Payments for Ecosystem Services of the Middle Route of the South-to-North Water Transfer Project in China

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The candidate confirms that the work submitted is his/her own, except where work which has formed part of jointly-authored publications has been included. The contribution of the candidate and the other authors to this work has been explicitly indicated below. The candidate confirms that appropriate credit has been given within the thesis where reference has been made to the work of others.

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Abstract

The South-to-North Water Transfer Project, which aims to mitigate the severe water shortage in the north of China, is the largest water transfer project in the world. However, the success of the middle route of this project is threatened by water pollution in the water supply area and insufficient funding to tackle this problem. This study focused on how to use the policy instrument of Payments for Ecosystem Services (PES) to ensure the success of water protection of the middle route project.

Non-market valuation was conducted in this study to provide policy suggestions on the design of PES schemes for water protection. From the service demand perspective, a Contingent Valuation survey with a total of 755 questionnaires was conducted in 4 cities (i.e. Beijing, Tianjin, Shijiazhuang and Zhengzhou) along the water transfer route in order to investigate urban residents' Willingness To Pay (WTP) for the service of water protection. From the service supply perspective, a Choice Experiment survey with 246 questionnaires was conducted in 7 villages in the water supply area in order to reveal farmer households' preferences for different designs of two water protection programs, namely the existing Sloping Land Conversion Program (SLCP) for reforestation and a hypothetical fertilizer reduction program.

Results of the Contingent Valuation survey indicate that urban residents' WTP for water protection was significantly influenced by their income, their knowledge of the water transfer project and their attitudes to the general idea of PES. Model estimation results show that, on average, respondents in Beijing, Tianjin, Shijiazhuang and Zhengzhou were willing to pay an increase of 0.71, 0.25, 0.39 and 0.36 yuan/m^3 in the water price, respectively. In this case, though the annual WTP per capita would only account for 0.14%, 0.04%, 0.09% and 0.07% of the annual disposal income per capita in the four cities, respectively, the total annual WTP of all water users in the four cities could account for 76% of the annual cost of water protection in the water supply area. Therefore, It is argued that a multi-source PES scheme co-funded by water users and governmental budgets is financially feasible without imposing a heavy financial burden to water users in the four cities.

Moreover, results of the Choice Experiment survey show that farmer households in the water supply area significantly preferred higher annual payment, longer contracts and less restrictions on the land use activities

regarding both water protection programs. The trade-offs between the three attributes indicate that, on average, farmer households were willing to forgo about 8 yuan/mu/year (mu is a commonly used unit of land which equal to 1/15 hectare) for each extra SLCP contract year and 13 yuan/mu/year for the permission of planting each 10% more “commercial trees” (which are more profitable but generate less ecological benefits). Furthermore, analysis also found that the current SLCP contracts have underestimated farmer households’ preference for the “commercial trees”, and thus are discouraging them to choose the “ecological trees” which are less profitable but generate more ecological benefits. For the hypothetical fertilizer reduction program, farmer households were willing to forgo about 26 yuan/mu/year for every extra contract year but required 16 yuan/mu/year for reducing each 10% of the use of nitrogen and phosphorus fertilizers.

Overall, this research contributes to the literature of linking non-market valuation and PES studies in environmental and natural resources management. It is concluded that PES is a promising policy instrument to secure the supply of clean water for the middle route of the South-to-North Water Transfer Project in China, and non-market valuation methods (Contingent Valuation and Choice Experiments) are useful tools to reveal public attitudes and preferences in the design of PES schemes.

Table of Contents

Acknowledgements .... **iii**

Abstract .... **v**

Table of Contents .... **vii**

List of Tables .... **xiii**

List of Figures .... **xv**

Chapter 1 Introduction **1**

1.1 Research Background 1

1.1.1 The South-to-North Water Transfer Project in China 1

1.1.2 A Threat to the Success of the Middle Route Project 4

1.1.3 The Promise of a New Policy Instrument and the Research Needs 5

1.2 Research Aim and Objectives 7

1.3 Significance and Contributions 8

1.4 Structure of the Thesis 9

Chapter 2 Literature Review **11**

2.1 A Brief Review of Payments for Ecosystem Services 11

2.1.1 Origin in the 1980s 12

2.1.2 Development in the 1990s 12

2.1.3 Mainstreaming in the 2000s 13

2.1.4 Criticisms and Reflections on PES 16

2.2 The Chinese Version of PES: Ecological Compensation 19

2.2.1 What is Ecological Compensation? 20

2.2.2 Practice of Ecological Compensation Policy 21

2.3 Studies on Sloping Land Conversion Program and Limitations 23

2.3.1 Ecological and Socio-economic Effects of SLCP 23

2.3.2 Farmers' Post-program Land Use Decisions 24

2.3.3 Choice Modelling Studies on SLCP 25

2.3.4 Limitations of the Existing SLCP Studies. 26

2.4 Non-market Valuation Methods for WTP and Choice Modelling Studies 29

2.4.1 Major Economic Valuation Methods for Ecosystem Services 30

2.4.2 Contingent Valuation 30

2.4.3 Choice Experiments 32
2.5 A Missing Bridge between Non-market Valuation and PES Studies 33
2.6 Summary 35
Chapter 3 Research Design and Methodology 37
3.1 Contingent Valuation Survey in Northern Cities 37
3.1.1 Four Cities in the Contingent Valuation Survey 37
3.1.2 Survey Sampling and Implementation 39
3.1.3 Questionnaire Design of the Contingent Valuation Survey 43
3.2 Econometric Models for Contingent Valuation 46
3.2.1 Non-parametric Model for Contingent Valuation 46
3.2.2 Parametric Models for Contingent Valuation 49
3.2.2.1 Random Utility Model 49
3.2.2.2 Random Willingness to Pay Model 54
3.2.2.3 The Choice between the Probit and the Logit Model 56
3.2.2.4 Simulated Confidence Interval of Parametric Models 57
3.2.2.5 Double Bound Dichotomous Choice Model 58
3.3 Implementation of Contingent Valuation Models 60
3.3.1 The Initial Full Model 61
3.3.2 Stepwise Regression and Best Subset Regression 63
3.3.3 Integration of Automatic Model Selection Procedures and Manual Adjustment 64
3.4 Choice Experiment Survey in the Water Supply Area 68
3.4.1 Study Area and Survey Sampling and Implementation 68
3.4.2 Questionnaire Design of the Choice Experiment Survey 70
3.5 Econometric Models for Choice Experiment 76
3.5.1 The Classic Conditional Logit Model 76
3.5.2 The Random Parameters Logit Model for Revealing the Heterogeneity in Respondents' Preferences 77
Chapter 4 Public Willingness to Pay for Water Protection 81
4.1 Respondents' Characteristics, Environmental Awareness, Knowledge and Opinions 81
4.2 Non-parametric Model Estimates of WTP for Water protection 85
4.3 Parametric Models for Estimating Public WTP for Water protection 89

4.3.1 Parametric WTP Models for Respondents in Beijing 89

4.3.2 Parametric WTP Models for Respondents in Tianjin 93

4.3.3 Parametric WTP Models for Respondents in Shijiazhuang 98

4.3.4 Parametric WTP Models for Respondents in Zhengzhou 102

4.4 Comparison of the Final Parametric Models of Four Cities 106

4.5 Respondents' Mean WTP for Water Resource Protection 110

4.6 Summary 119

Chapter 5 Farmer Households' Preferences for the Design of Water Protection Programs 121

5.1 Characteristics of Farmer Households 121

5.1.1 The Difference between SLCP Participant and Non-participant Households 123

5.1.2 Representativeness of the Sample Households 124

5.2 Farmer Households' Participation in Sloping Land Conversion Program 125

5.2.1 What was the most important reason for farmer households' participation in the SLCP? 125

5.2.2 Have the SLCP-participant households enrolled all their qualified sloping land in the program? If not, why? ... 127

5.2.3 Will farmer households keep the converted forestland after the expiration of their SLCP contracts? 128

5.2.4 Are farmer households willing to continue with the SLCP under the current contract? 129

5.2.5 What are the non-participating farmer households' reasons for not participating the SLCP? 130

5.3 The SLCP's Effect on Farmer Households' Livelihood 131

5.3.1 Comparison of Income per mu from Trees and Crops 131

5.3.2 Comparison of Households' income from Sloping Land before and after the SLCP 133

5.3.3 Comparison of the Total Income of SLCP Participant and Non-participant Households 135

5.4 Choice Modelling Results of Farmers Households' Preferences for the Design of Water Protection Programs 137

5.4.1 Farmer Households' Preferences for the Design of SLCP 138

5.4.1.1 Marginal Values of Contract Length and Commercial Trees 138

5.4.1.2 Farmer Households' Preferences for Longer SLCP Contracts 140

5.4.2 Farmer Households' Preferences for the Design of Fertilizer Reduction Program... 143

5.5 Heterogeneity in Farmer Households' Preferences for the Design of Water Protection Programs...................................... 145

5.5.1 Estimation Results of the Random Parameters Logit Model 145

5.5.1.1 Farmer Households' Heterogeneous Preferences for the Design of SLCP 145

5.5.1.2 Farmer Households' Heterogeneous Preferences for the Design of Fertilizer Reduction Program 148

5.5.2 Factors Causing Heterogeneity in Farmer Households' Preferences for the Design of Water Protection Programs.. 150

5.6 Summary.. 153

Chapter 6 Discussion and Implications 157

6.1 Financial Feasibility of PES for Water Protection 157

6.1.1 Aggregate WTP for Water Protection 157

6.1.2 Comparison with the results of Similar Studies 159

6.1.2 Total WTP versus Total Cost of Water Protection 161

6.2 Improving Sloping Land Conversion Program in the Water Supply Areas.. 162

6.2.1 Marginal Values of Program Attributes in Similar Studies 162

6.2.2 Using Information of Farmers' Trade-offs between Program Attributes to Improve SLCP 163

6.2.3 Hypothetical Program for Reducing Fertilizers 166

6.3 Summary... 167

Chapter 7 Conclusions and Perspectives.. 169

7.1 Overview of Research Findings.. 169

7.2 Policy Recommendations... 174

7.3 Major Contributions to the Literature 175

7.4 Limitations and Directions of Future Research............................ 176

7.5 Conclusions.. 177

List of References 179

List of Abbreviations.. 193

Appendix 1 Questionnaire of the Contingent Valuation Survey 195

Appendix 2 Questionnaire for Household Survey in the Water Supply Area (participants of the Sloping Land Conversion Program) 205

Appendix 3 Questionnaire for Household Survey in the Water Supply Area (non-participants of the Sloping Land Conversion Program).. 215

List of Tables

Table 2.1 WTP Studies on Water Quality Improvement in China 32

Table 3.1 Characteristics of the Four Cities 39

Table 3.2 Potential Explanatory Variables in the Initial Full Model 61

Table 3.3 Defined Attributes of the Sloping Land Conversion Program 71

Table 3.4 Choice Cards of the Sloping Land Conversion Program 73

Table 3.5 Defined Attributes of the Hypothetical Fertilizer Reduction Program 74

Table 3.6 Choice Cards of the Fertilizer Reduction Program 75

Table 4.1 Characteristics of Respondents in Four Cities 82

Table 4.2 Explanatory Variables of Respondents' Environmental Awareness, Knowledge and Opinions 84

Table 4.3 WTP Estimates of the Non-parametric Model (yuan/m^3) 88

Table 4.4 Parametric WTP Models for Respondents in Beijing 90

Table 4.5 Parametric WTP Models for Respondent in Tianjin 94

Table 4.6 Parametric WTP Models for Respondents in Shijiazhuang 99

Table 4.7 Parametric WTP Models for Respondents in Zhengzhou.... 103

Table 4.8 Final Parametric WTP Models of Four Cities 107

Table 4.9 Comparison of Single Bound and Double Bound Models... 113

Table 4.10 Estimates of Respondents' Mean WTP by Different Models 115

Table 5.1 Characteristics of Farmer Households 122

Table 5.2 Reasons for Keeping Forestland after the Expiry of SLCP Contracts 128

Table 5.3 Gross Income per mu from Major Trees and Crops 132

Table 5.4 Total Income of Two Groups of Farmer Households 136

Table 5.5 Conditional Logit Model of Farmer Households' Preferences for the Design of SLCP 138

Table 5.6 Farmer Households' Choices for Policy Scenarios of SLCP 141

Table 5.7 Modelling Effect of Contract-length and Aggregate Payment 142

Table 5.8 Conditional Logit Model of Farmer Households' Preferences for the Design of Fertilizer Reduction Program 143

Table 5.9 Radom Parameters Logit Model of Farmers Households' Preference for the Design of SLCP 146

Table 5.10 Radom Parameters Logit Model of Farmer Households' Preference for the Design of Fertilizer Reduction Program 149

Table 5.11 Heterogeneity in Farmer Households' Preference for the Contract length of SLCP... 151

Table 5.12 Heterogeneity in Farmer Households' Preference for the Contract length of Fertilizer Reduction Program 153

List of Figures

Figure 1.1 Water Resources per Capita in China 2

Figure 1.2 The South-to-North Water Transfer Project in China 3

Figure 2.1 Yearly Publications of PES Studies 15

Figure 3.1 Four Cities in the Contingent Valuation Survey 38

Figure 3.2 Sampling Locations in Beijing (200 questionnaires) 41

Figure 3.3 Sampling Locations in Tianjin (249 questionnaires)............ 41

Figure 3.4 Sampling Locations in Shijiazhuang (98 questionnaires) 42

Figure 3.5 Sampling Locations in Zhengzhou (210 questionnaires) 42

Figure 3.6 Econometric Models in Contingent Valuation 60

Figure 3.7 Integrated Model Selection and Improvement Procedure 66

Figure 4.1 Original Percentages of *No* Answer in Four Cities............... 86

Figure 4.2 Imposing Monotonicity on the Data of Shijiazhuang and Beijing for Non-parametric Estimation 87

Figure 4.3 Explanatory Variables in the Final Model of Beijing 92

Figure 4.4 Explanatory Variables in the Final Model of Tianjin............. 97

Figure 4.5 Explanatory Variables in the Final Model of Shijiazhuang 101

Figure 4.6 Explanatory Variables of the Final Model of Zhengzhou ... 105

Figure 4.7 Effect of Random Draws on Simulated Confidence Intervals of the Mean WTP.. 111

Figure 4.8 Simulated Confidence Intervals of the Mean WTP (Double Bound Parametric Model) 114

Figure 5.1 The Most Important Reason for Participation in the SLCP.. 126

Figure 5.2 Comparison of Gross Income from Trees and Crops 132

Figure 5.3 Distribution of Farmers' Income from Sloping Land.......... 134

Figure 5.4 Distribution of Marginal Value Estimates of the SLCP...... 140

Figure 5.5 Distribution of Marginal Values Estimates of the Fertilizer Reduction Program 144

Chapter 1
Introduction

In this introductory chapter, Section 1.1 introduces the research background of this thesis. Section 1.2 outlines the research aim and objectives. Section 1.3 highlights the significance and contributions of this research to multiple stakeholders. Section 1.4 describes the structure of this thesis.

1.1 Research Background

1.1.1 The South-to-North Water Transfer Project in China

Water shortage is one of the greatest challenges for China's sustainable development. Although China's total water resources is the sixth largest in the world, its water resources per capita is only a quarter of the world average due to its large population (Zhang 2009). This problem is exacerbated in the north of China due to the highly uneven distribution of the water resources. With 44.4% of the country's total population and 59.5% of its total arable land, the north of China only possesses 14.4% of its total water resources (Xie *et al.* 2008). In Beijing and other regions of the north, the water sources per capita is less than 500 m^3/year while this figure is over 1700 m^3/year in the south (see Figure 1.1). As many rivers have undergone severe cessation of water flows or pollution, water supply in the north has heavily relied on the groundwater which has been damagingly overexploited to meet the increasing water demand of the fast growing economy and population. For example, the average groundwater table of Beijing has continuously declined by 20 metres from 1975 to 2005 (Stone and Jia 2006). On the other hand, the south of China frequently suffers from disastrous floods caused by the monsoon climate, particularly in the Yangtze River Basin (Varis and Vakkilainen 2001; Xie *et al.* 2008).

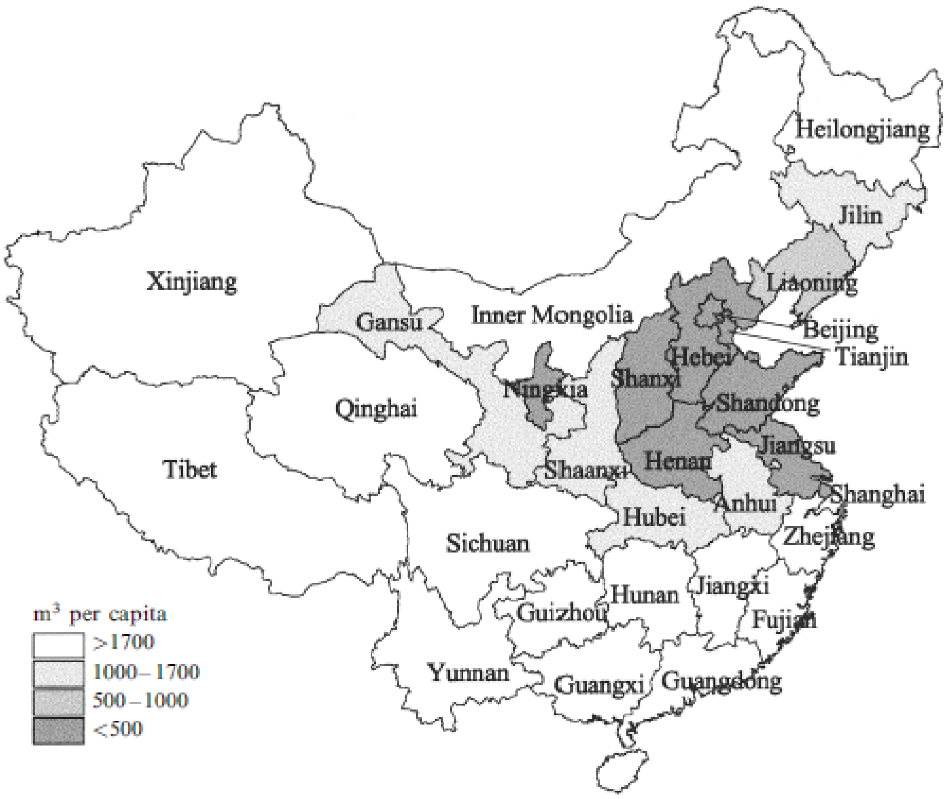

Figure 1.1 Water Resources per Capita in China

Source: Yang and Zehnder (2001)

The idea of transferring the surplus water from the south to the north was first proposed in the early 1950s, but debates over its rationality, feasibility, the design of water transfer routes and potential environmental impacts lasted for half a century (Liu 1998; Liu and Zheng 2002; Berkoff 2003). Finally in 2002, the Chinese central government launched the South-to-North Water Transfer Project (SNWTP) which aimed to transfer about 44.8 billion m^3/year of water from the Yangtze River and its largest tributary (the Hanjiang River) to the north and northwest of China via the eastern, middle and western routes (see Figure 1.2). The total budget of the whole project will amount to 500 billion yuan (£50 billion) by 2050 (Stone and Jia 2006).

So far, the western route project of the SNWTP which aims to transfer 17 billion m^3/year of water is still at the planning stage and is unlikely to start the construction before 2020. The middle route project which aims to transfer 13 billion m^3/year of water has completed the construction and will start to transfer water after the flood season (September) of 2014. The eastern route project which aims to transfer 14.8 billion m^3/year of water has begun the water transfer since November of 2013.

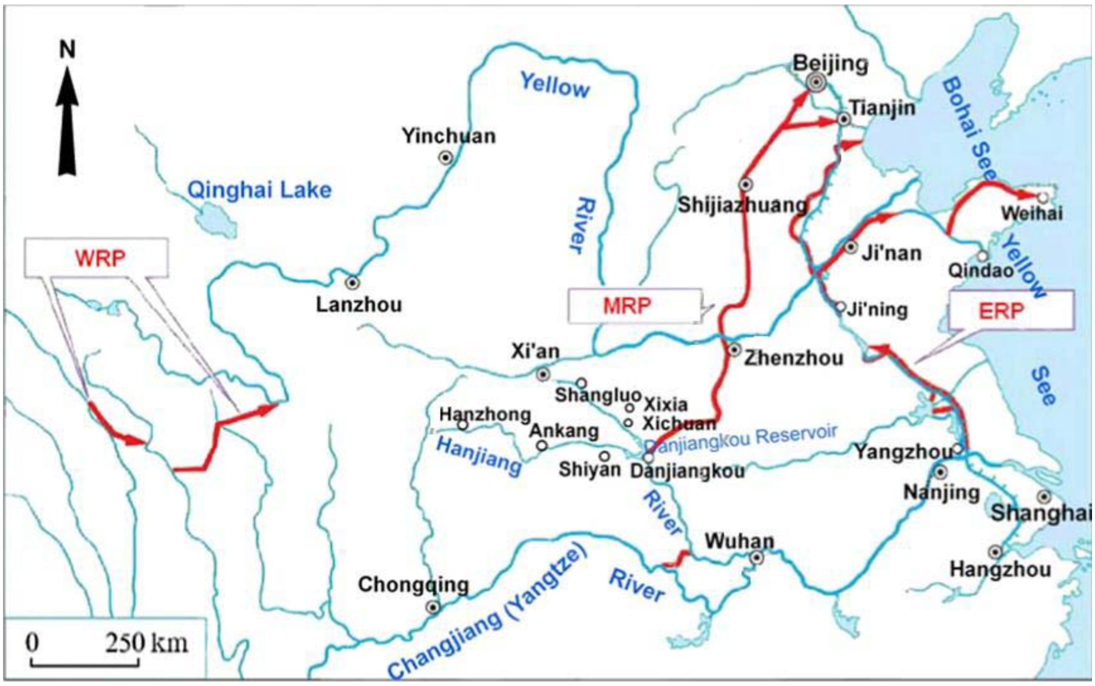

Figure 1.2 The South-to-North Water Transfer Project in China

WRP: the western route project. **MRP**: the middle route project. **ERP**: the eastern route project.
Adapted from Wei *et al.* (2010a)

Particular attention has been paid to the middle route project by policymakers and researchers. While the east route project needs a series of pumping stations to transfer water, the middle route can divert water entirely by gravity (Zhang 2009). The source of the middle route project, i.e. the Danjiangkou Reservoir, is much cleaner than the source of the eastern route project, i.e. the lower reaches of the Yangtze River (Zhang 2005). Thus high expectation has been given to the middle route to provide high-quality drinking water for northern cities such as the capital city of China, Beijing. In fact, the middle route is also the only water transfer route that is responsible for supplying water to Beijing.

