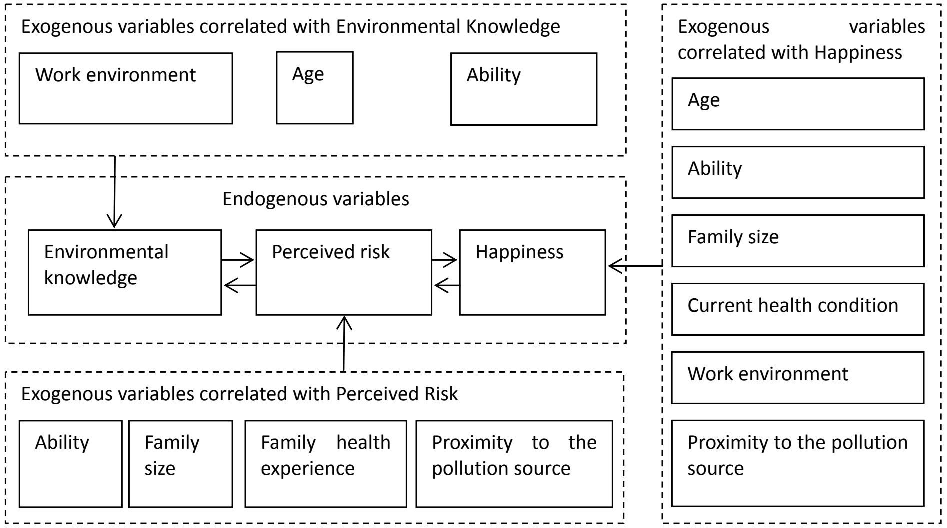

Figure 5.1 The Happiness –Perceived Risk –Environmental Knowledge (H-P-E) Model

Perceived risk (PR) is defined as an individual's judgment or assessment of hazards or dangers that might pose immediate or long-term threats to their health and well-being (Adeola, 2007). Perceived risk is assumed to have a negative impact on a respondent's happiness. This hypothesis is supported by Van Praag and Baarsma (2005), who found that perceived noise negatively influences people's happiness. In addition,Rehdanz and Maddison (2005) studied the impact of perceived air pollution on happiness in Germany and found that higher perceived air pollution significantly diminishes happiness. Perceived risk is measured by the set of items presented in Table 5.5.

We also assume a reverse effect from happiness on perceived risk. Direnfeld and Roberts (2006) point out that happiness tends to trigger recall of positive information which leads to optimistic assessments; that is, higher happiness levels result in lower risk perception. For example, Foo (2011) examined how emotion influences risk perceptions of Singaporeans and found that happiness negatively affects perceived risk.

We define environmental knowledge (EK) as a body of knowledge of an individual or group of people relating to their environment (Johnson, 1998). We hypothesize that environmental knowledge impacts on people's perceived risk. The sign of the impact can be positive or negative. Wallquist et al. (2010) examined the impact of knowledge of Carbon Dioxide Capture and Storage (CCS) on perceived risk and found that more knowledge eased people's concerns. On the other hand, Klerck and Sweeney (2007) investigated the effect of people's knowledge on perceived risk associated with GM food in Australia and found a positive relationship. Because of these opposite outcomes, we do not *a priori* specify the expected sign of the impactforthis case study. It is an empirical matter.

We also hypothesize a reverse effect from perceived risk on environmental knowledge. That is, high perceived risk will induce people to collect more and better information about the risk (Osberghaus and Reif, 2010). In a similar vein, behavior aimed at avoiding or mitigating risks will encourage people to acquire more environmental knowledge in general and of the perceived risks in particular (Laird et al., 2003). We expect a positive impact.The questions used to measure environmental knowledge are presented in Table 5.4.

Regarding the exogenous variables of the H-P-E model, we postulate that income has a positive impact on happiness (Easterlin, 2001; Siahpush et al., 2005; Rojas, 2006; Welsch,2006; Smyth and Qian, 2008). Income in this paper is monthly net income of the household[1] to which the respondent belongs. We distinguish ten classes (see Table 5.2). We also assume a positive effect of education on happiness (Stevenson and Wolfers, 2008; Chen, 2010). Education is measured as the respondent's highest education level achieved (see Table 5.2). Following inter alia Straughan and Roberts (1999), Starr (2009), Newell and Green (1997), Cavalcanti Sá De Abreu and Lins(2010), Cottrell (2003), Kim (2009), Khan (2013) and Ndunda and Mungatana (2013) we postulate that individuals with medium or highincomes have higher level of environmental knowledge and perceived risk thanlower income individuals. Note that income and education are endogenous in that they depend on ability. To account for this, we take both variables as observed indicators (i.e. functions) of the latent variable ability (see Sections 5.3 and 5.4 for a definition of a latent variable and a brief discussion of the simultaneous use of latent and observed variables in one model framework).

Because older people can better regulate emotions than younger individuals, we hypothesize a positive impact of age on happiness (Labouvie-Viefand Blanchard-Fields,1982; Inglehart, 1990; Kahnemanand Krueger, 2006; Cheng et al., 2011). The impact of age on environmental knowledge is ambiguous. On the one hand, young people tend to have more recentinformation on (inter alia) environmental issues and risks than older generations(CavalcantiSá De Abreu andLins,2010). On the other hand, older individuals have more experience with the environmental problems in Jinchuan. We assume that family size negatively impacts on happiness. The reason isthatin larger families the household's material resources are shared by a larger number of people (Blanchflower and Oswald,2004; Van Praag and Baarsma,2005; Keister, 2004). We also include family size in the perceived risk equation because a larger family may possess more information to assess risk.Hence, the expected impact is negative (Ajetomobi and Binuomote, 2006; Amaefula et al., 2012; Xu et al., 2010).

A respondent's current health condition, measured by self-evaluation (see Table 5.2), is expected to positively impact on happiness (Graham, 2008; Graham,2009). This assumption is supported by Bickerstaff (2004) who points out that people's understanding of polluted air is embedded in daily life through their own, and their family members', health experience. Hence, we postulate a positive impact of family health experience on perceived risk (see also Howell et al., 2003; Bickerstaff and Walker,1999 and Krueger,1999). We measure family health experience by means of a dichotomous variable which takes the value 1, if

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[1] We take family as a communitarian group where resources, particularly financial resources, are pooled. Rojas (2007) points out that household income is a better predictor of a person's happiness than personal income in a communitarian family.

the respondent or one or more of his or her family members have been hospitalized for cardiovascular diseases or respiratory diseases, and 0 otherwise.

Tait et al. (1989) and Dravigne et al. (2008) argue that the harsher people's work environment, the unhappier they will be. Thus, we hypothesize that a harsh work environment (i.e. in the mine or in smelters of the Jinchuan mining company, denoted JMC) negatively influences people's happiness. We also assume that people working in the mining company have better knowledge of Jinchuan's environmental issues than non-JMC employees because JMC is the culprit of Jinchuan's environmental issues (see Juang et al., 2010 andArcury et al., 2002 for similar arguments). We distinguish three work environment classes(see Table 5.2).

In addition to subjective risk, we also take objective risk into account, as measured by Proximity to the pollution source (smelting plants). Since pollution is subject to distance decay, we postulate that objective risk decreases along with distance to the pollution source. The same applies to other nuisances associated with the smelting plants, such as noise and reek. Moreover, people may get used to,or take measures to reduce such nuisances.Hence, the furtherone lives away from the pollution source, the lower is the suffering; that is a positive happiness effect. On the other hand, since the air is seriously polluted, house prices and rents are lower in the areas close to the smelting plants.[2](See also Bookwalter (2012) who found a similar effect for South Africa.) Moreover, the best medical facilities, shopping areas and schools of Jinchuan are located in the heavily polluted area (see Figure 5.2). The outcome of these opposing effects on happiness is uncertain. We expect that proximity to the pollution source negatively influences perceived risk. The reason is that respondents who live further away from the smelting plants are less exposed to air pollution than those live nearby (Bickerstaff and Walker, 2001;Riddel, 2009; Combest-Friedman et al., 2012). We distinguish three distance categories (seeTable 5.2).