The middle route project contains 1,274 km of water canals and tunnels which start from the Danjiangkou Reservoir in the middle reaches of the Hanjiang River, then run northward across the Henan and Hebei provinces and arrive at the municipalities of Beijing and Tianjin (see Figure 1.2). The domestic and industrial water demand in northern cities will be the priority of the supply of the transferred water, so local water resources can be spared for agricultural use and ecological restoration. A northern section of the middle route project was first completed in 2008 to transfer water to Beijing for securing the water supply for the Olympic Games. By the May of 2014, the middle route project has cost over 200 billion yuan (£20 billion) in total[1].

1.1.2 A Threat to the Success of the Middle Route Project

The success of the middle route project is dependent on, among other things (e.g. engineering management), whether the Danjiangkou Reservoir can maintain a high water quality. This is particularly doubtful in China where water quality in rivers, lakes and reservoirs has extensively deteriorated in the past three decades (Liu and Diamond 2005; Xie *et al.* 2008). Most of the surrounding and upstream districts of the Danjiangkou Reservoir are mountainous and deprived districts which have inadequate wastewater treatment facilities (Zhang 2009). Over 80% of the 13 million residents in those districts are farmers, and non-point source pollution caused by their agricultural activities is a major threat to the water quality in the districts (Zhang *et al.* 2009).

In order to maintain the water quality of the Danjiangkou Reservoir at a relatively high level of Class II [2], the Chinese central government issued The Plan of Water Pollution Control and Soil Conservation in Danjiangkou Reservoir and Upstream Districts (referred to as the governmental water protection plan) in 2006. This plan designated 40 counties in three provinces (i.e. Hubei, Henan and Shannxi) that cover 88,100 km^2 as the water supply area (of the middle route project) to implement multiple water quality protection measures, including inter alia construction of wastewater treatment plants and soil conservation projects, closure of heavy-pollution factories, reforestation on sloping farmland and logging ban. The budget of the water protection plan amounts to about 19.5 billion yuan (£1.95 billion) for the period of 2006-2020, and it is co-funded by the central government and local governments in the water supply area[3].

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[1] This cost is more than double the planned budget in 2001 (92 billion yuan) due to the rising commodity prices in the last decade.

[2] The national Environmental Quality Standards for Surface Water (GB3838-2002) of China defines five classes of water quality, and Class I is the highest quality level. Class III is the threshold level safe for drinking after treatment (it is also the required water quality of the eastern route project).

[3] For water treatment facilities, the central government undertakes the cost of construction while the local governments undertake the cost of operation. Soil conservation projects are generally funded in a fifty-fifty form.

The implementation of this water protection plan has brought a heavy financial burden to the governments in the water supply area as the GDP per capita of this area is less than half of the average GDP per capita of the whole country. Moreover, the budget of the governmental water protection plan focuses on the direct cost of engineering projects but has largely overlooked the opportunity cost of residents such as farmer households to change their economic/agricultural activities. In fact, policy makers of the this plan did foresee this funding problem and they called for diversification of the funding sources and establishment of compensation mechanisms between the water consuming area (northern cities) and the water supply area. However, no clear picture has been drawn by researchers and policy makers for such compensation mechanisms so far. Insufficient funding could lead to the failure of water quality protection of the Danjiangkou Reservoir and thus threatens the success of the middle route project.

1.1.3 The Promise of a New Policy Instrument and the Research Needs

In fact, insufficient funding for water quality (watershed) protection can be seen as a typical problem of market failure and externality effect (Kinzig *et al.* 2011; Jack, Kousky and Sims 2008). Since the service of water protection is not priced in the current market, beneficiaries of such service (water users) are not paying for it and service providers like upstream farmers receive little benefits or even incur economic loss from water protection activities. Such market failure has caused extensive degradation of ecosystems around the world (MEA 2005a). In the last two decades or so, there has been a growing interest in applying Payments for Ecosystem Services (PES), a market and incentive-based policy instrument, to motivate environmental protection by direct payments to land managers (Chichilnisky and Heal 1998; Ferraro and Kiss 2002; Engel, Pagiola and Wunder 2008; Kinzig *et al.* 2011). Despite debates over its academic definition, theoretical framework and socio-economic impact (Muradian *et al.* 2010; Farley and Costanza 2010; Kronenberg and Hubacek 2013), payment schemes labelled as PES have been widely applied in both developed and developing countries for watershed protection, forest conservation, biodiversity protection and carbon sequestration (Wunder, Engel and Pagiola 2008; Schomers and Matzdorf 2013).

In addition to the innovative nature of using direct payment to motivate environmental protection, some PES schemes exhibit another innovative nature i.e. they are directly funded by beneficiaries of the environmental protection rather than governmental budgets. For example, in Costa Rica, the pioneer developing country to apply the PES, downstream water users are levied additional water fees to pay upstream land managers for watershed protection through forest conservation. Similar schemes can also be found in Honduras, Nicaragua, Colombia, Mexico, Tanzania and other countries (Kosoy *et al.* 2007; Munoz-Pina *et al.* 2008; Moreno-Sanchez *et al.* 2012; Lopa *et al.* 2012).

The examples of user-funded PES schemes for water protection in other countries raise the question: can such a scheme also be established for the middle route project in China? This question is particularly important for policy makers since the large populations in the northern cities (e.g. Beijing has over 17 million residents) imply a great potential to raise water protection funds if a user-funded PES scheme is possible. To answer this question, information is needed on whether residents in the northern cities are willing to pay for water protection and whether their willingness to pay (WTP) is enough to make substantial supplement to or even replace the governmental funding. However, no studies in the literature have provided such information yet. Interestingly, despite the great attention policy makers have paid to the water quality issues of the middle route project, the opinions of millions of residents in the northern cities are largely overlooked. Therefore, a study on their WTP for water protection is also a chance to bring the public voice in water resources management to the academia and policy arena.

Although user-funded environmental programs are still uncharted waters for Chinese policy makers and researchers, there have been several government-funded programs to directly pay farmers for environmental protection activities in China. A national-scale program funded by the central government i.e. the Sloping Land Conversion Program (SLCP) which pays farmers to convert sloping farmland to forestland for reducing soil erosion, has been implemented in the water supply area of the middle route project since 1999. Later this program was incorporated into the central government's water protection plan (issued in 2006). However, the SLCP has some critical limitations.

Firstly, the program adopted two flat payment levels[4] across the country despite the much greater regional heterogeneity of China (Liu *et al.* 2008). Secondly, the contracts of the SLCP in terms of the annual payment, contract year and requirements of reforestation were designed by policy makers in the late 1990s and have not updated ever since then despite the substantial development and changes in the socio-economic contexts of China. Thirdly, the SLCP was designed in a top-down process which lacked consultation with the rural households (Bennett 2008). These limitations call for studies in the water supply area on farmer households' opinions about the design of the SLCP, especially their required payment levels under different policy scenarios (e.g. different contract lengths). Such studies can help to improve the SLCP for better adapting to the local socio-economic context but have rarely been conducted yet.

Moreover, although the SLCP plays an important role in water protection in the water supply area, it only enrols land with a gradient larger than 25 degrees which is more vulnerable to soil erosion. Many farmers have relatively flat farmland and grow crops for their livelihoods. The use of nitrogen and phosphate fertilizers on those croplands could cause non-point source pollution to the surface water and result in eutrophication in the Danjiangkou Reservoir. However, this problem has not been taken account of either by the SLCP or any other water protection measures in the central government's Plan. Therefore, it is also worthwhile to examine the farmer households' opinion about a new (hypothetical) program that pays them for reducing the use of fertilizers in the water supply area.

While the WTP study in northern cities focuses on the fundraising issue on the consumer/demand side of PES, the study in the water supply area focuses on the program design issue (from farmer households' perspective) on the provider/supply side of PES. Together the studies on both sides constitute a systematic research of developing PES for water protection.

1.2 Research Aim and Objectives

This study aims to answer the research question of how to design Payments for Ecosystem Services schemes for the water protection of the middle route

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[4] The two payment levels are 3450 yuan/hectare/year in the south and 2400 yuan/hectare/year in the north due to approximately different productivities of farmland.

of the South-to-North Water Transfer Project in China. Major research objectives are as follows:

(1) Conduct a literature review on PES and its application in China context.

(2) Review the existing literature on the SLCP to identify the strengths and limitations, review the methods for estimating the public's WTP for water protection and modelling public choices of policy scenarios of PES programs

(3) Design surveys to collect research data and develop models in order to:

(a) Investigate public WTP for water protection in northern cities and identify influential factors on their WTP.

(b) Assess the financial feasibility of a user-funded PES scheme for water protection of the middle route project.

(c) Investigate farmer households' opinions about the design of SLCP and a new (hypothetical) fertilizer reduction program in the water supply area, especially their required payment levels under different policy scenarios.

(4) Analyse the collected data and results from the model estimation, and provide critical discussion on the research findings and implications.

(5) Make suggestions and recommendations on the use of the research findings, in particular on the policy making of the South-to-North Water Transfer Project and projects of a similar nature.

1.3 Significance and Contributions

This research makes multiple contributions to the academia, policy makers and the public in both northern cities and the water supply area. For the academia, this research:

(1) Contributes to the literature of estimating public WTP for water protection and increases the knowledge of influential factors on public WTP for water protection.

(2) Contributes to the PES literature on the SLCP, a national-scale PES scheme for reforestation in China and reveals insights of farmer households' opinions about the design of PES schemes and their choices between different policy scenarios.

(3) In a holistic view, this research contributes to the literature of developing PES for water protection and incorporates public opinions in the design of PES.

For the policy makers, this research provides policy suggestions on:

(4) Solving the problem of insufficient funding for water protection of the middle route of the South-to-North Water Transfer Project.

(5) Improving the design of the SLCP and introducing a new fertilizer reduction program in the water supply area.

For the public in the northern cities and the water supply area, this research:

(6) Helps to bring their voice to the academia and policy makers.

Potentially, the success of water protection of the middle route project will ensure the supply of clean water to residents in the northern cities, and better designed SLCP (and probably a new fertilizer reduction program) will prevent the decline in farmer households' livelihood or even improve it under the PES program.

Lastly, although this research is based on a case study in China, the practical problem stimulating this research (e.g. insufficient funding for water protection) and its underlying idea (e.g. PES) are universal in the world, especially the developing countries. Thus the knowledge and insights obtained from this study can also be helpful for applying PES in the context of large-scale water infrastructures in other countries.

1.4 Structure of the Thesis

This thesis comprises 7 chapters. Following this introductory chapter, Chapter 2 reviews the relevant literature of this research. It first provides a brief review on the PES and China's indigenous policy instrument with the similar idea of PES (i.e. Ecological Compensation). It is followed by a review of the existing literature on the SLCP and their limitations. Then the methods for estimating public WTP for water protection (Contingent Valuation) and modelling public choices of policy scenarios of water protection programs (Choice Experiments) are critically evaluated to identify the gap between the PES studies and the WTP/Choice Modelling studies that this study aims to fill.

Chapter 3 depicts the research design and methodology adopted in this study. It first describes the Contingent Valuation survey in the northern cities for investigating the public WTP for water protection. It is followed by detailed explanation of the econometric models for Contingent Valuation and descriptions of the modelling procedures adopted in this research to develop and refine the models. Then the Choice Experiments survey in the water supply area to reveal farmer households' choices and preferences for the design of water protection programs. The econometric models for the choice experiments study are explained at the end of Chapter 3.

Chapter 4 depicts and discusses the results of the Contingent Valuation survey in the northern cities in detail. It starts with the description of the characteristic of the 755 respondents in 4 northern cities and their environmental awareness, knowledge and attitudes. Then it presents the model results derived from each city to explain respondents' willingness to pay higher water prices for water protection of the middle route project. It is followed by a comparative analysis of the final (best) models of the four cities. To conclude the chapter, the estimates of respondents' mean WTP by multiple models are compared and discussed.

Chapter 5 presents and discusses the results of the Choice Experiments survey in the water supply area in detail. It starts with the description of the characteristics of the 246 farmer households interviewed in 7 villages in the water supply area and it is followed by the survey results of the households' participation in the SLCP and their post-program land use decisions. Then an analysis of the effect of SLCP on participants' livelihoods is presented and it is followed by the choice modelling results on farmer households' preferences for the design of water protection programs and the heterogeneity in their preferences.

Chapter 6 discusses the implication of the research results from Chapters 4 and 5. It first assesses the financial feasibility of establishing a user-funded PES scheme for water protection of the middle route project. It then discussed improvements that should be made on the current SLCP contracts and the policy implications of the hypothetical fertilizer reduction program.

Chapter 7 summarizes the major research findings and policy recommendations that are offered by this research. Research limitation and future research directions are also given to conclude this thesis.

Chapter 2
Literature Review

Following the introductory chapter, this chapter provides a review of the relevant literature of this research. Section 2.1 provides a brief review on the PES. Section 2.2 introduces Ecological Compensation (EC), China's indigenous policy instrument with the similar idea to PES. Section 2.3 reviews existing literature on the SLCP and their limitations. Section 2.4 reviews the non-market valuation methods for estimating public WTP for water protection (Contingent Valuation) and modelling public choices of policy scenarios of water protection programs (Choice Experiments). Section 2.5 highlights a literature gap between the PES studies and the non-market valuation studies that this study aims to fill. Section 2.6 provides a summary of this chapter.

2.1 A Brief Review of Payments for Ecosystem Services

The well-being of human societies relies on "the benefits people obtain from ecosystems" which have been conceptualized as Ecosystem Services, including provisioning services like food production, regulating services like water purification, supporting services like nutrient cycling and cultural services like recreational benefits (MEA 2003). Over the past 50 years, 60% of the global ecosystem services have undergone rapid degradation (MEA 2005a). This is partly due to the fact that many ecosystem services such as water purification by upstream forests are not priced in existing markets, causing the problem of externalities that markets failed to tackle (Kinzig *et al.* 2011; Jack, Kousky and Sims 2008). For example, farmers in upstream watersheds usually receive much less benefits from forest conservation than timber logging, thus they have no incentives to conserve the forests for ensuring water purification for downstream water users.

Payments for Ecosystem Services (PES) is an emerging policy instrument to tackle the market failure and externality problem in the management and protection of ecosystem services. This section gives an overview of the origin and development of PES wherein the basic terms, concepts and rationale underpinning this study are introduced in the relevant contexts.

2.1.1 Origin in the 1980s

Efforts from economists to tackle the problem of externalities can be traced back to the 1920s and 1960s. While Pigou (1920) suggested the use of governmental taxes and subsidies to internalize externalities, Coase (1960) argued that externalities could be resolved through private negotiation and transaction if transaction cost was low and property rights were clearly defined and enforced (Gómez-Baggethun *et al.* 2010). With the emergence of modern environmentalism in the 1960s, researchers of Environmental and Resources Economics began to develop a range of non-market valuation methods such as Travel Cost and Contingent Valuation to place monetary value on environmental benefits like water quality improvement so that these environmental benefits could be incorporated in cost-benefit analysis for decision making (Liu *et al.* 2010). Yet, these environmental benefits were not conceptualized as ecosystem services until the 1980s when researchers initially introduced the concept to explain the importance of biodiversity from an economic perspective (Ehrlich and Ehrlich 1981; Gómez-Baggethun *et al.* 2010).

Also in the 1980s, some developed countries started to implement government-funded, national-scale conservation programs, such as the Conservation Reserve Program (CRP) in the U.S. (Claassen, Cattaneo and Johansson 2008) and the Environmentally Sensitive Areas (ESA) program in the U.K. (Dobbs and Pretty 2008), to compensate farmers for reducing negative externalities of agriculture activities like soil erosion and increasing positive externalities like scenic landscapes (Baylis *et al.* 2008). Since the concept of PES was not formed yet at that time, these programs were referred to by the term of Agri-environmental Program/Scheme/Policy which is still widely used at present in developed countries (Gibbons *et al.* 2011; Whittingham 2011; von Haaren *et al.* 2012; Hasund 2013).

2.1.2 Development in the 1990s

The 1990s witnessed the development of ecosystem services studies symbolized by the publication of Costanza *et al.* (1997)'s study on the economic value of the world's ecosystem services in the highly influential journal, *Nature* (Gómez-Baggethun *et al.* 2010). In the same period, a famous example of paying for watershed services was established by New York City and later reported in *Nature* (Chichilnisky and Heal 1998). Since 1996, New York City has invested US$1-1.5 billion to restrict land use in the upstream watershed (in the Catskill Mountains) by land acquisition and conservation easement so that the natural soil ecosystems can be restored to better purify drinking water for nearly 9 million downstream water users. And by doing this, the city saved $6-8 billion that would be required to build a new filtration plant (Smith and Porter 2010; Smith *et al.* 2013).

It is also in the 1990s that conservation payment programs emerged in the developing countries. In 1997, Costa Rica launched the first and most well-known national payment program in developing countries to pay farmers and forest owners for reforestation and forest conservation in order to ensure multiple services provided by forest ecosystems, including water provision, biodiversity conservation, carbon emission mitigation and scenic beauty for recreation and ecotourism (Zbinden and Lee 2005; Pagiola 2008). The name of this program, Payments for Environmental Services [5], has become a widely used term in literature (Herrador and Dimas 2000; Sanchez-Azofeifa *et al.* 2002; Pagiola, Arcenas and Platais 2005; Kosoy *et al.* 2007; Wunder, Engel and Pagiola 2008; Swinton 2010; Newton *et al.* 2012), which is generally interchangeable with the term, Payments for Ecosystem Services (Shelley 2011)[6]. Moreover, Costa Rica's PES program is innovative compared with agri-environmental programs implemented earlier in developed countries because part of the program funding comes directly from beneficiaries (e.g. water users) of ecosystem services instead of government budgets. This "Principle of Beneficiaries Pay", together with the use of direct payment to providers of ecosystem services, was one of the key elements to form the concept of PES (Wunder 2006; Wunder 2007; Engel, Pagiola and Wunder 2008).

2.1.3 Mainstreaming in the 2000s

The worldwide acceptance of the concept of Ecosystem Services was greatly consolidated by the international project of Millennium Ecosystem Assessment during 2001-2005 which involved more than 1,300 experts from 95 countries to appraise "the condition and trends in the world's ecosystems and the services they provide" (MEA 2005b; Carpenter *et al.* 2006; Gomez-Baggethun *et al.* 2010). With the growing awareness of the economic values of ecosystem services and the absence of markets to present these values,

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[5] This is the English translation of the original Spanish program name *Pagos de Servicios Ambientales* (PSA) (Zbinden and Lee 2005).

[6] Shelley (2011) provides interesting discussion on the nomenclature issues of PES and she suggested that consistent use of the choosing term (Payment for Environmental/Ecosystem Services) was actually more important than the choice itself.

researchers and policy makers are increasingly interested in establishing market-based mechanisms like PES to motivate conservation (Mooney, Cropper and Reid 2005; Gomez-Baggethun *et al.* 2010). The success of Costa Rica's PES program, as reported by Ferraro and Kiss (2002)'s influential paper in *Science*, was followed by a number of similar programs which were implemented in Mexico (Munoz-Pina *et al.* 2008), Nicaragua (Pagiola *et al.* 2007), Bolivia (Asquith, Vargas and Wunder 2008) and Ecuador (Wunder and Alban 2008), making Latin America the focal region of PES practice in the world. Countries in Southeast Asia and Africa such as Cambodia (Clements *et al.* 2010), Vietnam (McElwee 2012), Madagascar (Wendland *et al.* 2010) and Zimbabwe (Frost and Bond 2008) also launched conservation programs bearing the characteristics of PES such as the use of direct payments and transactions between beneficiaries and providers of ecosystem services.