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[2] Housing allocation is to a very limited extent based on supply and demand. Rather, it is the local government and the mining company that allot relatively cheap housing to their employees. These houses are mainly located near the company in heavily polluted areas. This information is based on discussions with local officials and administrators.

Table 5.1 The expected signs of the relationships in the H-P-E model

	Equation 1	**Equation 2**	**Equation 3**
	HAP	PR	EK
Happiness (HAP)		(-)	
Perceived risk (PR)	(-)		(+)
Environmental knowledge(EK)		(+/-)	
Family size (FS)	(-)	(-)	
Current health condition (CHC)	(+)		
Age (AGE)	(+)		(+/-)
Ability	(+)	(+)	(+)
Family health experience (FHE)		(+)	
Proximity to the pollution source(PPS)	(+/-)	(-)	
Work environment (WE)	(-)		(-)

5.3. METHODOLOGY

The conceptual model (Figure 5.1 and Table 5.1) contains both latent variables (happiness, perceived risk, environmental knowledge) and observed variables (e.g. age and family size). Latent variables (or theoretical constructs) refer to those phenomena that are supposed to exist but cannot be directly observed (Oud and Folmer, 2008). However, they can be measured by observed variables or indicators. For example, the theoretical notion of happiness is measured by questions about people's satisfaction with their financial condition, interpersonal relationships, working condition and other dimensions of life (Table 5.3).

A structural equation model (SEM) allows simultaneous use of both latent and observed variables within one framework (Jöreskog and Sörbom, 1996; Bollen, 1989). A SEM is made up of two components; viz. the measurement model and the structural model.[3] The measurement models relate the latent variables to their indicators, as follows:[4]

$$\boldsymbol{y} = \boldsymbol{\Lambda}_y \boldsymbol{\eta} + \boldsymbol{\varepsilon} \tag{5.4}$$

$$\boldsymbol{x} = \boldsymbol{\Lambda}_x \boldsymbol{\xi} + \boldsymbol{\delta} \tag{5.5}$$

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[3] It is possible to include means and intercepts into the system. However, we delete them here because in the application we standardize all latent variables.

[4] Note that directly observed variables can be conveniently included in the system by defining an identity relationship between an observed variable and the corresponding latent variable.

where $\boldsymbol{\eta}$ is an m×1 vector of endogenous latent variables, $\boldsymbol{\xi}$ a n×1 vector of exogenous latent variables, **y** a p×1vector ofendogenous observed variables,and **x** a q×1 vector of exogenous observed variables. $\boldsymbol{\Lambda}_y$ is a (p×m) matrix that specifies the relationships (loadings) between the endogenous observed variables **y**and the endogenous latent variables $\boldsymbol{\eta}$ while $\boldsymbol{\Lambda}_x$ is a (q×n) matrixwith the loadings of the observed variables $\boldsymbol{x}$ on the exogenous variables $\boldsymbol{\xi}$.$\boldsymbol{\varepsilon}$ and $\boldsymbol{\delta}$ are the measurement errors of $\boldsymbol{y}$ and $\boldsymbol{x}$**,** respectively. The covariance matrices of $\boldsymbol{\varepsilon}$ and $\boldsymbol{\delta}$ are $\boldsymbol{\Theta}_\varepsilon$ $(p \times p)$ and $\boldsymbol{\Theta}_\delta$ $(q \times q)$, respectively.

The structural model specifies the relationships between the exogenous and the endogenous latent variables, and the relationships among the latent endogenous variables mutually:

$$\boldsymbol{\eta} = \boldsymbol{B}\boldsymbol{\eta} + \boldsymbol{\Gamma}\boldsymbol{\xi} + \boldsymbol{\zeta} \qquad (5.6)$$

where $\boldsymbol{B}$ is an (m×m) matrix that contains the structural relationships among the latent endogenous variables, $\boldsymbol{\Gamma}$ an (m×n) matrix of the impacts of the exogenous latent variables on the endogenous latent variables and $\boldsymbol{\xi}$ a random (p×1) vector of errors with covariance matrix $\boldsymbol{\Psi}$ $(p \times p)$.The covariance matrix of $\boldsymbol{\xi}$ is $\boldsymbol{\Phi}$ (nx$n$).

A prerequisite for estimation of a SEM is that it is identified. One condition for identification of a SEM is that all latent variables have been assigned measurement scales. This can be done by fixing one measurement coefficient for each latent variable, usually at 1, or by fixing the variances of the latent variables, usually also at 1. In the application below, we apply the latter method. In addition to fixing the measurement scales, the order and rank conditions need to be met for identification. The latter may be tedious to check. However, the software programs LISREL 8 and OpenMxgive indications of identification problems by evaluating the information matrix at the minimum of the fitting function. If the estimated information matrix is singular, the model is not identified (Silvey, 1970). Jöreskog (1981) shows that the rank of the information matrix indicates which parameters are not identified.

Estimation of a SEM is commonly conducted by minimizing the distance between the observed covariance matrix and the theoretical covariance matrix which is a function of the unknown model parameters. Several of the variables in the H-P-E model, particularly the indicators of happiness, perceived risk and environmental knowledge (see Tables 5.3, 5.4 and 5.5), are ordinal or dichotomous. Moreover, since a small minority of the respondents disagrees with the statements relating to the environmental issues in Jinchuan, the indicators of environmental knowledge are skewed and thus highly non-normal. Jöreskog and Sörbom (1989, 1993), Lee and Poon (1987), Muthén and Satorra (1995),Jöreskog and Sörbom (1996), Flora and Curran(2004) argue that when ordinal or non-normal variables are analyzed as interval or normal variables, the commonly used estimators, particularly maximum likelihood, may lead to distorted parameter estimates, incorrect chi-square goodness of fit measure and incorrect standard errors. When some or all of the observed variables are ordinal or binary and the distribution of some variables is skewed, WLS based on the matrix of polychoric correlations of the observed variables should be applied. The WLS fitting function reads

$$\mathbf{F}_{\mathbf{WLS}} = [\boldsymbol{\rho} - \boldsymbol{\rho}(\boldsymbol{\theta})\ ]'\ \mathbf{W}^{-1}\ [\boldsymbol{\rho} - \boldsymbol{\rho}(\boldsymbol{\theta})] \qquad (5.7)$$

where $\boldsymbol{\rho}$ is a vector of the elements in the lower (or upper) half, including the diagonal, of the matrix of polychoric correlations. $\boldsymbol{\theta}$ is the vector of correlations of the theoretical matrix which is a function of the unknown model parameters (i.e. the factor loadings, thestructural model parameters, the variances and covariances of $\boldsymbol{\xi}$ and of the errors). The vector $\boldsymbol{\rho}(\boldsymbol{\theta})$ denotes the restrictions imposed on the population polychoric correlation matrix. $\mathbf{W}^{-1}$ is a positive-definite weight matrix. Browne (1982, 1984) shows that if $\mathbf{W}^{-1}$ is the correct weight matrix, F_{WLS} is an asymptotically efficient estimator of the parameters, standard errors and chi-square overall test statistic. (For an overview of the main advantages of the use of SEM, see amongst othersFolmer and Oud, 2008)).

Estimation of a SEM can be done by a variety of software packages of which LISREL 8 (Jöreskog and Sörbom, 1996) and OpenMx (in R) are probably best known. The packages include various test statistics, notably z- statistics for individual parameters, R-squared for structural and measurement equations, and overall goodness of fit statistics. The packages can also be used to obtain modification indices, which give indications of options for model improvement by freeing fixed or constrained parameters.

The conceptual model presented in Figure 5.1, in terms of equations (4–6), reads as follows:[5]

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[5] See Table 5.2 for a definition of the labels in the equations (5.8)-(5.10).