The increasing application of PES programs stimulated researchers' efforts to conceptualize this emerging policy instrument with rigorous definition and economic theory/principle. Wunder (2005) was the first to propose a clear definition of PES in terms of five criteria, i.e. "a PES scheme is: (1) a voluntary transaction where (2) a well-defined ecosystem service (or a land-use likely to secure that service) (3) is being 'bought' by a (minimum one) service buyer (4) from a (minimum one) service provider (5) if and only if the provider secures the provision of ecosystem service (conditionality)". This definition became prevalent due to its adoption by Engel, Pagiola and Wunder (2008), the most cited paper in PES literature [7], which comprehensively reviewed and discussed major issues of PES design and implementation in view of environmental economics. In this paper, Engel, Pagiola and Wunder (2008) considered the Coase Theorem of internalizing externalities by voluntary transaction (under clear property rights and low transaction cost) as the theoretical basis of PES and classified PES programs into user-financed programs and government-financed programs, so the agri-environmental programs using voluntary contracts with farmers and direct payments for conservation in developed countries were also regarded as part of PES practice around the world, although these programs actually existed before the term PES was coined.

[7] All Bibliometric information used in this PhD study was retrieved from Web of Science and double-checked on 15 May 2014.

Interestingly, both Wunder (2005)'s definition and Engel, Pagiola and Wunder (2008)'s discussion used the term of Payments for Environmental Services instead of Payments for Ecosystem Services. In fact, the latter term did not appear in literature until 2007 (McNeely 2007; Corbera, Kosoy and Tuna 2007) but has been increasingly used and has gradually become dominant in recent years (Figure 2.1). This could be logically connected to the aforementioned increasing acceptance of the concept/term of Ecosystem Services after the Millennium Ecosystem Assessment. Given this trend of terminology choice in PES literature and the predominant use of Ecosystem Services in the wider academic and policy arena, the term Payments for Ecosystem Services has been chosen for this PhD study as shown in the thesis title.

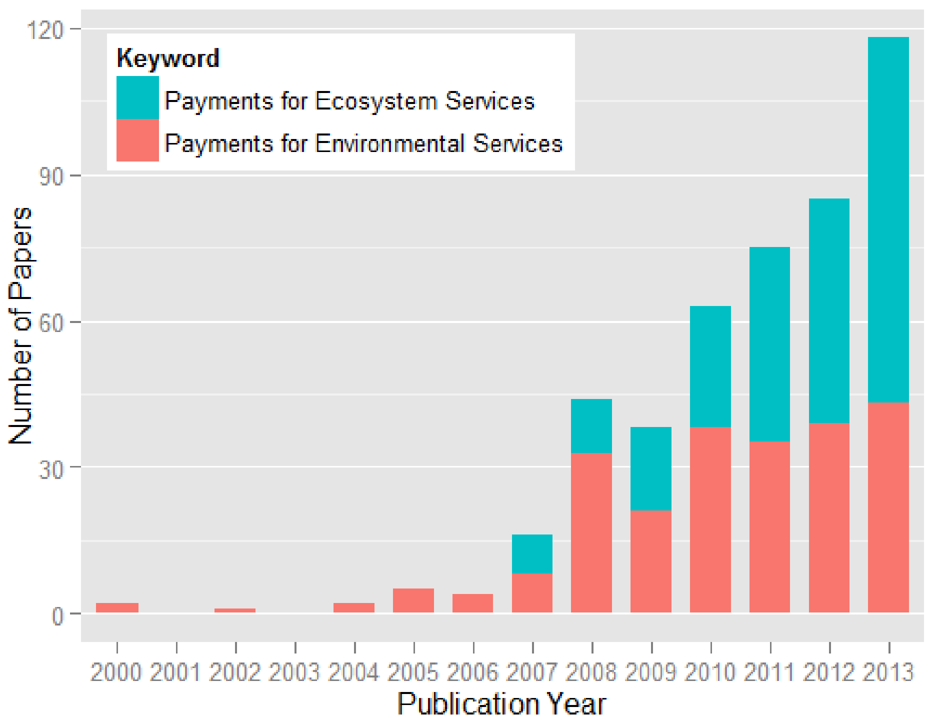

Figure 2.1 Yearly Publications of PES Studies

Data Source: Web of Science, last accessed on15 May 2014

Disregarding the choice between the two similar PES terms, the overall publications of PES studies have experienced a fast growth since 2007 (Figure 1). By the end of 2013, 437 PES studies have been published in over 100 journals such as Ecological Economics (15.3%), Ecology and Society (4.6%), Environmental Conservation (3.7%), Land Use Policy (3.7%)

and Forest Policy and Economics (3.2%).[8] Hoepner *et al.* (2012) assessed 6597 papers (in any topics) published in 14 major peer-reviewed journals in the area of environmental and ecological economics between 2000 and 2009, their results showed that 2 of the top ten most influential papers were PES studies (Engel, Pagiola and Wunder 2008; Wunder, Engel and Pagiola 2008). These bibliometric analyses demonstrate that PES has attracted interests in diverse research areas and become one of the most influential study topics in environmental and ecological economics.

Entering this new decade, a new direction of PES study and practice are the efforts and discussions to integrate PES with Reduced Emissions from Deforestation and Degradation (REDD) in tropical regions as a result of the growing international concern of climate change (Pattanayak, Wunder and Ferraro 2010; Corbera 2012; Mahanty, Suich and Tacconi 2013). Meanwhile, the term of PES is also receiving growing acceptance in developed countries where Agri-environment Policy/Programs dominate the discussion of conservation payments schemes. For example, the Department for Environment Food & Rural Affairs of the UK recently published *Payments for Ecosystem Services: A Best Practice Guide* to help with the design and implementation of PES programs, particularly for watershed protection at catchment and local scale (Smith *et al.* 2013).

2.1.4 Criticisms and Reflections on PES

The increasing popularity of PES has raised criticisms and reflections on its conceptualization, distributional effect, design and implementation. The prevalent definition of PES (Wunder 2005) was criticized for being too narrow to encompass the majority of PES programs in practice which did not meet the criteria of voluntary transaction and conditional payments due to some extent of forced participation, loose monitoring and weak sanction on non-compliance of conservation contracts (Muradian *et al.* 2010; Farley and Costanza 2010). The mainstream conceptualization of PES following Coase's theorem on externalities (Engel, Pagiola and Wunder 2008) was also criticized for over-emphasizing market transactions which are difficult to be realized for many ecosystem services due to technical and institutional constraints (Muradian *et al.* 2010; Farley and Costanza 2010; Tacconi 2012). Therefore, Muradian *et al.* (2010) provide an alternative definition of

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[8] These are the top five journals that published the most PES studies. Values in the parentheses are the percentage of published papers in the total of 437 papers.

PES, i.e. “a transfer of resources between social actors, which aims to create incentives to align individual and/or collective land use decisions with the social interest in the management of natural resources”. Tacconi (2012) reviewed debates over PES definition and revised Muradian *et al.* (2010)’s definition as “a PES scheme is a transparent system for the additional provision of environmental services through conditional payments to voluntary providers”.

The alternative definitions proposed by Muradian *et al.* (2010) and Tacconi (2012) are broader to encompass possibly all existent PES programs, but they lose the plainness of Wunder (2005)’s definition to explain the basic logic and characteristics of PES mechanism. Moreover, the violation of the criteria of voluntary and conditionality in existent PES programs is largely an implementation problem to be overcome rather than the reason for loosening the definition of PES. Instead of criticizing the narrowness of Wunder (2005)’s definition, it may be better to consider it as a theoretical reference while acknowledging the great difficulties to establish such ideal PES programs in real life.

The distributional effect of PES is another focal point of researchers’ concerns and criticisms. Vatn (2010) and Van Hecken and Bastiaensen (2010) raised similar concerns from the institutional and political views that paying upstream farmers as providers of watershed ecosystem services implicitly grants them the property rights over upstream water resources (which is highly controversial before the PES mechanism is introduced) and turns the normative paradigm of “Polluters Pay” into “Pay the Polluters”. Thus, they argued that a clearly defined baseline/reference point of ecosystem services is needed to determine whether PES is justified or not. Another concern for PES is that the introduction of economic incentives may in some cases “crowd out” intrinsic conservation motivation from local culture and social norms (Vatn 2010; Muradian *et al.* 2010; Muradian *et al.* 2013). Furthermore, Kronenberg and Hubacek (2013) suggested that without careful account of institutional issues like rent seeking, unequal bargaining power of service beneficiaries and providers and capacity building for future development, the rapid development of PES can be detrimental to regional and potentially national economies, causing an “Ecosystem Services Curse” analogous to the known “resource curse”.

Another widely concerned issue is the social-economic effect of PES in poverty alleviation. In practice, poverty alleviation is often an embedded objective of government-funded PES programs under the expectation of pursuing a win-win solution for environment and development (Wunder, Engel and Pagiola 2008; Liu *et al.* 2008; Turpie, Marais and Blignaut 2008), but evidences of achieving this dual goal are not convincing (Engel, Pagiola and Wunder 2008; Pagiola 2008; Muradian *et al.* 2010). Actually, advocators of PES are quite cautious about claiming PES as a win-win solution. Instead, they argued that PES programs must focus on the efficiency of conservation and consider poverty alleviation as a positive side-effect which should not distract the primary environmental goal (Ferraro and Kiss 2002; Pagiola, Arcenas and Platais 2005; Kinzig *et al.* 2011; Wunder, Engel and Pagiola 2008). This efficiency-prioritizing argument, which is deemed an environmental economics perspective, has incurred criticisms from the ecological economics perspective which insist on a more holistic consideration of efficiency and equity (Muradian *et al.* 2010; Farley and Costanza 2010; Tacconi 2012).

Ensuring the voluntary participation is an important safeguard to prevent negative distributional and socio-economic effect of PES. As Wunder, Engel and Pagiola (2008); (2013) suggested, the voluntary nature would require PES to be “interpersonal win-win across all participants”, i.e. farmers would not participate unless the payments at least match their (anticipated) opportunity cost, so they could be better off (or at least not worse off) under the PES program. It is also important to mitigate the unequal barging power of the beneficiaries and providers of ecosystem services in PES by improving information availability and involving providers in the PES designing process (Kronenberg and Hubacek 2013). In practice, efforts have been found to deal with controversial distributional effect of PES like turning the paradigm “Polluters Pay” into “Pay the Polluters”. For example, Wen, Siu and Hubacek (2012) reported a two-way (“carrot and stick”) payment mechanism for watershed protection in China wherein the downstream Zhejiang province pays the upstream Anhui province about US $16 million as a reward if the water quality of the Xin’an River is better than the average level of the last three years, but the same amount of payment will be delivered in the opposite way, as penalty, if the water quality deteriorates.

With regard to the practical design and implementation of PES programs, in addition to the aforementioned failure to meet the conditionality criteria due to weak monitoring and sanction (Muradian *et al.* 2010), criticisms have focused on low efficiency caused by poor targeting, i.e. adopting uniform payments and contracts which neglect the heterogeneity in the importance of different land in producing ecosystem services and in the opportunity cost of different farmers to protect ecosystems (Wunder, Engel and Pagiola 2008; Pagiola 2008; Munoz-Pina *et al.* 2008; Bennett 2008; Uthes *et al.* 2010). This is particularly the case of government-funded PES programs in developing countries, such as the PES program of Costa Rica (Pagiola 2008) and the SLCP of China (Bennett 2008). In contrast, PES programs in developed countries have applied differentiated payments and contracts for years, e.g. the Conservation Reserve Program of the U.S. uses auction to reduce the cost of enrolling farmers (Claassen, Cattaneo and Johansson 2008), and the Countryside Stewardship Scheme in the U.K. signed different contracts for each "agreement farm" according to specific environment concerns (Dobbs and Pretty 2008). The experiences of developed countries may not be simply copied to developing countries due to technical and institutional constrains, but the efforts to better understand local farmers' expectation of PES payments and contracts for better program designing are warranted.

2.2 The Chinese Version of PES: Ecological Compensation

Literature of PES in China is dominated by studies on SLCP (which will be reviewed in detail in Section 2.3). In fact, SLCP is part of China's environmental economic policy of Ecological Compensation (EC). Though most Chinese researchers treat EC and PES as synonymous terms and adopt PES to report their studies in international journals, EC is used by Chinese policy makers and mass media as a buzzword in recent years. In addition to national EC programs in forest restoration and conservation (including SLCP), the National Environmental Protection Bureau (NEPB) [9] has issued the *Guidelines on Pilot Practice of Ecological Compensation* to help with policy experiments of regional and inter-regional EC programs for, inter alia, watershed protection and natural reserves protection (NEPB 2007). The central government of China has also commenced the legislation process of a national *Ecological Compensation Ordinance* since 2010.

There is a lack of review of China's EC policy in international literature from a more holistic view instead of introducing a single program of this policy tool. This section briefly introduces the conceptual framework and major practice of EC policy in China, which serves as the indigenous policy context

[9] The NEPB was upgraded to the Ministry of Environmental Protection in 2008.

of this PhD study. A number of Chinese EC studies were also reviewed to complete this section.

2.2.1 What is Ecological Compensation?

The most influential two definitions of EC were provided in the most cited Chinese EC study (Mao, Zhong and Zhang 2002) [10] and the NEPB *Guidelines on Pilot Practice of Ecological Compensation* (NEPB 2007) respectively. Mao, Zhong and Zhang (2002) were the first to provide a formal definition of EC, i.e. a policy instrument that "charges (raises the cost of) environment and resource damaging behaviours to decrease the external diseconomy, or compensates (raises the benefit of) environment and resource protection behaviours to increase the external economy". Also in this paper, Pigou's theory of external economy and diseconomy (positive and negative externalities) and Coase's theorem of property rights transaction for tackling externalities were considered as the theoretical basis of EC.

In the NEPB guidelines (NEPB 2007), EC was described as "an environmental economic policy that adjusts relationships between stakeholders in ecological conservation via both administrative and market means and on the basis of the value of ecosystem services and the direct and opportunity cost of conservation". The guideline also stated the basic principles of EC as "Developer Protects (the environment), Destroyer Restores, Beneficiary Pays, and Polluter Pays". In other words, developers of natural resources must undertake the external cost and compensate for the damage/pollution to the environment and nature resources, and beneficiaries of ecological protection should remunerate protectors of ecosystems. Moreover, four priority conservation issues were designated by the NEPB for EC policy experiments, namely natural reserves protection, conservation of important ecological function districts (e.g. shelter forests belts against desertification), ecological restoration of mining districts and watershed protection.

The descriptions above indicate that eco-compensation is also a policy instrument to tackle the problem of externalities in conservation like PES. To some extent, the NEPB's vague description of "an environmental economic policy that adjusts relationships between stakeholders in ecological

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[10] This bibliometric information was retrieved from the China Academic Journals Full-text Database, the most comprehensive full-text database of Chinese journals, and double-checked on 18 May.

conservation……" resembles Muradian *et al.* (2010)'s broad definition of PES as "a transfer of resources……to align individual and/or collective land use decisions with the social interest in the management of natural resources". However, a distinct difference between EC and PES is that policy makers of EC have included both the Beneficiary Pays Principle (BPP) and Polluter Pays Principle (PPP) as the basic principles of this policy tool. The intention is to apply the PPP to decrease negative environmental externalities while apply the BPP to increase positive externalities. But as discussed by Van Hecken and Bastiaensen (2010) regarding controversies over PES, whether an externality is positive or negative is actually a tricky political and moral question. A similar question could also arise in the practice of EC, causing controversies over which principle should be applied in which circumstance.

2.2.2 Practice of Ecological Compensation Policy

The inclusion of both PPP and BPP in the conceptual framework of EC reflects two branches of policy practice shaping the current concept of EC, i.e. BPP-based, government-funded compensation policies/programs for ecological benefits of forest ecosystems and PPP-based policy experiments of levying fees on mineral resources exploitation for ecological restoration. Early policy practice in both branches originated in the 1980s, but substantial progress was made in the late 1990s and early 2000s.

In 1998, the National People's Congress of China approved the amendment of the National Forestry Law, wherein Article 8 (6) stipulates that "The State shall establish the Forest Ecological Benefit Compensation Fund (FEBCF) for the planting, tending, protection and management of forests". This is the first Chinese law to legitimize economic compensation for the provision of ecological benefits. Accordingly, the national FEBCF was founded during 2001-2004 which paid state-owned forestry companies, village communities or private forest managers who signed annual contracts with local forestry departments 75 yuan/hectare/year [11] for the protection and management of designated "prime public welfare forests" [12] (Han *et al.* 2006). By 2007, the

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[11] 5% of this payment is allowed to be used by local forestry departments to cover the cost of inspection and other administration affairs.

[12] The National Bureau of Forestry has classified China's forests into two major types, i.e. "commercial forests" which can be managed for timber production and "prime public welfare forests" which should be protected for providing ecological benefits. All the prime public welfare forests amount to 105 million hectare, accounting for 37.2% of the total forests of

FEBCF had allocated 13.34 billion yuan to cover 44.53 million hectares of forests (Dai *et al.* 2008). Recently in 2013, the payment level has been raised to 225 yuan/hectare/year for those community and private-owned forests (Cao 2013). Encouraged by the central government, many local governments have also established local FEBCF for the conservation of a total of 76.67 million hectares of “local public welfare forests” that are not designated as “prime public welfare forests” by the Ministry of Forestry. The payment level of Local FEBCF varies in different regions, largely depending on the financial capability of local governments (Dai *et al.* 2008).

It was also in 1998 that China underwent disastrous floods in multiple watersheds including, inter alia, the Yangtze River and Yellow River (the largest two rivers of China). Apart from the abnormal climate, it was widely believed that forest destruction and degradation in the upstream watersheds were the major reasons for the disastrous floods. To learn from this experience, the central government commenced two large-scale payments programs for forest conservation and restoration in the following years, namely the Natural Forest Conservation Program (NFCP) and the SLCP.

The NFCP launched the pilot scheme in 1998 and extended to the full scale of 17 provinces in 2000. This program pays state-owned forest companies to cease commercial logging of natural forests and afforest additional 31 million hectares of mountain areas (Cao *et al.* 2010). The payments of NFCP vary for different activities, e.g. 1050 yuan/hectare/year for logging cease and 3000-4500 yuan/hectare/year for afforestation (Liu *et al.* 2008). The total budget of NFCP amounted to 96.2 billion yuan from 2000 to 2010, and the ratio of central government funding to local governments funding was about 8:2. After the completion of the first duration in 2010, the NFCP was prolonged from 2011 to 2020 with the total budget increasing to 244 billion yuan by the central government.

The SLCP launched the pilot scheme in 1999 and extended to the full scale of 25 provinces in 2002. Farmers signed volunteer contracts to convert sloping farmland (with gradients larger than 15° in Northwest China and 25° in other regions) to forestland or grassland (Liu *et al.* 2008). The duration of SLCP contracts is 2 years for grassland, 5 years for “economic forests” (fruit trees or trees with medicinal use) and 8 years for “ecological forests” (timber trees which are supposed to provide more ecological benefits). Payments of

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China. About 59.5% of them are state-owned, 34% community-owned and 6.5% private-owned.

SLCP were both in kind (grains) and in cash at the beginning of the program, but they have been paid all in cash since 2004 at the level of 3450 yuan/hectare/year in the upper reach of the Yangtze River and 2400 yuan/hectare/year in the upper and middle reach of the Yellow River (Bennett 2008). In 2007, the central government announced the extension of SLCP with the same duration.

2.3 Studies on Sloping Land Conversion Program and Limitations

As the largest PES program in the developing countries, SLCP has attracted great interest from both Chinese and international researchers. Studies on SLCP have dominated the literature of PES related to China. Major research issues of SLCP studies are evaluation of its ecological and socio-economic effects, and assessment of its sustainability, i.e. whether farmers will convert the forestland back to farmland after the program expires. There are also two choice modelling studies found in SLCP literature. This section reviews major studies on SLCP and discusses their limitations.

2.3.1 Ecological and Socio-economic Effects of SLCP

Most research findings of the SLCP's ecological effects were positive. As Liu *et al.* (2008) reported, nearly 9 million hectares of cropland had been converted to forest or grassland under SCLP after 8 years of implementation in 25 provinces, which increased the overall forest in these provinces by 2%. Zhou *et al.* (2009) found that the decrease of sediment concentration in the middle-reach Yellow River and upper-reach Yangtze River was strongly correlated with the implementation of SCLP. Deng, Shangguan and Li (2012) reported the reduction of surface runoff by 18% and soil erosion by 45.4% in 11 watersheds (involving farmland conversion) in the period of 2003-2007 compared with 1998-2002. Increases in soil organic carbon sequestration following the SLCP were also reported in literature (Song *et al.* 2014b). Nevertheless, a few studies have raised concerns over the low diversity of trees planted under the SLCP (Liu *et al.* 2008) and the inappropriateness of large-scale afforestation in the arid and semi-arid regions of China (Cao 2011).

In contrast, investigations of SLCP's socio-economic effects generated rather mixed results. Cao *et al.* (2009) interviewed 1768 farmer households in Shaanxi Province (North China) in 2005 and found that only 19.1% of the households felt their livelihood was negatively affected by SLCP. Li *et al.*

(2011) conducted regression analysis based on 1074 household survey questionnaires collected in Shaanxi Province in 2008, results showed that participation in SLCP had significantly positive effect on household income, and there was less income inequality among participants of the program than among non-participants. More recently, Song *et al.* (2014a) interviewed 146 households in Shanxi [13] (North China), Anhui and Hubei Province (both in Central China) in 2011, their results indicated that SLCP had generated minor improvements in livelihood for the majority of participating farmers. It is also reported that participation in the SLCP had shifted farmers from crops farming to off-farm work [14] and diversified farmers' income source (Ye, Chen and Hong 2003; Liu *et al.* 2008; Uchida, Rozelle and Xu 2009).