Measurement models

$$\begin{bmatrix} \mathrm{HAP1} \\ \vdots \\ \mathrm{HAP5} \\ \mathrm{PR1} \\ \vdots \\ \mathrm{PR5} \\ \mathrm{EK1} \\ \vdots \\ \mathrm{EK8} \end{bmatrix} = \begin{bmatrix} \lambda^{y}_{11} & 0 & 0 \\ \lambda^{y}_{21} & 0 & 0 \\ \vdots & \vdots & \vdots \\ \lambda^{y}_{51} & 0 & 0 \\ 0 & \lambda^{y}_{6\,2} & 0 \\ 0 & \lambda^{y}_{7\,2} & 0 \\ 0 & \lambda^{y}_{8\,2} & 0 \\ \vdots & \vdots & \vdots \\ 0 & \lambda^{y}_{10\,2} & 0 \\ 0 & 0 & \lambda^{y}_{11\,3} \\ 0 & 0 & \lambda^{y}_{12\,3} \\ \vdots & \vdots & \vdots \\ 0 & 0 & \lambda^{y}_{18\,3} \end{bmatrix} \times \begin{bmatrix} \mathrm{HAP} \\ \mathrm{PR} \\ \mathrm{EK} \end{bmatrix} + \begin{bmatrix} \varepsilon_1 \\ \vdots \\ \varepsilon_5 \\ \varepsilon_6 \\ \vdots \\ \varepsilon_{10} \\ \varepsilon_{11} \\ \vdots \\ \varepsilon_{18} \end{bmatrix} \qquad (5.8)$$

$$\begin{bmatrix} \mathrm{EDU} \\ \mathrm{IN} \\ \mathrm{AGE} \\ \mathrm{FS} \\ \mathrm{CHC} \\ \mathrm{FHE} \\ \mathrm{MAP} \\ \mathrm{SAP} \\ \mathrm{MS} \\ \mathrm{NMS} \end{bmatrix} = \begin{bmatrix} \lambda^{x}_{1\,1}\;0\;0\;000000 \\ \lambda^{x}_{21}\;0\;0\;000000 \\ 0\;\;100000000 \\ 0\;\;0\;1\;000000 \\ 0\;\;0\;0\;100000 \\ 0\;\;0\;0\;010000 \\ 0\;\;0\;0\;001000 \\ 0\;\;0\;0\;000100 \\ 0\;\;0\;0\;000010 \\ 0\;\;0\;0\;000001 \end{bmatrix} \times \begin{bmatrix} \mathrm{Ability} \\ \mathrm{AGE} \\ \mathrm{FS} \\ \mathrm{CHC} \\ \mathrm{FHE} \\ \mathrm{MAP} \\ \mathrm{SAP} \\ \mathrm{MS} \\ \mathrm{NMS} \end{bmatrix} + \begin{bmatrix} \delta_1 \\ \delta_2 \\ 0 \\ 0 \\ 0 \\ 0 \\ 0 \\ 0 \\ 0 \\ 0 \end{bmatrix} \qquad (5.9)$$

The structural model reads

$$\begin{bmatrix} \mathrm{HAP} \\ \mathrm{PR} \\ \mathrm{EK} \end{bmatrix} = \begin{bmatrix} 0 & \beta_{1\,2} & 0 \\ \beta_{2\,1} & 0 & \beta_{2\,3} \\ 0 & \beta_{3\,2} & 0 \end{bmatrix} \times \begin{bmatrix} \mathrm{HAP} \\ \mathrm{PR} \\ \mathrm{EK} \end{bmatrix} + \begin{bmatrix} \gamma_{1\,1} & \gamma_{1\,2} & \gamma_{1\,3} & \gamma_{1\,4} & 0 & \gamma_{1\,6} & \gamma_{1\,7} & \gamma_{1\,8} & \gamma_{1\,9} \\ \gamma_{3\,1} & 0 & \gamma_{2\,3} & 0 & \gamma_{2\,5} & \gamma_{2\,6} & \gamma_{2\,7} & 0 & 0 \\ \gamma_{3\,1} & \gamma_{2\,3} & 0 & 0 & 0 & 0 & 0 & \gamma_{3\,8} & \gamma_{3\,9} \end{bmatrix} \times \begin{bmatrix} \mathrm{Ability} \\ \mathrm{AGE} \\ \mathrm{FS} \\ \mathrm{CHC} \\ \mathrm{FHE} \\ \mathrm{MAP} \\ \mathrm{SAP} \\ \mathrm{MS} \\ \mathrm{NMS} \end{bmatrix} + \begin{bmatrix} \zeta_1 \\ \zeta_2 \\ \zeta_3 \end{bmatrix} \qquad (5.10)$$

5.4 EMPIRICAL RESULTS

5.4.1 The survey

Data was obtained from a survey inthe city of Jinchuan. The total population of Jinchuan is 204,000 (in 2010) and the total number of households is 60,400 distributed over seventeen communities. The number of households varies per community from 1,126 to 6,454.

A two-step stratified random sampling procedure was applied. First, following Wei (2008) and Jinchuan Environmental Quality Monitoring Report (2011), the city of Jinchuan area was divided into three sub-areas based on distance from the pollution source (i.e. the level of air pollution): (i) heavily polluted, (ii) moderately polluted, and (iii) lightly polluted (Figure 5.2). The number of communities varies per sub-area from four to six. Secondly, the number of interviewees in each community was randomly selected in proportion to its total size. Per hundred households we randomly selected 1-2 households which gave a sample size of 800.

Because the questionnaire was long (eight pages) and complex, the interviews were face-to-face rather than by telephone or mail.Prior to the survey, a pilot survey was held to test the draft questionnaire. The questionnaire was adjusted, corrected and re-worded, according to the results of the pilot survey. The interviewers were selected from a group of college students at Gansu Non-ferrous Metallurgy College in Jinchuan. Understanding the environmental issues of Jinchuan and the local language were two selection criteria. The interviewers were trained in order to acquaint them with the questionnaire and to familiarize them with communication with local residents.

Interviewees were family heads, usually the husband. All interviewees were holding Jinchuan “hukou” which means that they werepermanent Jinchuan residents who had lived in the area for at least ten years. The survey was carried out in August, 2012.

5.4.2 Descriptive statistics

In total, 800 interviews were held of which 41 (5.12%) were incomplete. There was no evidence of non-random drop out. Descriptive statistics are presented in Tables 5.2 – 5.5.

Figure 5.2 presents the lightly, moderately and heavily polluted areas, together with the location of schools, medical facilities and shopping areas. The prevailing winds for the period 2006-2010 are east and south-east during summer and west and north-west during winter. Figure 5.2indicates that air pollution decays by distance from the smelting plants and that the facilities are concentrated in the heavily polluted areas.

Table 5.3 shows the scores of the indicators of happiness.For the overall indicator(HAP1) and interpersonal relationships (HAP2), a vast majority of the respondents(more than 80%) is moderately to highly satisfied (scores 6 or higher) while only a rather small minority is unsatisfied to highly dissatisfied (a score of 5 or lower). Regarding work situation (HAP3) and financial situation (HAP4), nearly one third of the respondents are moderately to severely dissatisfied (a score of 5 or lower). Table 5.3 also indicates that a majorityof the respondents (78.6%) rate living in Jinchuan (HAP5) 6 or higher. We conclude that most of the respondents are satisfied with living in Jinchuan, though a substantial minority is dissatisfied with some aspects.

The respondents' environmental knowledgewas tested by eight indicators which can be divided into two categories (see Table 5.4). The first category(EK1-EK4) is about general environmental issues in the Jinchuan area while the second(EK5-EK8) relates to specific air pollutants. For each indicator a five points scale was used. Table 5.4 shows that most of the respondents agree or strongly agree that air pollution (97.8%), industrial solid wastes (86.9%) and water pollution (81.6%) are environmental issues in the Jinchuan area. Moreover, 93.2% either strongly agree or agree that Jinchuan's environmental issues are caused by local industrial activities. Finally, the majority of the respondents either strongly agrees or agrees that chlorine gas (85.5%), sulfur dioxide (82.3%), suspended particles (76%) and carbon dioxide (57.9%) are the main air pollutants. Note that all four gasses are main pollutants of smelters (Tamaki et al., 2002; Mylona and Tellus, 1996; Barcan, 2002;Worrell et al.,2001). It follows that its residents are well informed about Jinchuan's air pollution.

Perception of the risksof air pollution is measured by five indicators (Table 5.5). The first indicator (PAPL) relates to perceived health risk due to exposure: 'what is the average number of days per week that the air in Jinchuan was heavily polluted during the past year?' Table 5.5 shows that themajority (62.1%) answered '2 or 3' days indicating perception of medium exposure. For each of the other indicators (PR2-PR5), a five points scale ranging from "strongly agree" to "strongly disagree"was used. Table 5.5 indicates that the majority of respondents agrees or strongly agrees that air pollution increases the possibility of suffering from respiratory illnesses (95.9%), lung cancer (83.6%), cardiovascular illnesses (75%) and death (73.1%).

Table 5.2 Descriptive statistics for the observed exogenous variables

Variables	**Min**	**Max**	**Mean**	**S.D**
Age (AGE)	21	78	44.11	11.4
Family Size (FS)	1	6	2.95	0.78
Current health condition (CHC)	1	5	3.68	0.85
Family health experience (FHE)	0	1	0.33	0.48

Education (EDU)	**%**	**Household Net Income (￥ per month)**	**%**
Primary school	6.30%	1000-2000(￥)	4.70%
Middle school	23.60%	2000-3000(￥)	15.30%
High school	25.30%	3000-4000(￥)	18.30%
Vocational school,	25.30%	4000-5000(￥)	19.10%
Bachelor's degree	19.10%	5000-6000(￥)	20.90%
Master's degree	0.40%	6000-7000(￥)	13.00%
Proximity to the pollution source (PPS)	%	7000-8000(￥)	3.70%
Nearby smelting plants, severe air pollution (SAP)	29.60%	8000-9000(￥) 9000-10000(￥)	1.80% 1.10%
Medium air pollution (MAP)	29.80%	More than 10000(￥)	2.00%
Far away from smelting plants, light air pollution (LAP, reference case)	40.60%		
Work environment(WE)	%		
Non-JMC employee(reference case)	59.55%		
Miners or smelter workers of JMC (MS)	18.18%		
JMC employee, but not miner or smelter worker (NMS)	22.27%		

Note: ***Family size:*** number of family members living in the same house. ***Current health condition:*** respondent's self -evaluation of his/her own current health condition. (5=very good, 4=good, 3= no good, no bad, 2=bad, 1=very bad). ***Family Health experience***: 1 if therespondent or one or more of his/her family members have been hospitalized for cardiovascular diseases (e.g., hypertension, heart attack, chest pain, arrhythmia and miocardial infraction) or respiratory diseases (e.g., upper respiratory tract infection, bronchitis, pneumonia, asthma, and lung cancer), 0 otherwise.

The respondents' risk perceptions are in line with scientific evidence. Particularly, according to U.S. ATSDR (2010), exposure to chlorine may result in nasal irritation, sore throat, coughing, respiratory distress with airway constriction and accumulation of fluid in the lungs (pulmonary edema). In addition, cardiovascular collapse may occur after severe exposure. Sulfur dioxide can react with other compounds in the atmosphere to form small particles which can penetrate deeply into lung's sensitive parts and lead to,or worsen respiratory disease, for example, emphysema and bronchitis. These particles also can aggravate existing heart disease, resulting in increased hospitalization and premature death. (Nadel et al., 1965;Devalia et al., 1994). Suspended particles can get deep into the lungs and cause serious health problems including premature death for people with heart or lung disease,nonfatal heart attacks,irregularheartbeat,aggravated asthma,decreased lung function, andincreased respiratory symptoms, such as irritation of the airways, coughing or difficult breathing. (Seaton et al., 1995;Pope III et al., 1995). From this overview of the objective risks of the various pollutants and the corresponding risk perceptions in Table 5.5 it follows that the residents are well informed about the risks of the main air pollutants in the Jinchuan area.

5.4.3 The estimated SEM

Before going into detail, we point out that the estimated coefficients are standardized or beta coefficients. A standardized coefficient measures the standard deviation change in the dependent variable due to a standard deviation increase in an explanatory variable . The use of beta coefficients renders the scales of the regressors irrelevant and makes the estimated effects directly comparable.

As a first step, we estimated the full conceptual model (denoted initial model) presented in equations (5.8)-(5.10). The estimated measurement model (see Appendix Table D.5.2) showed that PR1, i.e. perception of the risk due to frequency of occurrence of serious air pollution in Jinchuan, had extremely low reliability (0.03). Factor analysis indicated that this was due to the fact that it measures a different dimension of perceived risk than the other four indicators (PR2-PR5). While PR1 measures perceived risk due to intensity of exposure, PR2-PR5 measure the perceived risk due to hazard of pollutants. Therefore, we decided to split the latent variable perceived health risk into two latent variables: PRL1 which measures perceived risk due to exposure, and PRL2 which measures the perceived health risks of the main air pollutants of Jinchuan.The final measurement models are presented in Table 5.7 which show that there are no indicators with extremely low reliabilities. The structural model was adjusted accordingly in that there are two latent perceived health risk variables.

In the initial structural model with PRL1 and PRL2 (Appendix D Table D.5.3) the impacts of happinesson the two perceived latent health risk variables was negligible and insignificant. Therefore, these relationships were deleted from the structural model. In addition, several of the exogenous explanatory variables were highly insignificant. We deleted them one by one in a stepwise backward elimination procedure starting with the variable with the largest p-value. The final model is presented in Table 5.8.

Figure 5.2 Heavily, moderately and lightly polluted areas of the Jinchuan mining area
Note: the dominant wind directions are from the east and south-east during summer and from west and north-west during winter (Source: Jinchuan Environmental Quality Monitoring Report, 2011; Wei, 2008)

Table 5.3 Frequency distribution of the scores on the indicators of happiness

Indicators	**Questions**	**Score**									
		1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
	How satisfied are you with:										
HAP1	Your current life as a whole?	4.60%	0.00%	0.50%	2.10%	9.70%	15.80%	19.20%	35.20%	12.70%	0%
HAP2	Your interpersonal relationships?	0.00%	0.10%	1.20%	2.10%	8.50%	17.10%	19.50%	35.20%	9.95%	6.20%
HAP3	Your financial condition?	0.20%	1.40%	3.40%	9.10%	16.20%	20.10%	18.50%	19.30%	6.90%	3.20%
HAP4	Your work situation?	1.50%	1.30%	2.30%	7.50%	20.90%	23.60%	23.30%	15%	3.60%	0.90%
HAP5	Living in Jinchuan?	0.70%	0.80%	2.40%	3.70%	13.90%	20.6.%	23.30%	24.10%	5.70%	4.90%

Table 5.4 Frequency distribution of the scores on the indicators of environmental knowledge

Indicators	**Questions**	**Strongly agree**	**Agree**	**Neither agree nor disagree**	**Disagree**	**Strongly disagree**
Jinchuan suffers from						
EK1	Air pollution	82.40%	15.40%	0.80%	0.80%	0.70%
EK2	Industrial solid waste	63.60%	23.30%	13.10%	2.60%	0.70%
EK3	Water pollution	51.00%	30.60%	11.90%	5.60%	0.90%
Environmental issues in Jinchuan are mainly caused by						
EK4	local industrial activities	76.40%	16.80%	4.80%	1.60%	0.40%
The main air pollutants in Jinchuan are						
EK5	Sulfur dioxide	65.20%	17.10%	15.50%	1.70%	0.50%
EK6	Suspended particles	48.50%	27.50%	21.30%	2.10%	0.50%
EK7	Carbon dioxide	29.70%	28.20%	29.00%	8.50%	4.60%
EK8	Chlorine gas	68.10%	17.40%	11.00%	2.80%	0.80%

Table 5.5 Frequency distribution of the scores on the indicators of perceived risk