On the other hand, some studies also found negative effects of SLCP on farmers' livelihood. A survey of 156 farmer households in Jilin Province (Northeast China) found that 58% of the farmers felt their life quality declined after participation in the SLCP (Wang and Maclaren 2012). In another survey of 137 farmer households in Sichuan Province (Southwest China) in 2004, 61% of farmers reported a decrease in household income after the SLCP, and only 20% reported an increase of income (Xu *et al.* 2007). There are also reports that SLCP had not actually shifted participants from on-farm to off-farm work (Uchida *et al.* 2007; Li *et al.* 2011).

2.3.2 Farmers' Post-program Land Use Decisions

Another important research question in SLCP studies is whether farmers will keep the forests or convert them back to farmland after the program ceases. This is usually referred to as the "sustainability" of SLCP in literature (Uchida, Xu and Rozelle 2005; Grosjean and Kontoleon 2009; Song *et al.* 2014a; Yang and Xu 2014). An similar term used in some PES studies is "permanence", which is an important criteria to evaluate the success of PES programs (Engel, Pagiola and Wunder 2008; Wunder, Engel and Pagiola 2008).

Generally, at least part of the participating farmers will not keep the forests without continuous payments. The percentage of farmers with the reconversion plan varied in different studies but was normally below 50%.

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[13] Shanxi and Shaanxi (mentioned earlier) are two different provinces in the north of China.

[14] This shift is desired by the policy designers of SLCP as off-farm work generates higher income and at the same time reduces the pressure of farming activities on rural ecosystems.

Uchida, Xu and Rozelle (2005) interviewed 144 farmer households in Ningxia Autonomous Region [15] (Northwest China) and Guizhou Province (Southwest China) in 2002, 34% and 29% of participants in the two provinces respectively would return to crop growing if the payment ceases. Cao *et al.* (2009) reported that 37.2% of farmer households in their survey planned to reconvert their forestland back to farmland, while this percentage was 16% in the study of Wang and Maclaren (2012) [16]. More substantial regional difference was found in another survey wherein 34.5% of farmers in Shanxi Province would not keep the forests when payments end, but only 2.3% of the interviewed farmers in Hubei Province had reconversion plan while all interviewed farmers in Anhui Province would keep the forest even without continous payments (Song *et al.* 2014a).

A few researchers have looked into the factors affecting farmers' post-program land use decisions. Yang and Xu (2014) applied the Ordered Probit model on data from a survey of 255 households conducted in 2005 in Shaanxi, Gansu (Northwest China) and Sichuan Province, they found that farmers would be less likely to convert enrolled land with steeper slopes and lower productivity. Moreover, larger share of crops income in farmers' total income and unduly delivered program payment in previous years would make farmers more likely to return to crops cultivation, while the flexibility of choosing trees planted in the enrolled land would reduce the possibility of reconversion. Chen *et al.* (2009b) applied the Tobit Regression model on data from a survey of 304 participating households in Wolong Nature Reserve (established for the famous giant panda) in Sichuan Province in 2006, their results indicated that the amount of enrolled forestland that households planned to convert back to farmland significantly decreased with the age of household heads and households' off-farm income but significantly increased with the number of labourers in the household and the total amount of land they have enrolled in SLCP.

2.3.3 Choice Modelling Studies on SLCP

Only two choice modelling studies have been found in SLCP literature, both of which investigated farmers' possible decisions after the current SLCP

[15] There are five ethnic autonomous regions in China (Ningxia, Xinjiang, Tibet, Inner Mongolia and Guangxi) which are equivalent to provinces in terms of the administrative level.

[16] Information of the study sites and sample sizes of these two studies can be found in last section, thus are not repeated here.

contracts expire. Using the same dataset of Chen *et al.* (2009b), Chen *et al.* (2009a) applied the Stated Choice model to reveal farmer households' willingness to re-enrol in SLCP under different policy scenarios which were composed of 3 program attributes at different levels, i.e. contract length, annual payment and hypothetical percentage re-enrolment by respondents' neighbours [17]. Results showed farmers' re-enrolment decisions would be significantly influenced by neighbours' behaviours and tended to follow the majority. The effect of contract length was not consistent. While farmers significantly preferred 6-year contract to 3-year contract, they did not show significant preference for 10-year contract over 6-year contract. As the authors explained, longer contracts bring more stable income and larger aggregate payments but at the same time limit farmers' flexibility to adapt to change in conditions such as market prices of crops.

Based on a survey of 286 farmer households in Ningxia and Guizhou Province in 2006, Grosjean and Kontoleon (2009) investigated farmers' preference for policy scenarios of new SLCP in terms of 5 program attributes, i.e. annual payment, the percentage of commercial forest (economic trees) allowed to be planted in the enrolled land, secured land tenure (no land redistribution after the current tenure expires), the rights of land renting and assurance of payment delivery. With no explanation, the contract length in all the policy scenarios was fixed to 30 years, which is much longer than the maximum duration of the current SLCP (8 years). Results indicated that all the five attributes showed significant and positive effects to farmers' willingness to enrol in a new SLCP, and farmers were willing to forgo 1.17 yuan/mu/year for every increase of 1% more commercial forest to be planted, 171.23 yuan/mu/year for no land redistribution, 26.18 yuan/mu/year for land renting rights and 114.87 yuan/mu/year for assured delivery of all payments.

2.3.4 Limitations of the Existing SLCP Studies.

Since study results of SLCP's ecological effects were overwhelmingly positive, the discussion here focuses on studies on the socio-economic impacts and sustainability of the program. Despite the valuable findings provided by existent literature, there are critical limitations to be overcome in terms of outdated survey data, overlooked study regions and methodology shortcomings.

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[17] These hypothetical neighbours' behaviours were considered an indication of "social norms" among farmer households (Chen et al 2009 a).

Firstly, most of the existing SLCP case studies were based on surveys conducted around 2005 or even earlier. Given China's rapid growth and change in the last decade, data from those case studies is becoming outdated and the corresponding findings may be no longer applicable to the current situations. New case studies conducted in more recent years are in great need to provide updated information and insights regarding SLCP.

Secondly, multiple studies have indicated that there were substantial regional disparities in SLCP's socio-economic effects and farmers' post-program land use decisions (Wang *et al.* 2007; Chen *et al.* 2009b; Grosjean and Kontoleon 2009; Song *et al.* 2014a), which means sufficient studies in different regions are important for better understanding the local implementation and impact of this program in China. However, current SLCP studies are too focused on several provinces such as Sichuan and Guizhou while the program has been implemented in 25 provinces. Only one SLCP study has been found in literature to conduct a survey with merely 44 farmer households in Hubei Province [18] (Song *et al.* 2014a). More case studies in those overlooked provinces and regions are necessary to fill in this literature gap.

Thirdly, although the impact of the program on participants' livelihood is one of the most sought research themes in SLCP literature, many of the existing studies used rather simple and general survey questions to investigate this issue, such as "How has your family's livelihood been influenced by SLCP" (Song *et al.* 2014a) or a yes/no question to the statement of "The SLCP adversely affected my income" (Cao *et al.* 2009). There is a lack of detailed information about which crops/trees farmers planted in the sloping land before and after participation in the SLCP and the income generated from the crops/trees. Such detailed information can help to better understand farmers' livelihood under the SLCP and provide quantitative evidence of the program's socio-economic impact.

Fourthly, although some SLCP studies included both participant and non-participant farmers for comparative or integrated analysis (Uchida *et al.* 2007; Grosjean and Kontoleon 2009; Li *et al.* 2011), these studies did not

[18] This survey is part of an integrated survey in three provinces with a total of 146 farmer households. The Danjiangkou Reservoir is located in Hubei Province. But the survey was conducted in a township near Wuhan, the capital city of Hubei Province, which is over 350 km away from the Danjiangkou Reservoir.

differentiate the non-participant farmers who have no qualified sloping land for the program[19] (simply referred to as unqualified farmers hereafter) from those who have qualified land but were truly unwilling to participate (referred to as unwilling farmers). The unqualified farmers will not be influenced by any improvement in the design and implementation of SLCP anyway unless there is a fundamental change in the program's criteria for land qualification. So there is hardly any relevance to include them in analysis of farmers' willingness to participate in a new (updated) SLCP[20]. Moreover, as gradient is a highly influential factor to land productivity, the income received from flat (unqualified) land can be substantially higher than that from sloping land (Yang and Xu 2014). It could be misleading to examine SLCP's impact on farmers' livelihood by comparing the unqualified farmers and participant farmers disregarding the topographic characteristics of their land (Uchida *et al.* 2007; Li *et al.* 2011). A better strategy is to exclude unqualified farmers from the survey and compare the participant farmers and those who have qualified sloping land but did not take part in the SLCP.

Fifthly, the current SLCP has been criticized for adopting uniform payment and contract length which neglects the regional heterogeneity of China (Xu *et al.* 2007; Liu *et al.* 2008), thus increasing local communities' input has been suggested in program design and implementation in order to adapt to local environmental and economic contexts (Bennett 2008). Although the possibilities of farmers' reconverting forestland back to farmland after the current SLCP contract expiries have been widely reported in literature (Uchida, Xu and Rozelle 2005; Cao *et al.* 2009; Chen *et al.* 2009b; Wang and Maclaren 2012; Song *et al.* 2014a; Yang and Xu 2014), a few studies have further investigated what adjustment in annual payment, contract length or other program attributes the local households prefer to continue with SLCP. As for the only two Stated Preference/choice studies investigating this issue, shortcomings are not negligible.

As reviewed above, Chen *et al.* (2009a)'s study provided interesting insight that social norms (neighbour behaviour of reconverting or keeping enrolled

[19] Only land with gradient larger than 25 degrees in the south of China or 15 degrees in the north is qualified for the SLCP.

[20] No studies clarified that they only included those truly "unwilling farmers" as non-participant farmers in analysis, nor have they discussed the possibility of the fundamental change in land qualification, so it is very likely that they have indeed overlooked this issue.

forestland after the current SLCP expires) could play an important role in farmers' post-program land use decisions, but they overlooked another important program attribute of SLCP, i.e. the percentage of economic trees allowed to be planted in the enrolled sloping land, which were proved be significantly influential on farmers' choices by Grosjean and Kontoleon (2009). Moreover, incorporating neighbour behaviour in the policy scenario is useful to reveal interesting insights but cannot provide practical policy suggestions since neighbour behaviour is not adjustable by policy makers of SLCP. With regard to Grosjean and Kontoleon (2009)'s study, they excluded another important program attribute, namely contract length, from policy scenarios and arbitrarily fixed it at 30 years. Such research design lost the ability to reveal farmers' preference for different contract lengths which is useful information for designing more flexible SLCP. Additionally, it is also arguable that Grosjean and Kontoleon (2009) adopted the assured delivery of program payment as one of the program attributes. Unduly and incomplete delivery of contracted payment should be considered as a problem in program implementation instead of an attribute of program design. It is not surprising that farmers would forgo some stated amount of payment to ensure the delivery of certain less payment, but asking farmers to trade-off program payment and assured delivery is less informative than revealing the trade-off between payment and contract length if the study aims at providing policy suggestions to improve the design of SLCP.

The review and discussion in this section indicate that the limitations of existing studies on SLCP call for: 1) updating case studies, especially in the overlooked province/regions; 2) better examination on the effect of the SLCP on participants' livelihood and 3) further studies of farmers households' preference for the design of SLCP.

2.4 Non-market Valuation Methods for WTP and Choice Modelling Studies

The previous three sections review the origin and development of PES, the Chinese indigenous policy instrument of Ecological Compensation which has a similar idea to PES and the existing literature of SLCP, the largest PES program in China. These sections serve as the policy context of this study. This section focuses on the literature regarding the methodological aspect of this study.

2.4.1 Major Economic Valuation Methods for Ecosystem Services

As mentioned in the Introduction chapter, this study aims to investigate public WTP for water protection. WTP is a welfare measure of the monetary value of ecosystem service, thus the methods for estimating WTP belong to the family of economic (monetary) valuation methods. The history of economic valuation for environmental goods/services can be traced back to the 1960s (Liu *et al.* 2010). Since then, a number of valuation methods have been developed. Generally, these methods can be classified into two groups, i.e. the Revealed Preferences Methods and the Stated Preferences Methods.

The Revealed Preferences Methods infer people's WTP for ecosystem services' values from their behaviours in real or surrogate markets (Pearce and Seccombe-Hett 2000). Major revealed preferences methods include the Hedonic Pricing Method and the Travel Cost Method. The Hedonic Pricing Method reveals the values of ecosystem services through the prices people pay for other goods in the market which are associated to the valued services (Farber, Costanza and Wilson 2002). For example, it is common to use this method to value local environmental resources such as aesthetic views and urban wetlands through the variations in housing prices (Mahan, Polasky and Adams 2000; Birol, Karousakis and Koundouri 2006). However, if the service is provided far away from the consumer like the case of this study, its value can hardly be captured by this method. The Travel Cost Method estimates the values of recreational sites/amenities by the cost people pay to visit them (Farber, Costanza and Wilson 2002). As indicated by its name, this method cannot be used to value the ecosystem services that do not involve any travel.

On the other hand, the Stated Preference Methods elicit people's WTP for ecosystem services through hypothetical survey questions, and they can be used to value ecosystem services that cannot be traded in either real or surrogate markets (Birol, Karousakis and Koundouri 2006). Therefore, the stated preference methods are also referred to as Non-market valuation methods. Contingent Valuation and Choice Experiments are two major non-market valuation methods and they are introduced as follows.

2.4.2 Contingent Valuation

Contingent Valuation constructs hypothetical scenarios to ask how much people are willing to pay (accept) for a certain increase/decrease in ecosystem services (Portney 1994; Carson 2000; Carson and Hanemann

2005). After nearly 50 years of development, the Contingent Valuation Method has become a widely accepted economic valuation method. In the U.S., it has become a standard tool in institutional decision-making for large-scale infrastructure projects at both the federal and state level. In Europe it has regularly been used since the 1980s. Contingent Valuation studies have also been used in developing countries such as the Philippines since the early 1990s (Bateman, Willis and Arrow 2002).

In comparison, Contingent Valuation studies in China did not appear in the literature until the early 2000s (Xu *et al.* 2003). This may be attributed to the different socio-economic context of China, where the market economy was only kick-started by the “Open and Reform” policy in 1978. Both policy makers and the public were unfamiliar with and even suspicious of the idea of using surveys to assign monetary values on public goods. However, in the past decade, China has witnessed an accelerated reform toward market economy after joining the World Trade Organization, a growing awareness of public participation in policy making and the development of ecosystem services valuation study in academia (Liu and Costanza 2010). Some researchers have started to conduct Contingent Valuation surveys to investigate individuals’ or households’ WTP for urban green spaces (Chen, Bao and Zhu 2006; Chen and Jim 2008; Chen and Jim 2011), biodiversity conservation (Chen and Jim 2010), air quality improvement (Wang and Mullahy 2006; Wang and Zhang 2009; Du and Mendelsohn 2011; Yu and Abler 2010; Hammitt and Zhou 2006), water pollution reduction in lakes (Zhen *et al.* 2011), ground water preservation (Wei *et al.* 2007), protection of natural reserves (Han *et al.* 2011), and health insurance (Barnighausen *et al.* 2007; Ying *et al.* 2007).

These studies have, to some extent, demonstrated the applicability of using Contingent Valuation for cost-benefit analysis and providing policy suggestions in the context of China. However, there are gaps in the literature. Firstly, many studies have used payment cards or open-ended questions to elicit respondents’ WTP, rather than the closed-ended referendum form of questions which are more reliable (Arrow *et al.* 1993a; Carson 2000; Hoyos and Mariel 2010). Secondly, the study areas of these studies were confined to a few cities (such as Beijing and Guangzhou) and regions despite China’s vast territory and significant income differences between different regions. Thirdly, only a few existing studies have been based on real environmental initiatives to produce results that are of high relevance to policy making. Therefore, there is a need for more careful designed case studies to examine the heterogeneity in residents' WTP in multiple study sites.

Particular focus is given to Contingent Valuation studies on water quality improvement (summarized in Table 2.1) in China.

Table 2.1 WTP Studies on Water Quality Improvement in China

Study	Time of Survey	Valued Services
Wang *et al.* (2013a)	2007	Rural households' WTP for improving water quality of two major local rivers from Grade IV [a] to Grade III, Yunnan Province, Southwest China
Wang *et al.* (2013b)	2007	Rural and urban households' WTP for improving water quality of Puzhehei Lake from Grade III to Grade II, Yunnan Province, Southwest China
Zhao *et al.* (2013)	2008	Urban households' WTP for restoring ecosystem services of a urban river in Shanghai, East China [a]
Zhang (2011)	2008	Urban households' WTP for improving water quality of Tai Lake (reaching at least Grade IV), East China
Jiang, Jin and Lin (2011)	2009	Urban households' WTP for ensuring water quality of upstream Min River at Grade III, Fujian Province, Southeast China
Shang *et al.* (2012)	2011	Urban households' WTP for improving river network [c], Shanghai, East China

[a] Surface water quality is classified into Grade I to V in China and Grade I is the highest water quality. Water used for tap water should be at Grade III or above.

Interestingly, none of these studies were conducted in North China, perhaps because water quantity is a more pressing issue in North China while water quality is a more urgent issue in South China. Therefore, this study can also increase the knowledge of residents' WTP for water protection in the north of China. The estimated WTP in these studies will be used to compare with the results of this study in Chapter 6.

2.4.3 Choice Experiments

Choice Experiment is a relatively new tool in the family of non-market valuation methods, which can be seen as an extension or variant of the traditional Contingent Valuation method. This method has its roots in

Lancaster's characteristics theory of value, the random utility theory and experimental design (Adamowicz *et al.* 1998; Louviere, Hensher and Swait 2000). In a Choice Experiment survey, respondents are asked to choose between different bundles of (environmental) goods, which are described in terms of their attributes/characteristics and the levels they take. One of these attributes is usually price. By repeating such choices and varying attribute levels, the researcher can infer the useful information of the implied ranking of these attributes, the marginal WTP for an increase or decrease in any significant attribute, and the implied WTP for a program which changes more than one attribute simultaneously.

Choice Experiments was thought to be first introduced into environmental research by Adamowicz, Louviere and Williams (1994) from marketing and transportation research areas. In the past 15 years, the CE method has been used in valuing ecosystem services or environmental protection activities including inter alia recreational hunting (Boxall et al. 1996) and climbing (Hanley, Wright and Koop 2002), ecotourism (Hearne and Salinas 2002), forest and wildlife protection (Adamowicz et al. 1998), fisheries management (Wattage, Mardle and Pascoe 2005), wetland management (Birol and Cox 2007), water supply (Scarpa, Willis and Acutt 2007), improvement of river ecology (Hanley, Wright and Alvarez-Farizo 2006) and landscape (Scarpa, Campbell and Hutchinson 2007).

Generally speaking, the existing Choice Experiments studies focused on the demand side of ecosystem services but largely overlooked the supply side of ecosystem services, i.e. what do farmers want from environmental schemes that are designed to ensure the provision of ecosystem services (Espinosa-Goded, Barreiro-Hurle and Ruto 2010). A few examples can be found in recent literature (Beharry-Borg *et al.* 2013; Ruto and Garrod 2009), but much more efforts are needed to fill this gap.

Detailed introduction and explanation of the economic models used for Contingent Valuation and Choice Experiments will be provided in Chapter 3.

2.5 A Missing Bridge between Non-market Valuation and PES Studies

As reviewed in the "history" section, non-market valuation has played an important role in researchers' efforts to tackle environmental externalities and in the conceptualization of ES which led to the development of PES. While non-market valuation attempts to place monetary value on ES which are not priced in conventional markets, PES programs endeavour to create a new market wherein those ES are bought by beneficiaries from providers. Theoretically, a PES program is feasible to improve the total social welfare only if the beneficiaries' willingness to pay (WTP) for the ES exceeds the payment that providers are willing to accept. Consequently, non-market valuation which can be used both in the demand-side for WTP (benefit) estimate and the supply-side for payment (cost) estimates can contribute to: 1) assessing the feasibility and welfare effect of PES programs with cost-benefit analysis, 2) providing guidance for determining payments amount in PES programs, and 3) targeting ES providers with low required payment (cost) and thus improving efficiency of PES programs (Whittington and Pagiola 2012; Ferraro 2011).

It is thus logical to suppose that non-market valuation is extensively applied in PES programs and studies. However, the fact is rather opposite. As Pattanayak, Wunder et al. (2010) noticed, despite the importance of estimating potential ES consumers' WTP and revealing how to induce them to pay for PES, there is almost no overlap of the non-market valuation and PES literatures. Most non-market valuation studies are not linked to real policy contexts and thus provide results with limited policy implication (Ferraro *et al.* 2012). Ferraro (2011) argued that it is a waste of effort to estimate ES values disconnected from real policies or programs since people are actually interested in understanding the benefits of environmental initiatives securing ES provision rather than the benefits of the ES itself.