Indicators	**Question**	**Score (days)**							
PR1	PAPL	0	1	2	3	4	5	6	7
		1.80%	17.60%	37.90%	24.20%	9.40%	4.60%	1.70%	2.60%
PR1	Actual								
Indicator	Questions				Strongly agree	Agree	Neither agree nor disagree	Disagree	Strongly disagree
Jinchuan’s air pollution increases the possibility of suffering from									
PR2	Respiratory illnesses				75.90%	20.00%	3.00%	0.80%	0.30%
PR3	Cardiovascular illnesses				46.90%	28.10%	20.90%	2.50%	1.60%
PR4	Lung cancer				53.10%	30.50%	13.40%	2.30%	0.80%
PR5	Death				42.30%	30.90%	19.70%	4.80%	2.40%

Before discussing the main relationships in the final model, we discuss the overall goodness of fit, presented in Table 5.6. Several overall goodness of fit indices of SEMs have been developed. The most widely reported are the χ2/DF (DF denoting degrees of freedom), the Goodness-of-Fit statistic (GFI), the Adjusted goodness-of-fit index (AGFI), the Standardized Root Mean Square Residual (SRMR) and the Root Mean Square Error of Approximation (RMSEA) (see Bentler and Bonnet, 1980; Jöreskog and Sörbom, 1993;

Tabachnick and Fidell, 2007; Byrne, 1998). Table 5.6 indicates that all the overall goodness of fit indices of the final model meet their critical values indicating that it has a satisfactory fit. In addition, a comparison of Table 5.6 and Table D.5.1shows that the revisions of the initial model, particular the deletion of the insignificant variables, are correct because of no deterioration in the overall goodness of fit statistics. Particularly, GFI and AGFI are equal in the initial and final model, the χ2/DF has improved, and SRMR and RMSEAhave slightly deteriorated. These outcomes support the final model which we now discuss in detail.

Table 5.6 Overall goodness of fit measures

Fit index	Final model	Critical value
χ2/DF	2.60	<3
Goodness-of-fit index(GFI)	0.97	>0.95
Adjusted goodness-of-fit index (AGFI)	0.96	>0.95
Root mean square error of approximation (RMSEA)	0.045	<0.05
Standardized root mean square residual (SRMR)	0.028	<0.08

Table 5.7 presents the loadings, standard errors and R^{2}s for each final measurement equation. The R^{2}s or reliability of an indicator is the percentage of the variance of the indicator explained by the underlying latent variable. For happiness, HAP4 is the most reliable indicator with R^2=0.31 and HAP5 the least with R^2=0.12. This means that happiness is better measured by HAP4 than by HAP5. From Table 5.7 it follows that all coefficients are significant and have satisfactory reliabilities. Moreover, the coefficients of the indicators of the latent variables happiness, environmental knowledge and ability are virtually identical in initial and final models. Finally, note that in the measurement model the latent variables are purged of their measurement errors which reduce attenuation in the structural model. For details we refer to, amongst others, Jöreskog (1973, 1977, 1981) and Bollen (1989).

Table 5.8 shows the estimated coefficients, standard errors, and of the final structural model. We first discuss the signs of the relationships and next the magnitudes of the effects. The results indicate that both perceived risk due to intensity of exposure (PRL1) and perceived risk due to hazard of pollutants(PRL2) significantly and negatively affect happiness, as hypothesized. Furthermore, environmental knowledge has a positive and significant impact on both latent perceived risk variables. However, in contrast to the assumption in the conceptual model, the perceived risk variables did not significantly impact on environmental knowledge in the initial structural model (see Appendix D, Table D.5.3). A possible explanation is that the suffocating and pungent odourof sulfur dioxide and chlorine gas, which are the main directly observable air pollutants in the Jinchuan areaissufficient evidence for the inhabitants' risk perception. The persistence of the odourrenders further knowledge acquisition redundant. We deleted the relationship in the final structural model.

Table 5.7 The final measurementmodel (standardized coefficients)

latent variables	Indicator	Coefficient	Standard error	R^2
Happiness (HAP)	HAP1	0.52	0.03	0.27
	HAP2	0.42	0.03	0.17
	HAP3	0.53	0.03	0.28
	HAP4	0.56	0.03	0.31
	HAP5	0.35	0.03	0.12
Perceived risk due to intensity of exposure (PRL1)	PR1	1.00	----	1.00
Perceived risk due to hazard of pollutants(PRL2)	PR2	0.56	0.04	0.31
	PR3	0.52	0.03	0.27
	PR4	0.61	0.03	0.38
	PR5	0.56	0.03	0.32
Environmental knowledge (EK)	EK1	0.51	0.04	0.26
	EK2	0.47	0.03	0.22
	EK3	0.39	0.04	0.15
	EK4	0.47	0.04	0.22
	EK5	0.56	0.03	0.31
	EK5	0.47	0.03	0.22
	EK7	0.32	0.03	0.10
	EK8	0.41	0.04	0.17
Ability (AB)	Education	0.41	0.04	0.17
	Income	0.52	0.04	0.27

Regarding the exogenous variables, in line with expectation and common knowledge, current health condition has a positive and significant impact on happiness.As hypothesized in the conceptual model, family size significantly and negatively influences happiness, possibly because the larger the family, the smaller the amount of the available resources to each family member. (Keister, 2004). Family size also has a negative impact on perceived risk due to hazard of pollutants(PRL2), possibly because of risk dilution; i.e.a bigger family has a larger capability to absorb risk (Ajetomobi and Binuomote, 2006; Amaefula et al., 2012). The impact of family size on perceived risk due to intensity of exposure (PRL1) was negligible and insignificant.

Ability, as measured by income and education positively and significantly influences happiness because it enlarges people's options to satisfy their needs and empowers them to be the driver of their own destiny. The positive impact on environmental knowledge andperceived risk due to hazard of pollutants (PRL2) derives from the fact that individuals with more ability can better master information. That is, they can acquire better understanding of the nature of environmental issues including those in Jinchuan, and make a better judgment of health risk caused by the main air pollutants in the Jinchuan mining area. Age positively and significantly influences happiness because when people move through adulthood, they acquire life experience which allows them to better regulate their emotions, particularly to maximize the positive and minimize the negative effects of events and situations (Seo and Barrett, 2007). The positive effect of age on environmental knowledge shows that the experience effect dominates the more recent knowledge effect. Apparently, the long spell of living in the area has led to better knowledge about Jinchuan's mining and smelting industries and related environmental issues.

As expected, family health experience positively and significantly influences people's perceived risk due to hazard of pollutants (PRL2).Apparently, family health experience tends to raise awareness and increase anxiety. Proximity to the smelting plants, as measured by the dummies SAP and MAP, have positive impacts onhappiness. Apparently, the benefits of living close to the smelting plants (cheap housing price and rents and good facilities) outweigh the negative health effects, and of reek and noise. The dummies also positively and significantly influencepeople'sperceived risk due to intensity of exposure (PRL1). Their impacts on perceived risk due to hazard of pollutants (PRL2) is positive, though marginally significant. Work environment, as measured by the dummies NMS and MS, negatively influences happiness. Moreover, the impacts for those who work in the mine or smelting plants are more negative than for the other employees of JMC.This indicates that a work environment without direct exposure to pollution and other hardships (as for non- JMC employees) improves people's happiness. The workplace is, after all, a place where people spend a substantial part of their lives. As predicted, people working in the mining company have better knowledge of Jinchuan's environmental issues than non-JMC employees.

Table 5.8 The final structural model (standardized coefficients)

Final model				
Explanatory variables	**HAP**	**PRL1**	**PRL2**	**EK**
Perceived risk due to intensity of exposure (PRL 1)	-0.11***			
	(0.02)			
Perceived risk due to hazard of pollutants (PRL 2)	-0.21***			
	(0.04)			
Environmental knowledge (EK)		0.16***	0.69***	
		(0.04)	(0.09)	
Family size (FS)	-0.11***		-0.09***	
	(0.03)		(0.03)	
Age (AGE)	0. 14***			0.06*
	(0.02)			(0.03)
Family health experience (FHE)			0.06*	
			(0.03)	
Current health condition (CHC)	0.17***			
	(0.02)			
Ability (AB)	0.52***		0.10*	0.35***
	(0.10)		(0.08)	(0.07)
Medium air pollution (MAP)	0.10**	0.08***	0.06	
	(0.04)	(0.03)	(0.04)	
Serious air pollution (SAP)	0.10**	0.18***	0.05	
	(0.04)	(0.03)	(0.04)	
JMC employee, but not miner or smelter worker (NMS)	-0.25***			0.06
	(0.05)			(0.05)
Miners and smelter workers of JMC (MS)	-0.26***			0.12**
	(0.05)			(0.06)
	0.29	0.05	0.53	0.14

Proximity to the pollution source (PPS) is represented by two dummy variables (1) SAP (Nearby smelting plants, severe air pollution) (2) MAS (medium polluted area). The reference category is LAP (far away from pollution source, light air pollution). Work environment (WE) is represented by two dummy variables: MS (miners and smelter workers of the Jinchuan Mining Company) and NMS (people who are JMC employees, but not miners or smelter workers). The reference category is non-JMC employee.
Note: Standard errors in parenthesis. *, **and *** :10%, 5% and 1%.

In addition to direct effects, the variables discussed in Table 5.8 also have indirect effects. An indirect effect of a variable is its effect on an endogenous variable through intervening endogenous variables (JöreskogandSörbom, 1996). The total effect is the sum of the direct and indirect effects. Table 5.9 presents the indirect and the total standardized effects of all variables on all endogenous variables in the final H-P-E model.

Table 5.9 shows that ability has the largest positive total effect (0.44) on happiness, followed by current health condition and agewith total effects of0.17 and 0.13, respectively. Perceived risk due to intensity of exposure (PRL1) and perceived risk due to hazard of pollutants (PRL2) negatively and significantly influence happiness with total effects -0.11 and -0.21, respectively. In absolute value, the two perceived risk variables together have the next largest impact on happiness (0.32). Although they have no direct effect on happiness, environmental knowledge and family health experience negatively and significantly impact on happiness through the two perceived risk variables with a total effect of -0.16 and -0.01, respectively. The total effect of family size is also negative: -0.09. The positive total effects of living in moderately (MAP) and heavily polluted districts (SAP) are mainly direct and derive from lower house prices and better facilities in these districts than in districts with less pollution. Miners and smelter workers (MS) and other JMC workers (NMS) have the largest negative total effects on happiness: -0.26 and -0.28, respectively.

Environmental knowledge, living in moderately (MAP) and heavily polluted districts (SAP) are three most important determinant of perceived risk due to intensity of exposure (PRL1)with total effects of 0.16, 0.08 and 0.18,respectively. Ability and age also positively and significantly influence perceived risk due to intensity of exposure with total effects of 0.06 and 0.01. Miners and smelter workers (MS) and other JMC workers (NMS) indirectly and positively influence PRL1 with total effects of 0.01 and 0.02, respectively. The total effect of NMS, however, is insignificant. Environmental knowledge has the largest positive total effect (0.69) on perceived risk due to hazard of pollutants (PRL2), followed by ability(0.34). The total effects of the other variables are very small (in absolute value <0.1). Ability is the most important determinant of environmental knowledge with a total effect of 0.35. The total impacts of the other variables are small.

Table 5.9 Indirect and total standardized effects (final model)

	Indirect effects				**Total effects**			
Variables	**HAP**	**PRL1**	**PRL2**	**EK**	**HAP**	**PRL1**	**PRL2**	**EK**
Perceived risk due to intensity of exposure (PRL1)					-0.11***			
					(0.02)			
Perceived risk due to hazard of pollutants (PRL2)					-0.21***			
					(0.04)			
Environmental knowledge (EK)	-0.16***				-0.16***	0.16***	0.69***	
	(0.04)				(0.04)	(0.04)	(0.09)	
Family size (FS)	0.02**				-0.09***		-0.09***	
	(0.01)				(0.03)		(0.03)	
Age (AGE)	-0.01*	0.01*	0.04*		0.13***	0.01*	0.04*	0.06*
	(0.00)	(0.01)	(0.02)		(0.02)	(0.01)	(0.02)	(0.03)
Family health experience (FHE)	-0.01*				-0.01*		0.06*	
	(0.01)				(0.01)		(0.03)	
Current health condition (CHC)					0.17***			
					(0.02)			
Ability	-0.08***	0.06***	0.24***		0.44***	0.06***	0.34***	0.35***
	(0.03)	(0.02)	(0.07)		(0.09)	(0.02)	(0.10)	(0.07)
Medium air pollution (MAP)	-0.02**				0.08*	0.08***	0.06	
	(0.01)				(0.04)	(0.03)	(0.04)	
Serious air pollution (SAP)	-0.03***				0.07	0.18***	0.05	
	(0.01)				(0.04)	(0.03)	(0.04)	
JMC employee, but not miner or smelter worker (NMS)	-0.01	0.01	0.04		-0.26***	0.01	0.04	0.06
	(0.01)	(0.01)	(0.05)		(0.07)	(0.01)	(0.05)	(0.05)
Miners and smelter workers of JMC (MS)	-0.02**	0.02**	0.08**		-0.28***	0.02**	0.08**	0.12**
	(0.01)	(0.01)	(0.04)		(0.05)	(0.01)	(0.04)	(0.04)

Note: Standard errors in parenthesis. *, **and *** :10%, 5% and 1%.

5.5 SUMMARY AND CONCLUSION

The neo-classical approach to measure (environmental) well-being by means of money measures derived from utility maximization under a budget constraint, has been criticized for not fully capturing the relevant dimensions of well-being and insufficiently accounting for psychological and sociological aspects. The notion of happiness has been introduced to capture broader dimensions of human life and to allow for comparison of their relative importance. It thus complements the conventional money measures based on constrained utility maximization.

The main focus of the paper is the impact of health risk on happiness. Based on recent socio-psychological and economic literature, we argue that the commonly used objective measures of environmental risk need to be supplemented with subjective notions, particularly perception. Both objective and subjective measures have been considered here to estimate the impact of (*inter alia*) perceived risk of air pollution on happiness, based on a cross-sectional data set of 759 households in the Jinchuan mining area, China. For this purpose, a four-equation structural equation model (SEM) is estimated.

The results of this paper support and extend Ferre-i-Carbonell and Gowdy's (2007) findings that environmental quality affects happiness. Its main outcome is that the more health risks an individual perceives (both in terms of exposure and hazardous pollutants), the less happy she or he is. Apart from perceived risk, ability, age, proximity to the pollution source, work environment and current health condition are important determinants of happiness.

Another important finding is that perceived health risk consist of two types: perceived risk due to intensity of exposure measured as the average number of days per week of severe pollution, and perceived health risk due to hazard of pollutants. The estimation procedure, structural equation model with latent variables, turned out to be instrumental in identifying the two types. The first type is systematically influenced by environmental knowledge and proximity to the pollution source; the second by environmental knowledge, family size, family health experience, ability, and proximity to the pollution source. Finally, environmental knowledge was found to be a function of age, ability andwork environment
.

The findings of this paper imply that improving air quality is an important policy measure to improve happiness in the Jinchuan area. Perception of its health risks, particularly of respiratory and cardiovascular illnesses including cancer and premature death, has the largest total negative effect on happiness and the next largest in absolute value. The results also show that risk perception is influenced by environmental knowledge. Therefore, improvement of air pollution should be widely communicated. For that purpose, a new environmental management institution could be created in which the government, scientific institutions, the mining and smelting company and citizen organizations would participate. The institution should respond to public concerns and stimulate dialogue and cooperation between the participants.

The present study can be extended in several ways as it only focuses on the relationship between air pollution and happiness. However, apart from air pollution, water pollution and solid waste are also environmental issues caused by mining and smelting in the Jinchuan area with associated health risks. It would be interesting to analyze how overall environmental degradation affects people's happiness. In addition, it would be interesting and important, both from a theoretical and policy point of view, to further develop the notions of happiness, perceived risk and environmental knowledge and to test their indicators, similarly to the development and measurement of theoretical notions like intelligence in psychology.