In real PES program implementation, non-market valuation has rarely been used to determine payment amount either (Liu *et al.* 2010). In user-financed programs, payment amount is typically negotiated by the beneficiaries and providers, which can be reasonable as it reflects Coase's theory of solving the externalities problem by voluntary transactions. In government-financed PES programs, payment amount is usually set based on implicit or explicit estimated opportunity costs of providing ES instead of the estimated ES values (Ferraro 2011; Wunder, Engel and Pagiola 2008). Liu, Costanza et al. (2010) contested this cost-based approach as it is prone to result in underpayment and thus fail to attract potential ES providers in important conservation areas, which is the case in the UK's Environmental Environmentally Sensitive Areas program and the US's Conservation Reserve Program. They also argued that many PES programs are based on shaky scientific foundation without guidance from ES valuation study, and applying a benefit-based approach supported by non-market valuation is a future direction of PES.

Clearly, there is a missing bridge between the non-market valuation and PES studies in literature which impedes the future development of the two research areas. Although studies applying non-market valuation in the context of PES programs are emerging recently (Van Hecken, Bastiaensen and Vasquez 2012; Moreno-Sanchez *et al.* 2012), substantial efforts of more empirical studies are in great need to fill the literature gap. By applying non-market valuation on both the demand and supply sides of potential PES schemes, this study is promising to contribute to building this missing bridge.

2.6 Summary

This chapter provides a literature review for this research. The review of the origin and development of PES shows PES is a promising policy instrument to tackle the problem of market failure (externality) and it has been widely applied for watershed protection. Reflections on the controversies over PES indicates that the distributional effects (such as effect on participants' livelihood) is one of the focal issues in PES studies, and increasing the public input such as consultation with farmer households is helpful to improve the design of PES and take account of its distributional effect. The Chinese version of PES, Ecological Compensation (EC), also aims to use economic measures to tackle the externality problem in environmental protection and apply the Principle of Beneficiary Pays. In most cases, PES and EC are interchangeable.

Review of the existing SLCP studies found that: 1) updating case studies, especially in the overlooked province/regions, 2) better examination on the effect of the SLCP on participants' livelihood and 3) further studies of farmers households' preference for the design of SLCP are needed to overcome the limitations of the current SLCP studies. They have also inspired the design of this research.

The Revealed Preference Methods and Stated Preference Methods are two major classes of economic valuation methods for estimating the monetary values of ecosystem services. This research chose the Contingent Valuation and Choice Experiments methods, which belong to the Stated Preference Methods, because water protection in the water supply area can hardly be reflected by any market behaviours of the residents in the northern cities. Lastly, the missing bridge between the non-market valuation and PES studies in literature justifies the research aim and design of this study. Detailed explanation of the econometric model used in Contingent Valuation and Choice Experiments will be provided in the next chapter.

Chapter 3
Research Design and Methodology

The last chapter discusses the importance of Payment for Ecosystem Services (PES) in tackling conservation issues like watershed protection and the necessity of bridging the gap between non-market valuation and PES studies. This chapter depicts the survey design and modelling methods used in this study to apply non-market valuation to develop PES for water protection from both the demand (consumer) and supply (provider) perspectives. The contents of this chapter are arranged as follows: Section 3.1 describes the survey design and implementation of the Contingent Valuation study in the four cities along the middle route project to investigate urban residents' WTP for water protection. Section 3.2 explains the econometric models used in the Contingent Valuation study. Section 3.3 describes the procedure designed in this study to integrate the automatic model selection techniques and manual adjustment for model construction and refinement in Contingent Valuation. Section 3.4 describes the design of the Choice Experiments survey in the water supply area to reveal farmer households' preferences for the design of water protection programs. Section 3.5 explains the econometric models used in the choice experiments study. Lastly, Section 3.6 provides a summary of this chapter.

3.1 Contingent Valuation Survey in Northern Cities

3.1.1 Four Cities in the Contingent Valuation Survey

Contingent Valuation is a non-market valuation method that uses surveys to elicit respondents' WTP for specified public goods/services (Portney 1994; Carson 2000; Carson and Hanemann 2005). In this study, four cities along the middle route of the SNWTP, i.e. Beijing (the capital of China), Tianjin (one of the four municipalities of China), Shijiazhuang (the capital of Hebei Province) and Zhengzhou (the capital of Henan Province), were chosen to conduct the Contingent Valuation survey in order to investigate urban residents' WTP for water protection (Figure 3.1). As four of the most important cities in the north of China, they will be the priority of the future supply of the transferred water. Among the four cities, Beijing has been supplied with transferred water since 2008 by a northern section of the middle route project which was completed before the whole middle route project in order to secure the water supply of the Beijing Olympic Games.

Tianjin has relied on transferred water from the adjacent Hebei Province through an earlier water transfer project since the 1980s. Shijiazhuang and Zhengzhou have not been supplied by any transferred water so far.

Figure 3.1 Four Cities in the Contingent Valuation Survey

Map adapted from Wei *et al.* (2010a), P2501

Table 3.1 presents the characteristics of the four cities. In general, there are considerable differences between the four cities. The disposable income per capita is highest in Beijing (32,903 yuan/year) and lowest in Shijiazhuang (20,534 yuan/year). The current domestic water price is highest in Tianjin (4.40 yuan/m^3) and lowest in Zhengzhou (2.40 yuan/m^3). The daily water consumption per capita is highest in Beijing (173 litre) and lowest in Zhengzhou (109 litre). While the industry sector accounts for 27.8% of the GDP of Beijing, they account for about half of the GDP of the other three cities. This heterogeneity of the four cities enabled them to represent a wide spectrum of cities along the middle route of SNWTP, so the results of this study could also have implications in a wider context for other cities.

Table 3.1 Characteristics of the Four Cities

City Characteristic	Beijing	Tianjin	Shijiazhuang	Zhengzhou
Area (million hectare)	1.64	1.18	1.58	0.74
Population (million)	17.55	12.28	9.77	7.52
Disposal Income per Capita (yuan/year)	32,903	26,921	20,534	21,612
Domestic Water Price (yuan/m^3)	4.00	4.40	3.63	2.40
Daily Water Consumption per Capita (litre) [a]	173	129	124	109
Agriculture in % of GDP	1.3	2.7	12.7	3.8
Industry in % of GDP	27.8	57.1	48.4	53.2
Service in % of GDP	70.9	40.2	38.9	43.0

Data source: the online database of the National Bureau of Statistics of China for the year 2012. GDP: Gross Domestic Product

[a] Since the data of Shijiazhuang and Zhengzhou are not available, the provincial data are presented here.

3.1.2 Survey Sampling and Implementation

There is no definite rule for the sample size of Contingent Valuation studies since it is subject to resources/budget and time constraints and the specific research questions and contexts. As a rule of thumb, it was suggested to have no less than 200 individuals or households to obtain reliable estimates of WTP (Loomis and Walsh 1997; Xu *et al.* 2003; Wei *et al.* 2007). A group of local undergraduate students were recruited in each city to conduct the survey as they were familiar with the city and spoke local dialects, which made it much easier to communicate with local residents and gain their trust and cooperation. The sample size for each city in this study aimed to follow the above-mentioned rule of thumb but was also subject to the number of interviewers that were successfully recruited for the survey. Accordingly, the final plan was to survey 200 questionnaires in Beijing, 250 in Tianjin, 100 in Shijiazhuang and 200 in Zhengzhou.

This study was carefully prepared with two rounds of pilot surveys. A preliminary survey was conducted at the early stage of this study in August 2010 with 50 questionnaires in each city in order to examine the feasibility of such a WTP study in these cities and the approximate range of the increase in water price that would be accepted by the residents. Then a pilot survey was conducted in January 2011 to test the questionnaire, especially the design and phrasing of the WTP question. After careful refinement of the survey design, the final survey was conducted in January and February 2012. In the end, a total of 755 questionnaires were successfully collected from the four cities, including 200 questionnaires in Beijing, 247 in Tianjin, 98 in Shijiazhuang and 210 in Zhengzhou. The extra 10 questionnaires in Zhengzhou were collected in a recently developed urban district in this city taking the suggestion from the local interviewers.

Person-to-Person interviews were conducted by the trained interviewers with the local residents. The survey was individual-based (but no more than one person was interviewed from the same household) rather than household-based since the estimated mean WTP can be conveniently used to calculate the WTP at the household and city levels using the data of household size, the population of water users and water consumption per capita in each city. Additionally, the data of average household water consumption was not available for use in this study, and it was extremely difficult in those cities to conduct in-house survey due to the entry control in many residential areas and the problem of distrust.

Clustered random sampling was applied in this survey based on the population of different administrative districts of the four cities. The number of respondents in each district was proportionate to the population in the district. Sampling locations included, inter alia, public squares, parks and resting areas of shopping centres where the respondents were more likely to have the leisure to complete the interviews of 10-15 minutes. The specific sampling locations in each district were decided by the interviewers who are familiar with the local settings. In each sampling location, generally 6-12 respondents[21] were randomly chosen. During the final survey in 2012, the interviewers reported the progress every day so that the sampling locations were marked onto maps and necessary adjustment could be made in time. The final distributions of sampling locations in the four cities are shown in Figure 3.2-3.5. A satellite map was used for Zhengzhou in order to better display the outline of its urban area, while the normal type of map was used for the other three cities.

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[21] There were 6 designed increments in water price in this survey to elicit residents' WTP for water protection which will be explained in the next section.

Figure 3.2 Sampling Locations in Beijing (200 questionnaires)

Figure 3.3 Sampling Locations in Tianjin (249 questionnaires)

Figure 3.4 Sampling Locations in Shijiazhuang (98 questionnaires)

Figure 3.5 Sampling Locations in Zhengzhou (210 questionnaires)

3.1.3 Questionnaire Design of the Contingent Valuation Survey

Following the suggestions on the design of Contingent Valuation surveys (Mitchell and Carson 1989; Arrow *et al.* 1993b; Carson 2000; Carson and Hanemann 2005; Whittington and Pagiola 2012), the questionnaire used in this survey was composed of three sections. The first section asked questions about the respondents' environmental awareness, knowledge and opinions regarding the water transfer project, the idea of Ecological Compensation (i.e. paying for the service of water protection in the context of this survey) and other water-related issues (detailed questions can be referred to in Appendix 1). These questions provided useful information that helped to explain respondents' answers to the policy scenario/proposal of levying a higher water price in the northern cities for funding the water protection of the water transfer project.

In order to help the respondents to fully understand the Contingent Valuation scenario, background information of the water transfer project, the water quality protection of the Danjiangkou Reservoir and the funding problem of the governmental water protection plan (i.e. The Plan of Water Pollution Control and Soil Conservation in Danjiangkou Reservoir and Upstream Areas) was briefly introduced to the respondents with illustrative pictures (Appendix 1) after they completed the questions in the first section.

The second section of the questionnaire contained two questions eliciting the respondents' willingness to pay a higher water price for water protection (which will be referred to as the WTP question for simplicity). The first WTP question was carefully phrased as below.

In order to overcome the funding problem in the long-term, it has been proposed to establish an Ecological Compensation scheme between the water supply areas and the cities which will benefit from the water quality protection, such as appropriately increasing the water price in those cities to supplement the funding for water quality protection. Some people think it is a good idea while others think it is not. Obviously, too much increase in water price will have impact on residents' spending in other aspects, while too little increase offers very limited help to solve the problem. We would like to hear your opinion on this issue.

If the water price increases (   ) yuan/m^3 for funding the implementation of "The Plan of Water Pollution Control and Soil Conservation in Danjiangkou

Reservoir and Upstream Areas" to ensure the reservoir's water quality maintaining at Class II, are you willing to pay?

Reminder[22]*: (1) the current water price in Beijing is 4 yuan/m^3; (2) according to the data from the National Statistics Bureau, a resident in Beijing generally consumes approximately 70m^3 of domestic water per year.*

A. Yes B. No C. I am not sure D. I don't know

Particular measures following the suggestion in the literature (Carson 2000; Carson and Hanemann 2005; Whittington and Pagiola 2012) were taken in phrasing the WTP question in order to reduce the survey bias. The statement "*Some people think it is a good idea while others think it is not.*" was to reduce the moral stress that the respondents might feel to show their reluctance to contribute to the water protection. The statement "*too much increase in water price will have impact on residents' spending in other aspects while too little increase offers very limited help to solve the problem*" was to remind the respondents of the income constraints in case they inflate their WTP beyond their real capacities and, on the other hand, maintain neutrality by reminding the respondents about the possible consequence of understating their real WTP.

The reminder in the WTP questions provided the respondents with the information of the current water price and the approximate average amount of water that an individual consumed each year so that the respondents could have a better idea about the implication of the proposed increase in water price. Moreover, the options *C* and *D* ("Not sure" and I don't know), were used to distinguish respondents who were unable to make the decision at that moment from those who truly rejected the offered increase in water price. Responses to these two options were excluded from econometric analysis to ensure the reliability of WTP estimate [23].

The specific increment of water price that was presented in the parenthesis in the WTP question was chosen by the interviewers from the following six values: 0.10, 0.20, 0.50, 0.80, 1.00 and 1.50 yuan/m^3. These values were determined based on the guidance in the literature, the result of the pilot survey and the recent increases in water price in the four cities.

[22] Contents of the reminder varied in the questionnaires for different cities.

[23] As a result, although four options were provided in the WTP question, it could still be seen as a dichotomous (yes/no) question.

Firstly, it was suggested in the literature that four to six design values which cover the quartiles of the expected WTP distribution were usually preferred to produce efficient and robust WTP estimates (Alberini 1995; Carson and Hanemann 2005). Secondly, a similar Contingent Valuation study in Southeast China found that urban residents were willing to pay an increase of 0.21- 0.51 yuan/m^3 in water price for reducing river pollution (Jiang, Jin and Lin 2011). Thirdly, the pilot survey showed that the mean WTP of residents in the four cities might range from 0.2 to 1.0 yuan/m^3. Lastly, the recent rises in the water price of the four cities were 0.3 yuan/m^3 in Beijing (in 2009) and 0.5 yuan/m^3 in both Tianjin (in 2010) and Shijiazhuang (in 2008) due to the rising cost of tap water and waste water treatment, while the water price of Zhengzhou has not changed since 2007. All this information provided the guidance and benchmark for determining the six increments of water price to elicit respondents' WTP in this study.

In the survey, each respondent was randomly offered with one of the six increments and each increment was randomly assigned to approximate equal number of respondents. The probabilities of respondents' yes/no answers to different increments were later used to estimate their mean WTP for water resource protection by multiple econometric models that will be explained in the next section.

The second WTP question was asked to the respondents depending on their answers to the first WTP question. If they answered yes, the second WTP question would offer them the immediately larger increment in the six values, otherwise the immediately smaller increment would be offered in the second WTP question. For the lower and upper bounds of the six increments, if the respondents refused the increase of 0.10 yuan/m^3 in the first place, 0.05 yuan/m^3 would be offered in the second WTP question. And if the respondents accepted 1.5 yuan/m^3 in the first WTP question, 2.00 yuan/m^3 would be offered in the following question.

The final section of the questionnaire collected respondents' demographic information such as age, income and education level. The demographic information, together with respondents' environmental awareness, knowledge and opinions collected in the first section of the questionnaire, were treated as explanatory variables for modelling respondents' answers to the WTP questions. Details of these explanatory variables will be introduced in Section 3.3.

3.2 Econometric Models for Contingent Valuation

Econometric models used for Contingent Valuation surveys with dichotomous choices (yes/no) can be classified into parametric models and non-parametric models (Bateman, Willis and Arrow 2001; Haab and McConnell 2002; Carson and Hanemann 2005; Akram and Olmstead 2011). When parametric models are applied, the probability of *yes* answer is assumed to follow certain statistic distribution (e.g. logistic or normal distribution), and parameters (coefficients) of explanatory variables are estimated in order to calculate respondents' mean WTP. When non-parametric models are applied, no probability distribution assumption is needed and the mean WTP is calculated only with the information of the offered prices and respondents' yes/no answers. The parametric models not only calculate the respondents' mean WTP but also explore the explanatory variables' influence on the WTP. But non-parametric models also exhibit the merit of simplicity (Haab and McConnell 2002). Since both of the two types of models have their merits, they are both applied in this study to estimate respondents' mean WTP for water protection.

3.2.1 Non-parametric Model for Contingent Valuation

The non-parametric model used in this study followed the elaboration by Haab and McConnel (2002). Consider a random sample of T respondents in a dichotomous choice Contingent Valuation survey, each respondent is offered one of the M different prices indexed as $t_j \mid j = 1, 2, \ldots, M$. Denote WTP_i as the ith respondent's WTP, a *yes* answer to the offered price t_j means $WTP_i \geq t_j$, while a *no* answer means $WTP_i < t_j$. The respondent's WTP cannot be directly observed in the dichotomous choice survey (since only yes/no answers are obtained), but can be treated as a random variable with an unknown cumulative distribution function $F_{WTP}(\bullet)$, namely the probability that WTP is less than a certain value. Then the probability that respondent j has the WTP less than price t_j (answering *no* to t_j) is

$$\Pr\left(WTP_i < t_j\right) = F_{WTP}(t_j) \qquad (3.1)$$

Accordingly, the probability of *yes* answer is $1 - F_{WTP}(t_j)$. The M different prices divide the full sample T into M subsamples $\{T = T_1, T_2, \ldots T_m\}$. The *yes* and *no* answers can be indexed as $\{Y = Y_j \mid j = 1, 2, \ldots, M\}$ and $\{N = N_j \mid j = 1, 2, \ldots, M\}$, where Y_j is the number of *yes* answers to the price t_j and N_j is the number of *no* answers. As Haab and Mcconnell (2002) explained, if the sample is randomly chosen and the prices are randomly assigned, the probability of observing the number of Y_j *yes* answers from the subsample T_j

can be interpreted as the probability of observing Y_j success outcomes in the number of T_j Bernoulli trials[24] with the success probability of $1 - F_{WTP}(t_j)$.

$$\Pr\left(Y_j \mid F_{WTP}(t_j), T_j\right) = \binom{T_j}{Y_j} F_{WTP}(t_j)^{N_j}(1 - F_{WTP}(t_j))^{Y_j} \qquad (3.2)$$

where $\binom{T_j}{Y_j} = \frac{T_j!}{Y_j!(T_j - Y_j)!}$ is the number of combinations (possible cases) that Y_j *yes* answers can occur in the random sub-sample of T_j respondents. Denote $F_{WTP}(t_j)$ as F_j for simplicity. It is this unknown distribution F_j that needs to be estimated to calculate respondents' mean WTP. For doing this, F_j is considered as an unknown parameter of the likelihood (probability) function of observing Y_j *yes* answers from the subsample T_j. And the aim is to find the value of F_j that maximizes the following likelihood function.

$$L(F_j \mid Y_j, N_j, T_j) = \binom{T_j}{Y_j} F_j^{N_j}(1 - F_j)^{Y_j} \qquad (3.3)$$

The combination term has no unknown parameter to be estimated, and the likelihood function can be transformed into the log-likelihood function for simplicity.

$$\ln \mathrm{L} = N_j \ln F_j + Y_j \ln(1 - F_j) \qquad (3.4)$$

The value of F_j that maximizes this log-likelihood function is the value that makes the derivative of Equation 3.4 equal to zero.

$$\frac{\partial \ln L}{\partial F_j} = \frac{N_j}{F_j} - \frac{Y_j}{(1 - F_j)} = 0 \qquad (3.5)$$

Equation 3.5 yields the maximum likelihood estimate of F_j.

$$F_j = N_j / T_j \qquad (3.6)$$

That is to say, the maximum likelihood estimate of the probability that a randomly chosen respondent has the WTP less than the given price just equals to the proportion of *no* answer in that subsample.

In principal, the proportion of *no* answers should monotonically increase with the increase in prices, namely respondents are more likely to say *no* to higher prices ($F_j \leq F_{j+1}$). However, this monotonicity may not hold in practice due to imperfect prices design and survey implementation, resulting in the situation of $F_j > F_{j+1}$. In this case, the violation of monotonicity needs to be "smoothed" to ensure the validity of the cumulative distribution function of

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[24] Bernoulli trials refer to random experiments with only two possible outcomes (success/failure) such as the experiment of coin flips (and see how many coins landed with the side of head).

the WTP. A conservative smoothing method is to combine the *j*th and (*j+1*)th subsamples into a pooled subsample T_j^* and discard the (*j*+1)th price as shown below (Turnbull 1976; Haab and Hicks 1997; Haab and McConnell 2002; Akram and Olmstead 2011).

$$F_j^* = \frac{N_j + N_{j+1}}{T_j + T_{j+1}} = N_j^*/T_j^* \quad (3.7)$$

This pooling procedure is repeated until the monotonicity of $F_j^*$is ensured. Then the monotonic F_j^* can be used to calculate the mean (expected value) of WTP according to the mathematic definition of expected values.

$$E(WTP) = \int_0^U W \, dF_{WTP}(\cdot) \quad (3.8)$$

where *U* is the upper bound of the range of WTP. The whole range of WTP is portioned into *M*+1* sub-ranges $\{0\sim t_1, t_1\sim t_2, \ldots, t_{M^*}\sim U\}$ by the *M** offered prices (the superscription * means the monotonicity of the proportion of *no* responses has been ensured). Then Equation 3.8 can be rewritten as

$$E(WTP) = \sum_{j=0}^{M^*} \left[\int_{t_j^*}^{t_{j+1}^*} W \, dF_{WTP}(\cdot)\right]. \quad (3.9)$$

This is the sum of the integral of WTP with respect to the probability that the WTP falls within each sub-range ($t_j^* \sim t_{j+1}^*$). By assuming that the WTP falls at the lower bound (t_j^*) in each sub-range, a conservative estimate of the mean WTP is

$$E_{LB}(WTP) = \sum_{j=0}^{M^*} t_j (F_{j+1}^* - F_j^*) \quad (3.10)$$

where t_0 = 0, t_1 ... t_{M^*} are the *M** offered prices after the smoothing procedure. In order to calculate Equation 3.10, it is reasonable to set $F_0^* = 0$ and $F_{M^*+1}^* = 1$, which means no respondent answers *no* to the price 0 and everyone answers *no* to the upper bound of WTP ($t_{M^*+1} = U$). This upper bound of WTP does not need to be specified because for the last sub-range of WTP $t_{M^*}\sim U$, the lower bound value t_{M^*}(namely the highest offered price) is used for the conservative estimate.