APPENDIX D. THE INITIAL MODEL

Table D.5.1 Overall goodness of fit measures

Fit index	Initial model	Critical value
χ2/DF	2.75	<3
Goodness-of-fit index(GFI)	0.97	>0.95
Adjusted goodness-of-fit index (AGFI)	0.96	>0.95
Root mean square error of approximation (RMSEA)	0.048	<0.05
Standardized root mean square residual (SRMR)	0.029	<0.08

Table D.5.2 Measurement models

Latent variables	Indicators	Coefficient	Standard errors	R2
Happiness (HAP)	HAP1	0.52	0.03	0.27
	HAP2	0. 42	0.03	0.18
	HAP3	0.52	0.03	0.27
	HAP4	0.56	0.03	0.31
	HAP5	0.34	0.03	0.12
Perceived risk (PR)	PR1	0.16	0.03	0.03
	PR2	0.56	0.06	0.31
	PR3	0.52	0.05	0.27
	PR4	0.61	0.05	0.37
	PR5	0.56	0.05	0.31
Environmental knowledge (EK)	EK1	0.51	0.07	0.26
	EK2	0.46	0.07	0.21
	EK3	0.39	0.06	0.15
	EK4	0.47	0.07	0.22
	EK5	0.56	0.08	0.31
	EK5	0.47	0.07	0.22
	EK7	0.31	0.05	0.10
	EK8	0.42	0.06	0.17
Ability (AB)	Education	0.41	0.04	0.17
	Income	0.51	0.04	0.26

Table D.5.3 Structural model

Variables	HAP	PR	EK
Happiness (HAP)		-0.03 (0.10)	
Perceived risk (PR)	-0.22** (0.08)		0.29 (0.24)
Environmental knowledge (EK)		0.48 * (0.30)	
Family size (FS)	-0.12*** (0.02)	-0.09*** (0.02)	
Age (AGE)	0. 14*** (0.03)		0.06* (0.03)
Family health experience (FHE)		0.06* (0.03)	
Current health condition (CHC)	0.17*** (0.02)		
Ability (AB)	0.53*** (0.11)	0.19*** (0.12)	0.27*** (0.08)
Medium air pollution (MAP)	0.10** (0.04)	0.06 (0.04)	
Serious air pollution (SAP)	0.10* (0.04)	0.09** (0.04)	
JMC employee, but not miner or smelter worker (NMS)	-0.25*** (0.05)		0.04 (0.05)
Miners and smelter workers of JMC (MS)	-0.26*** (0.05)		0.09* (0.05)
	0.28	0.32	0.21

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Chapter 6

Conclusions and discussion

6.1 INTRODUCTION

The main purpose of this thesis is to conduct a comprehensive valuation of Jinchuan residents' preferences for avoiding health risks caused by air pollution. For that purpose, I collected a cross-sectional data set of 759 households in the Jinchuan mining area, based on a stratified sample. Four papers were developed all which have been submitted to international journals. One paper has recently been published. Below, in section 6.2, I present the main findings of this thesis and in section 6.2 the main policy conclusions that can be drawn from the analyses. Finally, in section 6.4 I discuss some suggestions for further research.

6.2 MAIN RESEARCH FINDINGS

Research question 1: *What is the relationship between environmental knowledge and perceived health risk caused by air pollution? In addition, how are both variables influenced by socio-demographic characteristics?.*

This research question was addressed in Chapter 2 entitled "*Environmental Knowledge and Perceived Health Risk Among the Residents of the Jinchuan Mining Area, China".* Before going into detail, note that perception of health risk was defined as the subjective likelihood of the occurrence of a negative event related to health for a person or a group of people over a specified time period (Menon et al. 2008) and environmental knowledge as the cumulative body of knowledge of the interdependency between human society and its natural environment (Berkes et al. , 2000), A first finding is that Jinchuan's residents perceive serious air pollution in their city. Particularly, 97.8% perceive that Jinchuan's air is seriously polluted. Moreover, the majority (more than 70%) perceives that Jinchuan's air pollution increases the possibility of suffering from cardiovascular illness, respiratory illnesses, lung cancer and even premature death.

The estimated SEM measurement model indicates that perceived health risk is made up of two different types. One is health risk due to intensityof exposure, the other health risk due to hazardousness of pollutants. The estimated structural environmental knowledge- perceived health risk model shows that perception of intensity due to exposure is systematically influenced by environmental knowledge and proximity to the pollution source. Perceived health risk due to hazardousness of pollutants is impacted by environmental knowledge, family size, family health experience, ability, and proximity to the pollution source.

The reverse effect- from perceived risk on environmental knowledge is insignificant. A possible explanation is that the suffocating and pungent odor of sulfur dioxide and chlorine gas, which are the main observable air pollutants in the Jinchuan mining area, is sufficient evidence for the existence of the health risks such that further knowledge acquisition is not necessary. Environmental knowledge is found to be a function of age, ability and work environment.

The second research question is: *What are the determinants of the choices in a choice experiment (CE) aimed at reducing the acute health risks*[1] *acute upper respiratory tract infection, acute bronchitis and acute pneumonia? Furthermore, how much are people willing to pay for reducing these acute health risks correlated with air pollution?*

This research question was addressed in chapter 3 enitled "*Valuing acute health risks of air pollution in the Jinchuan mining area, China: A choice experiment with environmental knowledge and perceived health risk as co-determinants"*

The following attributes were considered: type, duration and activity restriction, while price is the main cure characteristic. In addition to the attributes of the illness-cure combination, respondents' household net income, education, family health experience, family size, age, work environment, proximity to the pollution source, environmental knowledge and perceived risk were considered as determinants of the choice mode. A combined SEM - random parameter logit model (RPL) was applied to estimate the choice model.

The estimates indicate that the illness attributes, and the respondent characteristics ability, age, family health experience, work environment and proximity to pollution source are the main determinants of choice mode. I calculated the household WTP for each type of illness on the basis of the RPL estimates. TheWTP was found to vary by activity restriction and, to a less extent, by duration. Particularly, the more serious the activity restriction, the larger is the WTP. Taking all 24 illnesses investigated together, the mean household WTP is 94.87 CNY per year (0.18% of average yearly household income). Another important finding is that both kinds of perceived health risk indicated that residents may also use other mechanisms than medicines to reduce health risk.

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[1] These illnesses are common and clearly discernible risks of air pollution. This feature facilitates respondents' understanding of the health problem at hand, and thus of making a choice. See amongst others Bresnahan (1997) who points out that people are more sensitive to take actions against acute health problems than to chronic health impairments.

The third research question was "*What are the kinds of averting behaviors that the residents of Jinchuan take to reduce all possible kinds of perceived health risks associated with air pollution? Additionally, how much are people willing e to pay for reducing health risks?*.

This research question was addressed in Chapter 4 entitled "*Air pollution and perception-based averting behavior. The case of the Jinchuan mining area, China"*.

The following three indicators turned out to be significant indicators of averting behavior:

1. Investment in air purifying equipment and growing household plants;
2. Purchase of preventive and curing medicines and foods
3. Adjustment of daily activities.

Another finding is that people's perceived risk is a positive, significant indicator of their averting behavior. These results support the argument (Um et al., 2008 and Richardson et al., 2011) that higher perceived risk commonly drives people to take more action to mitigate the negative effects caused by air pollution. Apart from perceived health risk, ability, which is measured by income and education, is also an important determinant of averting behavior. We also found that environmental knowledge, ability, family size, family health experience and distance to pollution source influence respondents' perceived health risk. Environmental knowledge is associated with age, ability and work environment. The average WTP for improved air quality as derived from averting behavior expenses amounts to 2.0 % of average household income

The fourth research question reads: "*What are the determinants of happiness? Particularly, how does air pollution impact on happiness?*".

The research question was addressed in Chapter 5 entitled "*To what extent does air pollution affect happiness?The case of the Jinchuan mining area, China*".