Moreover, as Haab and McConnell (2002) explained, the variance of this lower bound estimate of the mean WTP is

$$V\left(E_{LB}(WTP)\right) = \sum_{j=1}^{M^*} \frac{F_j^*\left(1 - F_j^*\right)}{T_j^*} (t_j^* - t_{j-1}^*)^2 \quad (3.11)$$

The 95% confidence interval of the lower bound mean WTP can be readily calculated using the mean and variance calculated by Equation 3.10 and 3.11.

3.2.2 Parametric Models for Contingent Valuation

Unlike the non-parametric models which only use the proportions of *yes/no* answers to different offered prices to calculate the WTP, parametric models incorporate other explanatory variables such as respondents' characteristics to model the probability of their *yes* answers to the WTP question and calculate the mean WTP with the estimated parameters (coefficients). Generally, there are two fundamental approaches of constructing parametric models for Contingent Valuation studies, namely the Random Utility Model elaborated by Hanemann (1984), and the Random WTP Model proposed by Cameron (1988). Both of the two approaches are introduced as follows, and explanation is given on why the latter was preferred and adopted in this study.

3.2.2.1 Random Utility Model

The Random Utility Model interprets respondents' answers to the WTP question as the result of their comparison of the underlying utility of two circumstances, i.e. the status quo and the valuation scenario of paying the offered price for the specified ecosystem service. The utility that respondent *j* derives from a specified circumstance U_{ij} is assumed to consist of a deterministic, observable component V_{ij} and a random, unobservable error component ε_{ij}.

$$U_{ij} = V_{ij} + \varepsilon_{ij} \tag{3.12}$$

where i = 1 if the respondent answers *yes* to the offered price t_j, and i = 0 if he/she answers *no*. It is reasonable to suppose that the respondent would answer *yes* only if $U_{1j} > U_{0j}$. So the probability of *yes* answer is

$$\Pr(\text{yes}_j) = \Pr[V_{1j} + \varepsilon_{1j} > V_{0j} + \varepsilon_{0j}] \tag{3.13}$$

which can be rewritten as

$$\Pr(\text{yes}_j) = \Pr[\varepsilon_{1j} - \varepsilon_{0j} > -(V_{1j} - V_{0j})] \tag{3.14}$$

Define the difference between the two random components as $\varepsilon_j = \varepsilon_{1j} - \varepsilon_{0j}$, and denote the change in utility as $\Delta V = V_{1j} - V_{0j}$. Equation 3.14 becomes

$$\Pr(\text{yes}_j) = \Pr(\varepsilon_j > -\Delta V) = 1 - \Pr(\varepsilon_j < -\Delta V)$$

(3.15)

It can be noted that $\Pr(\varepsilon_j < -\Delta V)$ is the cumulative distribution function of ε_j with regard to $-\Delta V$. In order to construct a Random Utility Model, assumptions are needed to 1) specify the function of the deterministic utility component V_{ij} so that the utility change ΔV can be specified, and 2) to specify the statistic distribution of the random component ε_j.

The most commonly used function for the deterministic utility component is the linear utility function (Hanemann 1984; Loomis *et al.* 2000; Haab and McConnell 2002; Moreno-Sanchez *et al.* 2012).

$$V_{ij} = \alpha_i c_j + \beta_i y_j \tag{3.16}$$

where c_j is a vector of *m* explanatory variables with respect to respondent *j*, a_j is the vector of *m* coefficients (i.e. $\alpha_i c_j = \sum_{k=1}^{m} \alpha_{ik} c_{jk}$), y_j is the respondent's income and β_i is the coefficient of income. If the respondent answers *no* to the WTP question, $V_{0j} = \alpha_0 c_j + \beta_0 y_j$; if the answers is *yes*, it means the respondent is willing to forgo a portion of income (the offered price t_j) in exchange for the ecosystem service specified in the valuation scenario, i.e. $V_{1j} = \alpha_1 c_j + \beta_1 (y_j - t_j)$. So the utility change is presented as

$$\Delta V = V_{1j} - V_{0j} = (\alpha_1 - \alpha_0) c_j + \beta_1 (y_j - t_j) - \beta_0 y_j \tag{3.17}$$

It is reasonable to assume that $\beta_1 = \beta_0$ (denoted as β for simplicity), i.e. the marginal utility effect of income is constant in the status quo (no answer) and valuation scenario (yes answer) unless the offered price could cause substantial change to the respondent's income. Define $\alpha = \alpha_1 - \alpha_0$, Equation 3.17 becomes

$$\Delta V = \alpha c_j - \beta t_j \tag{3.18}$$

Now Equation 3.15 becomes

$$\Pr(\text{yes}_j) = 1 - \Pr[\varepsilon_j < -(\alpha c_j - \beta t_j)] \tag{3.19}$$

In order to estimate α and β, the statistic distribution of ε_j needs to be specified. It is usual to assume that ε_j is independently and identically distributed (IID) with the mean of *0*. Accordingly, there are two widely used statistic distributions, i.e. the *normal* and *logistic* distributions, both of which are symmetric and exhibit the nature that $F(x) = 1 - F(-x)$. So Equation 3.19 can be simplified as

$$\Pr(\text{yes}_j) = \Pr(\varepsilon_j < \alpha c_j - \beta t_j) \tag{3.20}$$

If ε_j follows a normal distribution with mean 0 and variance σ^2, this distribution of ε_j can be transformed into a *standard normal* distribution of ε_j / σ with mean 0 and variance 1. Then Equation 3.20 becomes

$$\Pr(\text{yes}_j) = \Pr\left(\frac{\varepsilon_j}{\sigma} < \frac{\alpha c_j - \beta t_j}{\sigma}\right) = \Phi\left(\frac{\alpha c_j - \beta t_j}{\sigma}\right) \tag{3.21}$$

where $\Phi(\,)$is the cumulative distribution function of standard normal distribution. This is the standard *probit* model in statistics/econometrics. For a sample of *T* respondents, define $I_j = 1$ if respondent *j* answered *yes* and $I_j = 0$ if the answer is *no*, the log-likelihood function for the responses of the whole sample is

$$\ln L\,(yes) = \sum_{j=1}^{T} I_j \ln\left[\Phi\left(\frac{\alpha c_j - \beta t_j}{\sigma}\right)\right] + (1 - I_j)\ln\left[1 - \Phi\left(\frac{\alpha c_j - \beta t_j}{\sigma}\right)\right]$$

(3.22)

The model parameters, α/σ and $-\beta/\sigma$, can be readily estimated by standard probit regression procedure of statistics/econometrics software packages which utilise the Maximum Likelihood Estimation algorithm to find the parameters that maximize the log-likelihood of Equation 3.22.

On the other hand, if ε_j follows a logistic distribution with mean 0 and variance $\pi^2\sigma_L^2/3$, this distribution of ε_j can be converted to a ***standard logistic*** distribution of ε_j/σ_L with mean 0 and variance $\pi^2/3$. Then Equation 3.20 becomes

$$\mathrm{P\,r}(\mathrm{yes_j}) = \Pr\left(\frac{\varepsilon_j}{\sigma_L} < \frac{\alpha c_j - \beta t_j}{\sigma_L}\right) = \left[1 + \exp\left(-\frac{\alpha c_j - \beta t_j}{\sigma_L}\right)\right]^{-1} \qquad (3.23)$$

This is the standard *logit* model, and the log-likelihood function of the logit model is

$$\ln L\,(yes) = \sum_{\mathrm{j=1}}^{\mathrm{T}} I_j \ln\left\{\left[1 + \exp\left(-\frac{\alpha c_j - \beta t_j}{\sigma_L}\right)\right]^{-1}\right\} +$$

$$\left(1 - I_j\right)\ln\left\{1 - \left[1 + \exp\left(-\frac{\alpha c_j - \beta t_j}{\sigma_L}\right)\right]^{-1}\right\} \qquad (3.24)$$

Likewise, the parameters, α/σ_L and $-\beta/\sigma_L$, can be estimated by standard logit regression procedure of statistic software packages to maximize the log-likelihood in Equation 3.24.

So far, a Random Utility Model (probit or logit) based on the linear utility function in Equation 16 has been established to use respondents' characteristics c_j and the offered price t_j to explain the probability of *yes* answer in a Contingent Valuation survey. The next step is to calculate respondents' mean WTP for the ecosystem service under valuation.

As a welfare measure of the monetary value of the ecosystem service, WTP is the amount of money/income that the respondent is willing to forgo in exchange for the environment service. In other words, WTP is the amount of money that makes $U_0 = U_1$, i.e. the loss of utility caused by forgoing that amount of money is equivalent to the utility that the respondent can derive from the environment service. For the Random Utility Model defined by Equations 3.12 and 3.16, $U_0 = U_1$ means

$$\alpha_0 c_j + \beta_0 y_j + \varepsilon_{0j} = \alpha_1 c_j + \beta_1(y_j - WTP_j) + \varepsilon_{1j} \qquad (3.25)$$

As mentioned above, define $\alpha = \alpha_1 - \alpha_0$, $\beta = \beta_1 = \beta_2$ and $\varepsilon_j = \varepsilon_{1j} - \varepsilon_{0j}$, Equation 3.25 yields

$$WTP_j = \frac{\alpha}{\beta} c_j + \frac{1}{\beta} \varepsilon_j \qquad (3.26)$$

In probit and logit models where ε_j is assumed to follow the normal and logistic distribution respectively, the mean of ε_j is *0*. So the expected value (mean) of respondent *j*'s WTP is simply

$$E(WTP_j) = \frac{\alpha}{\beta} c_j \qquad (3.27)$$

The ratio *α/β* can be easily calculated using the estimated parameters of the probit or logit model, thus the mean WTP of respondents in the whole sample is

$$E(WTP) = \frac{\alpha/\sigma}{\beta/\sigma} \overline{c_j} \text{ (probit model) } or \ \frac{\alpha/\sigma_L}{\beta/\sigma_L} \overline{c_j} \text{ (logit model)} \qquad (3.28)$$

where $\overline{c_j}$ is the sample mean of the explanatory variables.

Equations 3.21, 3.23 and 3.28 construct the widely used linear random utility model (probit or logit) for the estimation of respondents' mean WTP which adopts a linear function (Equation 3.16) to specify the deterministic utility component (V_{ij}) in a random utility model (Equation 3.12) and assumes a normal or logistic distribution of the random component (ε_j).

One drawback of the linear random utility model is that the variable of income, which may significantly influence respondents' answers in Contingent Valuation surveys, is not included in the probability functions (Equations 3.21 and 3.23). This is because the income term is incorporated in the function of V_{ij} in a linear form (Equation 3.16), and the marginal utility of income is assumed to be constant between the status quo and the valuation scenario (i.e. $\beta_0 = \beta_1$ in Equation 3.17). Thus when the utility difference ΔV between the two circumstances is specified, the income variable y_j is removed and only the change in the income, i.e. the offered price t_j is included in the probability functions. For relaxing the assumption of constant marginal utility of income and retaining the income variable in the probability functions, non-linear forms of income term, such as the log-linear form, can be used in specifying V_{ij}

$$V_{ij} = \beta \ln(y_j) + \alpha_i c_j \qquad (3.29)$$

where the marginal utility of income is $\frac{\partial V_{ij}}{\partial y_j} = \frac{\beta}{y_j}$, and the corresponding probability function is

$$\Pr(\text{yes}_j) = \Pr\left[\varepsilon_j < \alpha c_j + \beta \ln\left(\frac{y_j - t_j}{y_j}\right)\right] \qquad (3.30)$$

An even more complicated form of the income term is the Box-Cox Transformation

$V_{ij} = \beta \ln \frac{y_j^{\lambda}-1}{\lambda} + \alpha_i c_j$

(3.31)

where the marginal utility of income is $\frac{\partial V_{ij}}{\partial y_j} = \beta y_j^{\lambda-1}$, λ is the transformation parameter which can be flexibly chosen by researchers, and the corresponding probability function is

$$\Pr(\text{yes}_j) = \Pr\left[\varepsilon_j < \alpha c_j + \beta \frac{(y_j - t_j)^{\lambda} - y_j^{\lambda}}{\lambda}\right] \qquad (3.32)$$

Probit and logit models can be constructed depending on the normal or logistic distribution assumption about ε_j in Equation 3.20 and 3.32 (Bateman, Willis and Arrow 2001; Haab and McConnell 2002; Carson and Hanemann 2005).

In practice, the models with complicated, non-linear income terms are rarely used in empirical Contingent Valuation studies because of the consequent complication in WTP calculation. In fact, as the offered prices in Contingent Valuation surveys usually account for a very small portion of respondents' income, it is not necessary to suppose the marginal utility of income to vary with this small change (Haab and McConnell 2002). Moreover, since the offered price t_j in Equation 3.30 and 3.32 is no longer a separate independent variable but a component in the complicated income term, the effect of the offered price on the probability of *yes* answer, which is important to researchers and policy makers, can no longer be clearly revealed by the model estimation. Additionally, income information is usually prone to a great deal of measure error and often collected in the categorical form (income groups/ranges) rather than exact values in real surveys, which further weakens the rationale of using the models with complicated non-linear income terms.

However, the problem of removing the income variable from the probability function remains if the linear random utility model is preferred to the non-linear models. A more critical but rarely mentioned problem regarding the linear random utility model is that if the assumption of constant marginal utility of the income variable is plausible because the offered price would merely cause a small change to respondents' income, why the same assumption is not made for other explanatory variables such as respondents' age and education level given these variables are unchanged at all between the status quo and the evaluation scenario? If such assumption is made (i.e. α_0=α_1 in Equation 3.17), all the explanatory variables should be excluded from the probability functions just like the income variable when the utility difference is specified, then the offered price (the change in income) would be the only explanatory variable in the probability functions. This was indeed the case in Hanemann's original paper where the variables of respondents' characteristics were "suppressed" and represented by a constant term in his random utility model (Hanemann 1984). However, Contingent Valuation studies following Hanemann (1984)'s approach, such as Loomis *et al.* (2000)'s highly cited paper, just added other explanatory variables in their models without addressing why the assumption of constant marginal utility is made only for the income variable. Nevertheless, this does not mean that Hanemann (1984)'s original univariate model is satisfactory because it cannot reveal the effects of respondents' characteristics on their answers to the WTP question, and more problematically from the statistical aspect, the univariate model is likely to exhibit poor goodness of fit in practice.

The discussion above indicates that the random utility model exhibit a contradiction between the necessity for retaining income and other explanatory variables in the probability function and the illogicality of assuming inconstant marginal utility of these variables in order to retain them in the probability function. The Random Willingness to Pay Model, an alternative approach of constructing parametric models for Contingent Valuation studies, can avoid this contradiction and thus was adopted by this study.

3.2.2.2 Random Willingness to Pay Model

Researchers in favour of the random WTP model argued that it was an unnecessary "roundabout route" to introduce the utility interpretation for estimating the WTP as the random utility model did, and the respondent's *yes/no* answer could be simply interpreted as whether the WTP was larger than the offered price (Cameron 1988; Haab and McConnell 2002). Accordingly, the probability of *yes* answer can be defined as

$$\mathrm{Pr}(\mathrm{yes_j}) = \mathrm{Pr}\,(WTP_j > t_j) \qquad (3.33)$$

The random WTP model assumes that respondent *j*'s WTP is a linear function of his/her characteristics (explanatory variables) and a random error term.

$$WTP_j = \gamma C_j + \eta_j \qquad (3.34)$$

where C_j is the vector of characteristic, γ is the vector of parameters (coefficients) to be estimated (i.e. $\gamma C_j = \sum_{k=1}^{m} \gamma_k C_{jk}$), and $\eta_j$is the random error term which is assumed to be independently and identically distributed and symmetric with mean *0*. The remaining steps of constructing random WTP model are similar to aforementioned steps of constructing random utility model. Substituting Equation 3.34 into Equation 3.33, the probability function becomes

$$\Pr(\text{yes}_\text{j}) = \Pr(\gamma C_j + \eta_j > t_j) = \Pr\left[\eta_j > -(\gamma C_j - t_j)\right]$$

(3.35)

Since $\eta_j$is assumed to be symmetric, Equation 3.35 can be rewritten as

$$Pr(yes_j) = Pr(\eta_j < \gamma C_j - t_j)$$

If $\eta_j$is assumed to follow a normal distribution with mean 0 and variance σ^2, this general normal distribution of η_j can be converted to the standard normal distribution of η_j/σ with mean 0 and variance 1, then the probit model is

$$\Pr(\text{yes}_\text{j}) = \Pr\left(\frac{\eta_j}{\sigma} < \frac{\gamma C_j - t_j}{\sigma}\right) = \Phi\left(\frac{\gamma C_j - t_j}{\sigma}\right) \qquad (3.36)$$

Likewise, If $\eta_j$is assumed to follow a logistic distribution with mean 0 and variance $\pi^2\sigma_L^2/3$, this general logistic distribution of η_j can be converted the standard logistic distribution of ε_j/σ_L with mean 0 and variance $\pi^2/3$, then the logit model is

$$\Pr(\text{yes}_\text{j}) = \Pr\left(\frac{\eta_j}{\sigma_L} < \frac{\gamma C_j - t_j}{\sigma_L}\right) = [1 + \exp\left(-\frac{\gamma C_j - t_j}{\sigma_L}\right)]^{-1} \qquad (3.37)$$

Parameters (coefficients) of the probit and logit models in Equations 3.36 and 3.37, $(\frac{\gamma}{\sigma}, -\frac{1}{\sigma})$ and $(\frac{\gamma}{\sigma_L}, -\frac{1}{\sigma_L})$, can be estimated by standard probit and logit regression procedures.

Since WTP_j is directly defined in Equation 3.34, and the random term η_j has mean 0 in both normal and logistic distribution, so the expected value (mean) of respondent *j*'s WTP is simply

$$E(WTP_j) = \gamma C_j \qquad (3.38)$$

The vector of the unstandardized coefficients γ is simple the vector of the estimated coefficients of explanatory variables divided by the coefficient of the offered price in Equations 3.36 and 3.37.

$$E(WTP) = \frac{\gamma/\sigma}{1/\sigma}\overline{C_j} \text{ (probit model) or } \frac{\gamma/\sigma_L}{1/\sigma_L}\overline{C_j} \text{(logit model)} \qquad (3.39)$$

where $\overline{C_j}$ is the vector of the sample mean of explanatory variables.

It can be noticed that the expression of the mean WTP derived from the random WTP model (Equation 3.39) is similar to the expression of the linear random utility model (Equation 3.28). However, since the WTP function is directly defined in the random WTP model, there is no problem of removing income or other explanatory variables from the probability function as occurred in the random utility model.

3.2.2.3 The Choice between the Probit and the Logit Model

As explained in preceding sections, parametric models for Contingent Valuation can be classified into the probit and logit (regression) models depending on what distribution (normal or logistic) the random term in the estimation function is assumed to follow. In fact, as the difference between the two distributions is slight, the probit and logit models usually yield similar results (Haab and McConnell 2002). The literature of Contingent Valuation studies usually applied one of the two models and the choice of model is basically the authors' personal preferences without explicit explanation. This study adopted the logit model because it provides a more straightforward and intuitive interpretation of the estimated coefficients.

For the convenience of explanation, the probability function of the probit model (Equation 3.36) can be simplified as $\Pr(yes) = \Phi(KX)$, where *X* represents the explanatory variables and *K* represents the coefficients. As introduced before, $\Phi(\,)$ is the cumulative distribution function of the standard normal distribution. That is to say, the estimated coefficients *K* of the probit model represent the change in the z-value[25] caused by each unit change in the explanatory variables *X*. This z-value interpretation of the coefficients is not so straightforward and intuitive to indicate what the coefficients means in terms of the probability of respondents' yes answer to the WTP question.