The main finding is that both perceived health risk due to intensity of exposure and due to hazardousness of pollutants negatively and significantly influences people's happiness, although in absolute terms, the total risk effect is less than the (positive) effect of ability, as measured by income and education. Other important determinants of happiness are family size, age, distance to the pollution source (smelting plants), work environment and current health condition.

In summary, in this thesis I have shown that environmental quality has a substantial impact on people's happiness. In addition, perceived health risk induces people to take risk reducing actions. Hence, traditional choice experiments and averting behavior models should be extended to include psychological variables, notably perception and environmental knowledge. I have also found that structural equation modeling (SEM) is an important approach to estimate happiness and averting behavior models. Moreover, SEM can be conveniently combined with a random parameter logit model to estimate choice mode in choice experiments.

6.3 POLICY IMPLICATIONS

In this thesis, I have shown that air pollution has substantial impacts on risk reducing behavior and on happiness of the residents of Jinchuan. The findings are relevant to policy making in that they provide further ground for the development of comprehensive long and short run policies to control air pollution and reduce its negative health effects. Jinchuan policymakers are already developing strict environmental protection conditions for the local industries, especially the mining industry. The findings of this thesis show that these policies should be sustained and intensified because of the substantial effects on happiness and risk reducing behavior. Cleaner production and the cyclical economy ought to be top priority of local policy.

Reducing air pollution requires time. For the short and medium term, intermediate policy measures need to be taken. The thesis shows that environmental knowledge positively and significantly influences perceived health risk. Therefore, improvement of air pollution should be widely communicated. For that purpose, a new environmental management institution could be created in which the government, scientific institutions, the mining and smelting company and citizen organizations would participate. The institution would respond to public concerns and stimulate dialogue and co-operation between the participants. Moreover, information on air quality should be widely disclosed to allow residents to take risk reducing actions. For instance, in combination with the weather forecast, information on local air quality conditions could be communicated and risk mitigating actions such as reducing or abandoning outdoor activities could be recommended. Furthermore, the positive effect of age on environmental knowledge is also important from a policy perspective because it indicates that environmental knowledge among older age groups is better than among younger people. Therefore, more attention should be paid to young people's environmental education, e.g. in middle school.

6.4 SOME SUGGESTIONS FOR FUTURE RESEARCH

This research needs to be extended in several ways. Firstly, the definitions and measurements of averting behavior, perceived health risk, environmental knowledge and happiness need to be refined and tested in similar and other settings. In the course of this research I learned that there basically are two kinds of perceived health risk; one related to intensity of exposure, another to hazardousness of pollutants. There may be even more. Similarly with respect to the other theoretical constructs. Hence, it would be interesting and important, both from a theoretical and policy point of view, to further develop the key notions of happiness, averting behavior, perceived risk and environmental knowledge and to test their indicators, similarly to the development and measurement of theoretical notions like intelligence in psychology.

Secondly, further research should be conducted to analyze the correspondence between objective risk and perceived risk. Laboratory experiments have frequently indicated that individuals tend to under-estimate high-risk events and over-estimate small-risk events, which is an illustration of the fact that perceived risk differs from objective risk (Ellsberg, 1961; Riddel and Shaw, 2006; Shaw and Woodward, 2008).The laboratory outcomes have been confirmed by surveys(seeVan Praag and Baarsma (2005) and Rehdanz and Maddison (2008)).In this research, I have argued that perceived healthrisk should be used to analyze people’s behavioural responses to environmental degradation and their happiness. The impacts of objective risk on people’s behavioural responses to environmental degradation and their happinessshould also be studied. Moreover, the difference between the effects of objective risk and perceived risk on people’s behavioural responses to environmental degradation and their happiness should be analyzed.

Thirdly, this study has solely focused on people’s psychological and behavior responses to air pollution. However, apart from air pollution, water and soil are also heavily polluted by mining and smelting in the Jinchuan area. It would be worthwhile to see how each of these types of environmental degradation affects people’s psychological and behaviour responses.

Finally, this paper relates to a specific mining area in China. It is of great scientific importance to understand the universality of the concepts analyzed here and the applicability of their measurements in other geographical settings.

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Nederlandse samenvatting

NEDERLANDSE SAMENVATTING

Het hoofddoel van dit proefschrift is meting van de invloed van luchtvervuiling op welzijn in de Jinchuan mijnstreek, Gansu, China. De volgende drie onderzoeksvragen worden onderzocht. Ten eerste, wat is de relatie tussen enerzijds kennis van lokale luchtvervuiling en anderzijds perceptie van gezondheidsrisico's? En, hoe worden deze beide variabelen beïnvloed door socio-demografische karakteristieken? Ten tweede, wat zijn de voornaamste determinanten van de wijze waarop inwoners van Jinchuan henzelf en hun familieleden beschermen tegen gezondheidsrisico's die correleren met luchtvervuiling? En, welk bedrag zijn mensen bereid uit te geven aan het verlagen van gezondheidsrisico's? Ten derde, hoe beïnvloedt luchtvervuiling subjectief welbevinden oftewel geluk? De empirische analyses zijn gebaseerd op een gestratificeerde steekproef van 759 personen (cross sectie).

De eerste vraag wordt in hoofdstuk 2 geanalyseerd met behulp van een structureel model (SEM). De belangrijkste uitkomst is dat kennis van milieuvervuiling een positief en significant effect heeft op de perceptie van gezondheidsrisico's; het omgekeerde effect daarentegen is insignificant. Beide variabelen worden beïnvloed door sociaalpsychologische karakteristieken, in het bijzonder inkomen en opleidingsniveau.

De tweede vraag komt aan de orde in hoofdstuk 3 en 4. In hoofdstuk 3 worden met behulp van een keuze-experiment verschillende combinaties van acute gezondheidsrisico's en geneesmiddelen geanalyseerd teneinde de betalingsbereidheid voor de vermindering van acute gezondheidsrisico's gecorreleerd met luchtvervuiling te schatten. Met behulp van een gecombineerd random parameter logit model - structureel model wordt geschat dat de gemiddelde betalingsbereidheid voor de meest voorkomende acute aandoeningen 0,18% van het gemiddeld jaarinkomen van een huishouden bedraagt.

In hoofdstuk 4 wordt niet alleen gekeken naar acute gezondheidsrisico's en een beperkt aantal medicijnen ter bestrijding ervan, maar naar alle soorten gezondheidrisico's die verband houden met luchtvervuiling. Bovendien wordt ook gekeken naar andere manieren dan medicijnen om gezondheidrisico's te vermijden of te verminderen, zoals de installatie van luchtfilters en de beperking van activiteiten in de (vervuilde) buitenlucht. Uit de schattingen met behulp van een structureel model blijkt dat een toename in risicoperceptie ten gevolge van een extra dag zware luchtvervuiling leidt tot een extra beperking van activiteiten buitenhuis met 45 minuten per week. Voor de uitgaven aan medicijnen geldt dat hoe groter het gepercipieerde risico, des te groter de bereidheid to betaling ter vermijding ervan. De beide hoofdstukken tonen empirisch aan dat perceptie van gezondheidsrisico's mensen aanzet tot risico beperkende maatregelen. Daarom moeten traditionele keuze-experimenten en modellen van vermijdingsgedrag uitgebreid worden met psychologische variabelen, vooral perceptie van gezondheidsrisico en milieukennis.

Wat betreft derde vraag laat hoofdstuk 5 zien dat vermindering van luchtvervuiling de mate van welzijn (geluk) verhoogt, al hebben verbetering van inkomen en opleidingsniveau een groter effect. Andere belangrijke determinanten van geluk zijn gezinsgrootte, leeftijd, afstand van de woonomgeving tot de vervuilingsbron, werkomgeving en de huidige gezondheid situatie.

Het proefschrift concludeert dat vermindering van luchtvervuiling een belangrijk lange termijn beleidsdoel is. Daarnaast moeten lokale overheden informatie verschaffen over gezondheidsrisico's ten gevolge van luchtvervuiling, en mogelijkheden om deze risico's te verminderen.