Comparatively, the probability function of the logit model (Equation 3.37) which can be simplified as $\Pr(yes) = [1+\exp(-KX)]^{-1}$ has a useful and widely applied transformed expression

$$\ln\left[\frac{\Pr(yes)}{1-\Pr(yes)}\right] = KX \qquad (3.39)$$

where $\frac{\Pr(yes)}{1-\Pr(yes)}$ is the *odds* of respondents' *yes* answer. The left side of Equation 3.39, namely the logarithm of odds (log-odds), is called *logit*. So the coefficients *K* in the logit model represent the change in the logit caused

[25] Z-value is the number of standard deviations that a value deviates from the mean of a normal distribution.

by every unit change in the explanatory variables *X*. A more straightforward interpretation can be derived in terms of ***odds ratio***. For the convenience of explanation, suppose a simple univariate logit model $\ln(odds) = kx$, the logit of *yes* answer when the explanatory variable *x* is at the reference level is $\ln(odds_0) = kx_0$. When *x* increases by one, the logit becomes $\ln(odds_1) = k(x+1)$. The ratio of the two odds is

$$\text{odds ratio} = \frac{\text{odds}_1}{\text{odds}_0} = e^{k(x+1)}/e^{kx} = e^k \tag{3.40}$$

That is to say, the coefficient *k* in the logit model means that for each unit change in the explanatory variable *x*, the odds of respondents' *yes* answer becomes e^k times of the odds at the reference level. This odds-ratio interpretation of the logit model is more straightforward and intuitive than the z-value interpretation in the probit model.

3.2.2.4 Simulated Confidence Interval of Parametric Models

The 95% confidence interval of the estimate of mean WTP indicates the uncertainty in the estimation results. However, estimating the confidence interval for parametric models is not as convenient as the non-parametric model. The WTP expression of parametric models is the ration of estimated coefficients (Equation 3.39) which are treated as random variables that asymptotically follow a multivariate normal distribution[26] in the maximum likelihood estimation procedure. As there is no exact formula to calculate the variance of the ratio of random variables, it is difficult to construct the confidence interval of the WTP (Park, Loomis and Creel 1991).

In order to overcome this difficulty, a Monte Carlo Simulation approach (also known as the Krinsky-Robb procedure) was applied in this study to approximate the empirical distribution of the WTP and construct the 95% confidence interval (Krinsky and Robb 1986; Park, Loomis and Creel 1991; Haab and McConnell 2002). This simulation approach consisted of three steps. Firstly, repeated random draws were taken to simulate the multivariate normal distribution of coefficients with the same mean and associated variance-covariance matrix as the maximum likelihood estimation result. Secondly, each draw of coefficients was used to calculate a mean value of WTP so that an approximate distribution of the WTP estimates was approximated by all the simulated mean values of WTP. Lastly, the 95%

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[26] The model estimates of the coefficients are actually the means of these random variables.

confidence interval of the mean WTP is determined by 2.5% and 97.5% quantile values in the approximate distribution.

With regard to the number of repeated random draws, Krinsky and Robb (1986) suggested that 1000 draws was adequate to produce sufficiently accurate WTP distribution. While in the example presented by Haab and McConnell (2002), 5000 random draws were taken. In this study, the effect of the number of random draws on the simulation results of the confidence interval was investigated in detail. The results will be introduced in the next chapter (Section 4.5).

3.2.2.5 Double Bound Dichotomous Choice Model

The econometric models explained in the preceding sections are based on one dichotomous (yes/no) choice WTP question. Each respondent is offered one price which serves as a threshold (bound) of his/her WTP. A yes answer from the respondents means his/her WTP is larger than the offered price and a no answer means the opposite. These models can be classified as the Single Bound Dichotomous Choice Model. An improvement on the single bound model is to introduce the second WTP question in the survey. If the respondent answers yes to the first WTP question, a larger price is offered in the second WTP question; otherwise a smaller price is offered. By doing this, two thresholds are used to provide more precise information of respondents' WTP and thus improve the model estimation. Such econometric model for Contingent Valuation is called the Double Bound Dichotomous Choice Model (Hanemann, Loomis and Kanninen 1991; Carson and Hanemann 2005; Veronesi, Alberini and Cooper 2011).

Suppose respondent *j* is offered price t_{j1} in the first WTP question and price t_{j2} in the second WTP question. There are four possible situations of the answers to the two WTP questions. Firstly, if the respondent answers yes to both WTP questions, his/her WTP is larger than the second offered price t_{j2} (the larger one in the two offered prices). So the probability of the situation of *yes-yes* answers is

$$\Pr\left(yes, yes_j\right) = \Pr(WTP_j > t_{j2}) \quad (3.41)$$

According to the probability function of the logit random WTP model (Equation 3.37), Equation 3.41 becomes

$$\Pr\left(yes, yes_j\right) = [1 + \exp\left(-\frac{\gamma C_j - t_{j2}}{\sigma_L}\right)]^{-1} \quad (3.42)$$

Secondly, if the respondent answers yes to the first WTP question but answers no to the second one, his/her WTP is larger than t_{j1}but lower than t_{j2}. So the probability of the situation of *yes-no* answers is

$$\begin{aligned}
\Pr(yes, no_j) &= \Pr(t_{j2} > WTP_j > t_{j1}) \\
&= \Pr(WTP_j < t_{j2}) - \Pr(WTP_j < t_{j1}) \\
&= [1+\exp\left(-\frac{\gamma C_j - t_{j2}}{\sigma_L}\right)]^{-1} - [1+\exp\left(-\frac{\gamma C_j - t_{j1}}{\sigma_L}\right)]^{-1} \qquad (3.43)
\end{aligned}$$

Thirdly, if the respondent answers no to the first WTP question but answers yes to the second one, his/her WTP is lower than t_{j1} but larger than t_{j2}. So the probability of the situation of *no-yes* answers is

$$\begin{aligned}
\Pr(no, yes_j) &= \Pr(t_{j1} > WTP_j > t_{j2}) \\
&= \Pr(WTP_j < t_{j1}) - \Pr(WTP_j < t_{j2}) \\
&= [1+\exp\left(-\frac{\gamma C_j - t_{j1}}{\sigma_L}\right)]^{-1} - [1+\exp\left(-\frac{\gamma C_j - t_{j2}}{\sigma_L}\right)]^{-1} \qquad (3.44)
\end{aligned}$$

Lastly, if the respondent answers no to both WTP questions, his/her WTP is lower the t_{j2}(the lower one in the two offered prices). So the probability of the situation of *no-no* answers is

$$\begin{aligned}
\Pr(no, no_j) &= \Pr(WTP_j < t_{j2}) \\
&= 1 - \Pr(WTP_j > t_{j2}) \\
&= 1 - [1+\exp\left(-\frac{\gamma C_j - t_{j2}}{\sigma_L}\right)]^{-1} \qquad (3.45)
\end{aligned}$$

The log-likelihood function for the answers (to the two WTP questions) of all respondents in the sample *T* is

$$\begin{aligned}
\ln L = \sum_{j=1}^{T} \{ & I_{yes-yes} \ln[Pr(yes, yes_j)] + I_{yes-no} \ln[Pr(yes, no_j)] \\
& + I_{no-yes} \ln[Pr(no, yes_j)] + I_{no-no} \ln[Pr(no, no_j)]\} \qquad (3.46)
\end{aligned}$$

where $I_{yes-yes}$, I_{yes-no}, I_{no-yes} and I_{no-no} are binary indicators which equal to 1 if the respondent provides the corresponding answers, otherwise they equal to 0. Substitute Equations 3.42, 3.43, 3.44 and 3.45 into Equation 3.46, the log-likelihood function of the double bound model is

$$\begin{aligned}
\ln L = \sum_{j=1}^{T} \{ & I_{yes-yes}\left[\frac{1}{1+\exp\left(-\frac{\gamma C_j - t_{j2}}{\sigma_L}\right)}\right] \\
& + I_{yes-no}\left[\frac{1}{1+\exp\left(-\frac{\gamma C_j - t_{j2}}{\sigma_L}\right)} - \frac{1}{1+\exp\left(-\frac{\gamma C_j - t_{j1}}{\sigma_L}\right)}\right] \\
& + I_{no-yes}\left[\frac{1}{1+\exp\left(-\frac{\gamma C_j - t_{j1}}{\sigma_L}\right)} - \frac{1}{1+\exp\left(-\frac{\gamma C_j - t_{j2}}{\sigma_L}\right)}\right]
\end{aligned}$$

$$+I_{no-no}\left[1-\frac{1}{1+\exp\left(-\frac{\gamma c_j - t_{j2}}{\sigma_L}\right)}\right]\} \quad (3.47)$$

This complicate log-likelihood function cannot be estimated by the standard logit regression procedure in statistical/econometric software packages. Therefore, ad hoc computing codes for the statistical program *R* (R-Core-Team 2013) were written to conduct the maximum likelihood estimation with the special package “maxLik” (Henningsen and Toomet 2011). The estimated coefficients in Equation 3.47 can be used to calculate the mean WTP and construct the 95% confidence interval following the same method explained above for the single bound random WTP (logit) model.

3.3 Implementation of Contingent Valuation Models

As explained in Section 3.2 and illustrated in Figure 3.6, both non-parametric and parametric models were used in this study. Within the parametric models, the random WTP model was preferred to the random utility model, and within the random WTP model, the logit model was preferred to the probit model.

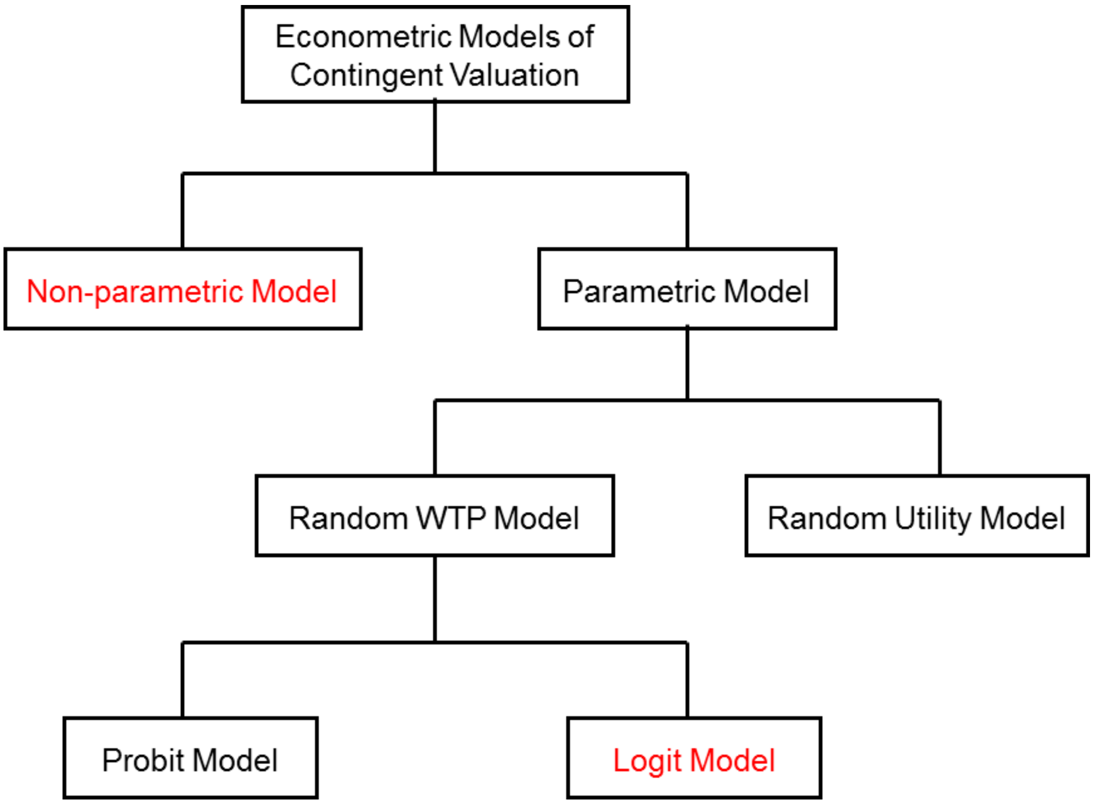

Figure 3.6 Econometric Models in Contingent Valuation

Models highlighted in red were applied in this study.

Implementation of the non-parametric model was quite straightforward as it only needed the information of the percentages of respondents' *no* answer to different increments in water price. Comparatively, implementation of the parametric model (the logit random WTP model) entailed more efforts in model building, evaluation and selection as it utilized a group of explanatory variables to explain the probability of respondents' *yes* answer to the WTP question and then calculated the mean WTP with the coefficients. A crucial question arose when implementing the logit random WTP model, i.e. what explanatory variables should be included in the model?

3.3.1 The Initial Full Model

Understandably, it is important not to overlook any variables that may significantly influence respondents' answers to the WTP question. Thus it is reasonable to build an initial full model that includes all the potentially important explanatory variables at the outset of the modelling procedure. Generally, explanatory variables in Contingent Valuations studies include respondents' environmental awareness, knowledge and attitudes, their experiences/behaviours related to the valued ecosystem services and their demographic characteristics (Spash *et al.* 2009; Vasquez *et al.* 2009; Ramajo-Hernandez and del Saz-Salazar 2012; Wang *et al.* 2013b). Accordingly, a total of 21 potential explanatory variables were considered for the initial full model of this study (Table 3.2).

Table 3.2 Potential Explanatory Variables in the Initial Full Model

Variable	Description and Coding
Perceive-shortage	Perception of the water shortage in the city: 1 to 3 (from Abundant to Scarce) [a]
Opinion-service	Opinions about the current tap water service: 1 to 3 (from Satisfactory to Dissatisfactory) [b]
Know-bill	Know their water bills: No = 0; Yes = 1
Know-price	Know the current water price: No = 0; Yes = 1
Heard-SNWTP	Have heard about the South-to-North Water Transfer Project (SNWTP): No= 1 [c]; Yes = 0
Know-benefits	Know the potential benefits of the SNWTP: 0 to 4 [d]
Heard-mid-route	Have heard the specific Middle Route of the SNWTP: No = 0; Yes = 1
Know-reservoir	Know the Danjingkou Reservoir as the water supply area of the middle route project: No = 0; Yes = 1

Heard-EC	Have heard about Ecological Compensation (EC): No = 0; Yes = 1
Understand-EC [e]	Can correctly describe the general idea of EC: No = 0; Yes = 1
Opinion-EC	Opinion about the general idea of EC [f]: 1 to 5 (from Highly agree to Highly disagree)
Price-increase	The proposed increase in water price in the WTP question: 0.1; 0.2; 0.5; 0.8; 1.0; 1.5 (yuan/m^3)
Household-size	Number of family members living with the respondents
Gender	Female = 0; Male = 1
Age	30 and below = 1; 31 to 40 = 2; 41 to 50 = 3; 51 to 60 = 4; Above 60 = 5
Education	College or higher = 1; High school = 2; Middle, primary school or below = 3 [g]
Income	Monthly gross income (in Chinese Yuan) [h]: Below 2500 = 1; 2500 to 4000 = 2; Above 4000 = 3
Job	Public Sector (government departments, state-owned companies and institutes) = 1; Private Sector (private companies, businessmen, freelancer) = 2; Retired = 3; Unemployed = 4;
Residence	Length of stay in the city (in years) [i]: Over 20 = 1; 10 to 20 = 2; 5 to 10 = 3; Below 5 = 4
Visit	Visited the water supply areas before: No = 0; Yes =1
Relatives	Have relatives or close friends living in the water supply areas: No = 0; Yes =1

[a] The original options of “Very abundant” and “Abundant” were merged into “Abundant”, “Very scarce” and “Scarce” were merged into “Scarce” in order to assure that there are enough number of answers in each category for the regression modelling.

[b] Similarly, the original options of “Very satisfactory” and “Satisfactory” were merged into “Satisfied”, “Very dissatisfactory” and “Dissatisfactory” were merged into “Dissatisfied”.

[c] Since most respondents have heard of the project before, the *no* answer was coded as 1, and the *ye*s answer was coded as 0 (the reference level). For regression analysis with categorical variable, it is better to take the category that has a fairly large number of observations as the reference level.

[d] A multiple-option question including four major benefits of the water transfer project and an “I Don’t know” option was asked to the respondents. Choosing each benefit scored 1 and choosing “I Don’t know” scored 0.

[e] This variable is different from the preceding one (Heard-EC) as respondents who have heard about *EC* did not necessarily understand its idea correctly.

[f] A brief description of the general idea of EC was given to the respondents before asking their opinions (but after the preceding question about whether they understand the general idea of EC).

[g] Primary and middle schooling are legally compulsory and free in China. A fairly large number of respondents have received college or higher education, so this category is coded with the smallest number as the reference level.

[h] The starting income level of the personal income tax in China was 2000 yuan/month before 1st September 2011 and rose to 3500 yuan/month thereafter.

Some original income ranges in the questionnaire (see Appendix 1) were merged into these three ranges so that each range contains enough number of observations for the modelling analysis.

[i] The longest residence was coded with the smallest number (as the reference category) due to the fairly larger number of respondents in this category.

The initial full model was not the best-fit model because not all the assumed important variables turned out to be truly important variables in the modelling results. Moreover, the Principle of Parsimony[27] means that statistic models should be simplified to have as few parameters as possible until removal of any variable would considerably reduce the model fit (Crawley 2007). Therefore, variables in the initial full model should be screened in order to obtain the improved model in terms of goodness of fit and simplicity.

Interestingly, while the importance of including all possibly important variables in the full model is generally well attended, the Principle of Parsimony and the necessity of model simplification and improvement seemed largely neglected in the Contingent Valuation literature. It is common to see logit/probit models with a number of variables in the literature and only some of them are significant, but it is not known whether the models can be further simplified and improved by removing some or all of the insignificant variables (Vasquez *et al.* 2009; Ramajo-Hernandez and del Saz-Salazar 2012; Wang *et al.* 2013b). This study introduced two powerful automatic model selection techniques, i.e. the Stepwise Regression and the Best Subset Regression in Contingent Valuation, and integrated them with manual adjustment for model construction and improvement.

3.3.2 Stepwise Regression and Best Subset Regression

Stepwise Regression and Best Subset Regression are two powerful automatic variable selection techniques which have been widely used in statistical modelling (Hosmer, Lemeshow and Sturdivant 2013) but not applied in Contingent Valuation studies. Stepwise Regression is an iterative selection procedure which starts from the full model and removes one variable (the least significant one) at a time until the model cannot be further improved[28]. The criterion used for evaluating models in the stepwise

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[27] This principle is also known as Occam's Razor which emphasizes paring down the complication of explanations (to research issues) to the bare minimum.

[28] Strictly speaking, this is called the backward stepwise regression, while the *forward* procedure starts from the *null model* (the model with no

regression is the Akaike Information Criterion (AIC), which is defined as (Akaike 1974; Crawley 2012)

$$\mathrm{AIC} = -2 \times L + 2(p + 1) \tag{3.48}$$

where *L* is the log-likelihood of the model and *p* is the number of parameters (coefficients) in that model. The smaller the AIC, the better the model is. So AIC not only takes account of the goodness of fit of the evaluated model (through *L*) but also its simplicity (through *p*). The stepwise regression iteration ends up with the model with the smallest AIC, i.e. the model exhibiting best goodness of fit with fewest variables. The statistic computing program *R* (R-Core-Team 2013) was used in this study to conduct the stepwise regression iteration.

Best Subset Regression (also called All Subset Regression) is another powerful automatic selection technique which can assess all the possible models that contain a subset of variables in the full model and selects the best model with the smallest AIC. That is to say, for a full model with 21 variables, the best subset regression procedure can assess all the 2^{21} = 2,097,152 possible subset models of the full model[29]. This is an exhaustive assessment procedure that can take hours for computation (depending on the working computer's speed). In this study, the up-to-date, special package "glmulti" for the *R* program was used to conduct the best subset regression procedure (Calcagno and de Mazancourt 2010; Calcagno 2013).

3.3.3 Integration of Automatic Model Selection Procedures and Manual Adjustment

The two automatic variable (model) selection techniques are sufficiently useful to determine the best model for ideal survey data with no missing values, but problems arose when applying them onto the real survey data. In the real survey, some respondents did not answer the questions regarding their private information such as income or their opinions about environmental issues, which caused a number of missing values in the

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variable but a constant) and adds one variable at a time until the model cannot be further improved.

[29] The total number of subset models of a full model with *n* variables equals to the sum of all possible combinations of *n* elements, i.e. $\sum_{0 \le k \le n} \binom{n}{k} = 2^n$. This total number includes two extreme cases, i.e. the null model (with no variable but a constant) and the full model itself.

survey data[30]. Since incomplete observations[31] with missing values were omitted in regression, the more variables (each variable corresponded to a question in the survey) included in a model, the more missing values there could be, and thus the fewer observations the model could contain. Obviously, a model with more observations could make better use of the survey data. However, some variables such as income were too important to be excluded from the model even if it could cause substantial reduction of observations.

The stepwise regression and best subset regression techniques can select the model with the smallest AIC from numerous possible models based on the initial full model, but they cannot take account of whether a variable should be retained despite the related reduction of observations. Moreover, as shown in Equation 3.48, the AIC is dependent on -2 × log-likelihood and the number of variables in the model. Since more observations could lead to larger value of -2 × log-likelihood[32], the two automatic selection procedures are likely to select a model with relatively few observations. That is to say, for datasets with missing values, the final model selected by the two automatic procedures may neither make good use of the survey data nor retain some important variables. In order to amend the drawbacks of the automatic model selection techniques in tackling data with missing values, manual adjustment was integrated with the automatic selection techniques in this study for model selection and improvement (illustrated in Figure 3.7).

The first stage of this integrated procedure was to construct the initial full model to obtain a general view of all explanatory variables' influence on respondents' answers to the WTP question. The second stage was to apply the best subset regression and stepwise regression techniques onto the initial full model in order to find which variables were removed by the two automatic selection procedures (due to insignificance) and caused substantial reduction of the observations (due to missing values). The third

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[30] The option of "No opinion" or "I don't want to answer" was provided for the respondents in this survey, which helped to ensure the reliability of the survey data.

[31] Each observation is a dataset that contains a respondent's answers to all the questions.

[32] For example, two additional observations (respondents) with the probability of 0.5 to answer yes to the WTP question would add -2 × log(0.5) = 1.38 to the AIC.

stage introduced the manual adjustment which removed those variables identified in the second stage and constructed a new (intermediate) full model that contained less variables and more observations than the initial full model. But variables like income were retained in this stage in spite of the resultant reduction of observations. Then the automatic stepwise regression technique was applied again onto the new full model to select the new (intermediate) stepwise regression model with the smallest AIC.

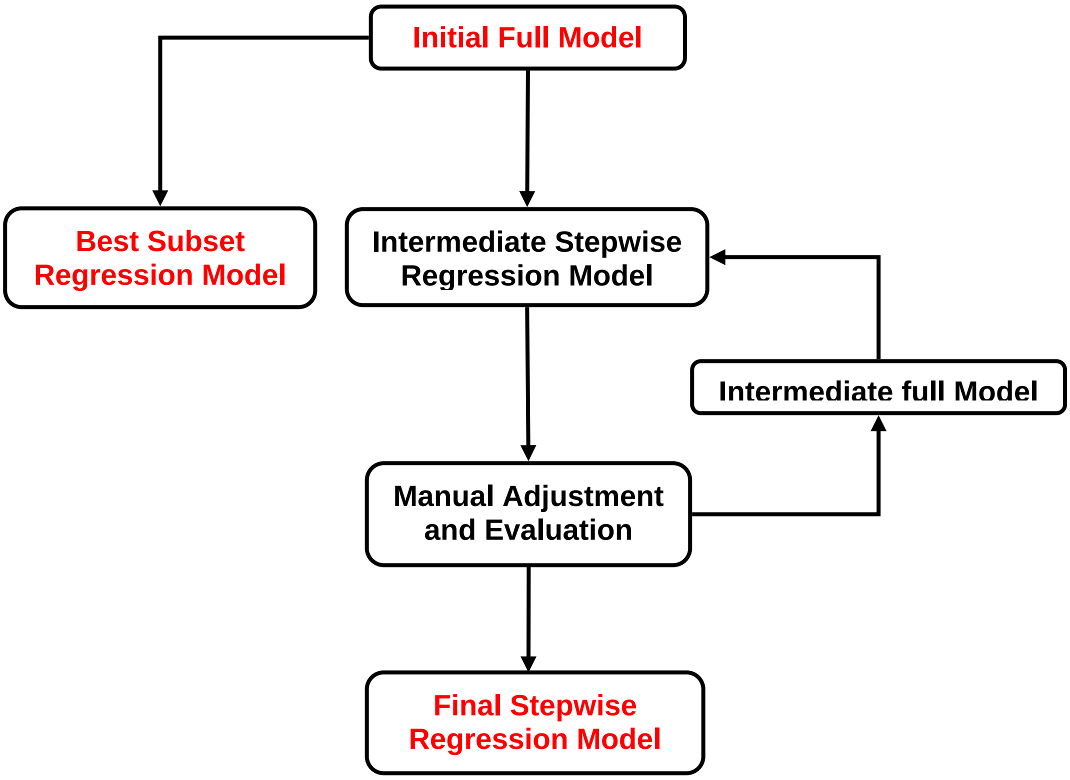

Figure 3.7 Integrated Model Selection and Improvement Procedure

Models highlighted in red were reported in this study (Chapter 4). Explanation of models in the figure was in the following texts.

It should be noted that variables identified in the second stage (insignificant and with missing values) were not all removed from the initial full model at the same time to construct the new full model. This is because even the removal of one variable from the initial full model could lead to substantial differences between the new stepwise model and the initial one (i.e. the stepwise model based on the initial full model). Variables not included in the initial stepwise model might become significant and thus retained in the new stepwise model, and vice versa. As a result, a trial-and-error method was used to remove redundant variables, which made the third stage an exhaustive and iterative selection process until the final stepwise regression model was determined to achieve the balance between best model fit (preciseness), most observations (fully use of the survey data) and fewest explanatory variables (simplicity)[33].

In addition to the AIC, two other criteria were also used in this study to evaluate numerous models in the integrated selection procedure, i.e. the overall model significance and the prediction error rate.

The overall model significance indicates whether the tested model is significantly better than the null model, i.e. the model with no explanatory variables but the intercept/constant. The Likelihood Ratio Test is generally used to the evaluate models' overall significance (Hosmer, Lemeshow and Sturdivant 2013).

$$G = -2\ln\left(\frac{L}{L_0}\right) \quad (3.49)$$

where L is the likelihood of the tested model, L_0 is the likelihood of the null model, and G is the log-likelihood ratio statistic which approximately follows the chi-square distribution with k degree of freedom where k is the number of explanatory variables in the test model. The P-value calculated based on G indicates the overall significance of the tested model.

The prediction error rate (the same test with a different presentation form is called classification table) is an intuitive criterion to indicate models' ability to explain/predict respondents' answers to the WTP question (Hosmer, Lemeshow and Sturdivant 2013). After the coefficients of the tested model are estimated, each respondent's probability of answering yes to the WTP question can be calculated by the probability function of the logit model (Equation 3.37). Setting 0.5 as the cut-off point, the respondent is predicted [34] to answer yes if the calculated probability is larger than 0.5, otherwise he/she is predicted to answer no. Then the prediction error rate of the tested model is

$$\text{Prediction Error Rate} = \frac{N_{Pr(Yes) > 0.5 \mid No} + N_{P(Yes) \leq 0.5 \mid Yes}}{N_{total}} \quad (3.50)$$

[33] It should be noted that the stepwise regression itself was also an iterative selection procedure. Moreover, the best subset regression technique was not applied in the third stage because it was far too time-consuming for the exhaustive and iterative examination.

[34] Strictly speaking, this is a posterior estimation as the "prediction" is actually made after the survey.

where $N_{Pr(Yes) > 0.5 | No}$ is the number of respondents who are predicted to answer yes (as the calculated probability is larger than 0.5) but actually answer no in the survey, $N_{P(Yes) \leq 0.5 | Yes}$ is the number of respondents who are predicted to answer no but actually answer yes, and N_{total} is the total number of respondents.

The integrated model selection procedure explained above focuses on the single bound dichotomous choice model because the automatic model selection techniques for the complicated probability function (Equation 3.47) of the double bound dichotomous choice model are not available so far. As a result, this study applied the integrated model selection procedure (Figure 3.7) to determine what variables should be included in the final stepwise regression model (single bound model). Then the double bound model was constructed with the same variables of the single bound model but a more complicated probability function. The integrated model selection procedure of this study has not been reported in the literature, it could be a methodological contribution of improving the model construction and selection in Contingent Valuation studies.

3.4 Choice Experiment Survey in the Water Supply Area

The previous three sections introduce the Continent Valuation survey and models for investigating urban residents' WTP for water protection, which focuses on the demand (consumer) side of PES schemes. This section and the following one introduce the Choice Experiment survey and models for revealing farmer households' preferences for the design of two water protection programs in the water supply area, i.e. the existing Sloping Land Conversion Program (SLCP) for reforestation and a hypothetical program for reducing the use of fertilizer on flat land that is not currently covered by the SLCP. This choice experiments study provides information and suggestions on how to improve and develop PES schemes from the supply (provider) side.

3.4.1 Study Area and Survey Sampling and Implementation

The Danjiangkou Reservoir will provide water for the middle route of the South-to-North Water Transfer Project. In order to ensure the water quality of the reservoir is at a relatively high level (Grade II in the national environmental standards for surface water), the central government of China designated 40 counties in three provinces which cover 88,100 km^2 around the reservoir and in its upstream watershed as the water supply area (Figure

3.1) to implement water protection measures both in urban and rural districts. This study focused on the rural districts because the point-source water pollution in urban districts such as effluents from factories are relatively easy to identify and treat by waste water treatment plants and facilities, but the non-point source agricultural pollution in the rural districts is dispersed and more difficult to monitor and control (Smith, Inman and Cherrington 2012).

Due to limited resources and time, it was unrealistic to conduct a survey in the whole water supply area. Hence, this study focused on villages around the Danjiangkou Reservoir because agriculture activities in these villages are likely to cause the most direct impact to the water quality of the reservoir. The choice of the specific villages was dependent on the locations of the villages and the availability of local informants/interviewers to help with the survey. A group of undergraduate students whose families are living in these villages were recruited and trained to conduct this survey.

A preparatory survey was conducted in one village with 5 farmer households at the early stage of this study in 2010 to assess the feasibility of such a choice experiment survey and obtain the general information of farmer households’ opinions about water protection programs. Further contacts of local interviewers in multiple villages were established in 2011 and the information of their own households was also used to refine the design of the survey questionnaire. The final survey was conducted in August and September of 2012 in 7 villages around the Danjiangkou Reservoir (Figure 3.8). In-house interviews were conducted with the heads of the farmer households by the recruited and trained local interviewers.

A total of 246 questionnaires were successfully collected in this survey. 161 of them were collected from households who had participated in the Sloping Land Conversion Program (SLCP) and 94 of them were collected from households who had qualified sloping land for the SLCP but did not participate in the program. The interviewed SLCP-participant households accounted for about 10% of the total number of participant households in their villages. As no information about the non-participant households was available prior to the survey, the interviewers had to consult with the heads of villages and adopted the Snowball Sampling strategy to find this kind of households.

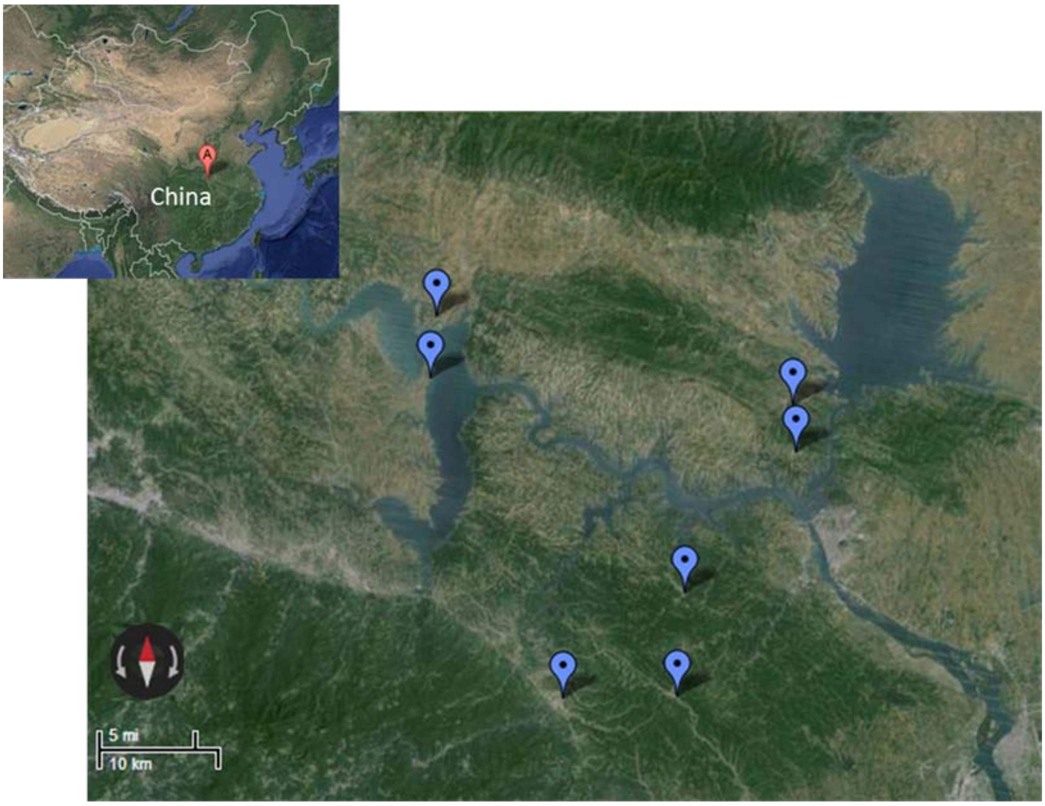

Figure 3.8 Surveyed Villages around the Danjiangkou Reservoir

Satellite images are adapted from the Google Map. The red bubble in the small graph indicates the location of the Danjiangkou Reservoir. Blue bubbles in the main graph represent the villages surveyed in this study.

3.4.2 Questionnaire Design of the Choice Experiment Survey

Two slightly different questionnaires (see Appendices 2 and 3) were used in this study for the two groups of farmer households, i.e. the SLCP-participant households and the non-participant households. For the participant households, the questionnaire was composed of four parts. The first part contained questions regarding the households' participation in the SLCP (e.g. their most important reasons to participate, the area of their enrolled land, the reason why some of them only enrolled part of their qualified land) and their land use decisions after the expiration of their SLCP contracts (e.g. had/will they convert the enrolled forestland back to farmland).

The second part of the questionnaire aimed to investigate the effect of the SLCP on the livelihood of the participant households. Detailed questions were asked about: 1) the trees planted on the enrolled sloping forestland after the SLCP and the annual gross income per mu [35] from each species of tree, 2) the crops planted on those sloping land before the SLCP and their annual gross incomes per mu, 3) the crops planted on the households' remaining farmland and their annual gross incomes per mu, and 4) other income sources of the households and the annual gross income from each source. The gross income was chosen (instead of the net income) because, as suggested by some local informants at the preparatory stages of the survey, some farmer households did not actually make detailed calculation of net income and the information of gross income was much less sensitive for the households to tell.

The third part of the questionnaire contained two sets of choice experiments questions for revealing farmer households' preferences for the design of the SLCP and a hypothetical fertilizer reduction program. As mentioned in Chapter 2, choice experiments disaggregate respondents' preferences for services/goods/projects into their preferences and trade-offs for defined attributes at different levels. In this survey, farmer households' preferences for the design of the SLCP were modelled as their preferences and trade-offs for three attributes (Table 3.3), and each attribute had three levels that were equally spaced in order to reveal the linear effects of the attributes (Hensher, Rose and Greene 2005). No more than three levels were adopted because the increase in the attributes' levels could exponentially increase the choice questions that households needed to consider and answer, which could burden them with tedious questions and reduce the reliability of their answers.

Table 3.3 Defined Attributes of the Sloping Land Conversion Program

Attributes	Levels
Annual Payment	200; 300; 400 (yuan/mu)
Contract-length	5, 10, 15 (years)
P-com-trees [a]	0%, 50%, 100%

[a] The maximum percentage of commercial trees allowed to be planted on the enrolled land.

[35] Mu is the commonly used unit of land in China which equals to 1/15 hectare.

The three levels of the attribute of annual payment were 200, 300 and 400 yuan/mu. Two similar choice modelling studies on the SLCP adopted the range of 100-300 yuan/mu (Chen *et al.* 2009a) and 100-800 yuan/mu (Grosjean and Kontoleon 2009) respectively[36]. The three levels adopted in this study were neither too low nor too high to make the policy scenarios overwhelmingly unattractive or attractive to the farmer households, in which case it would be difficult to reveal their trade-offs between multiple attributes.

The current contract length of SLCP is 3 years for converting the sloping farmland to grassland[37], 5 years for conversion to commercial forests and 8 years for conversion to ecological forests [38]. In Chen et al.'s (2006) study, the levels of contract length were set as 3, 6 and 10 years without discriminating commercial and ecological forests. In this survey, the three levels of contract length were 5, 10 and 15 years. Since long-term programs are more likely to generate long-term ecological benefits, this study set the longest contract length as 15 years in order to reveal the feasibility of extending the duration of SCLP to a larger extent.

The last defined attribute of the SLCP was the maximum percentage of commercial trees farmer households were allowed to plant on the enrolled land, which helped to reveal households' trade-off between the flexibility of land use activities and other attributes. As mentioned above, the two types of the current SLCP contracts were at the two ends of this attribute, i.e. the full flexibility of planting commercial trees (100%) and complete restriction on commercial trees (0%). This study added the midpoint (50%) to the whole spectrum of this attribute. The same design was also adopted by (Grosjean and Kontoleon 2009).

After defining the attributes of the SLCP and the levels of the attributes, Orthogonal Fractional Factorial Design (Hensher, Rose and Greene 2005) was used to design the policy scenarios, i.e. different combinations of the three attributes at different levels, and produce choice cards (with those

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[36] The current SLCP annual payment was 230 yuan/mu.

[37] This type of SLCP contract is mainly for farmer households in the north and northwest of China where precipitations are not enough for forests.

[38] "Commercial Forests/Trees" and "Ecological Forests/Trees" are two terms used in the implementation of the SLCP. The former refers to trees that are more profitable but can generate less ecological benefits (such as fruit trees) while the latter means the opposite. The species of trees within the two categories are designated by the National Forestry Bureau.

policy scenarios) presented to the farmer households. Such an orthogonal design method ensured that there was no correlation between the attribute levels so that the main effects of the attributes can be independently estimated (Hensher, Rose and Greene 2005). In the survey, each farmer household was presented with three choice cards regarding the design of the SLCP and each choice card contained three policy scenarios (Table 3.4). Each farmer household was asked to choose the most preferred policy scenario from each choice card. The chosen policy scenario was coded as 1 and the other two scenarios in the choice card were coded as 0, which means nine choice observations were collected from each household regarding their preferences for the design of the SLCP.

Table 3.4 Choice Cards of the Sloping Land Conversion Program

In the survey, the three choice cards were separately presented to each respondent in random order.

Annual Payment (yuan/year)	Contract Length (year)	P-com-trees [a]
Choice Card A		
200	5	0
300	10	100%
400	15	50%
Choice Card B		
200	10	50%
300	15	0%
400	5	100%
Choice Card C		
200	15	100%
300	5	50%
400	10	0%

[a] The maximum percentage of commercial trees allowed to be planted on the enrolled land.

In some choice experiment studies, a choice card was composed of two designed policy scenarios and an additional option of “Choose neither” or “Status quo”. The inclusion of such options might avoid compelling respondents to choose from the presented policy scenarios. However, it could cause the loss of the orthogonality in the experiment design (Hoyos 2010). As Hensher et al. (2005) suggested, when the main objective of the study is to reveal respondent’s trade-offs between multiple attributes, it is better to exclude the “Choose neither” option in order to obtain all respondents’ preference information. Moreover, putting three designed policy scenarios in a choice card reduced the number of choice questions the respondents needed to answer in case they felt bored about the survey and provided unreliable answers. This was particularly necessary for this study because the farmer households still needed to answer the other set of choice questions about the hypothetical fertilizer reduction program.

The three defined attributes of the hypothetical fertilizer reduction program are presented in Table 3.5. As no program has been implemented in China to pay farmers for reducing the use of fertilizers nor have studies on such programs been found in literature, the attributes and levels of the fertilizer reduction program in this study were largely defined by taking the attributes and levels of the SLCP as the benchmarks. Since the profitability of flat cropland is generally higher than sloping land, the three levels of the annual payment were set as 300, 400 and 500 yuan/mu. Given this hypothetical program is unfamiliar to the farmer households, long contracts like 10 and 15 years could be overwhelmingly risky for them. Therefore, the three levels of contract length were set as 2, 5 and 8 years, which were the lengths of the current three types of SLCP contracts. While a complete cut of the use of fertilizers could be too radical for the farmer households, a small percentage of reduction is unlikely to generate substantial environmental benefits. As a result, the three levels of the reduction percentage of fertilizer use were set as 25%, 50%, 75%. The two kinds of fertilizers (nitrogen and phosphate) were bound up in this attribute because they are both important causes of agricultural non-point source pollution and eutrophication in surface water and farmer households' trade-off between these two kinds of fertilizers is not the focus of this study.

Table 3.5 Defined Attributes of the Hypothetical Fertilizer Reduction Program

Attributes	Levels
Annual Payment	300; 400; 500 (yuan/mu)
Contract-length	2, 5, 8 (years)
P-fert-reduce [a]	25%, 50%, 75%

[a] The percentage of reduction in the use of nitrogen and phosphate fertilizers.

Using the same method of designing the choice cards for the SLCP, three choice cards were designed for the hypothetical fertilizer reduction program and each of them consisted of three policy scenarios (Table 3.6). Each farmer household was asked to choose the most preferred scenario from each choice card in the survey.

Table 3.6 Choice Cards of the Fertilizer Reduction Program

Annual Payment (yuan/mu)	Contract Length (year)	P-fert-reduce [a]
Choice Card A		
300	2	25%
400	5	75%
500	8	50%
Choice Card B		
300	8	75%
400	2	50%
500	5	25%
Choice Card C		
300	5	50%
400	8	25%
500	2	75%

[a] The percentage of reduction in the use of nitrogen and phosphate fertilizers.

The two sets of choice questions regarding the two water protection programs comprised the third part of the questionnaire used in the choice experiments survey. The last part of the questionnaire collected the demographic characteristics of the farmer households. These characteristics were later used to compare the SLCP-participant households and the non-participant households and help to reveal the heterogeneity in farmer households' preferences for the design of water protection programs.

The questionnaire used for the non-participant households was slightly different from the one used for the SLCP-participant households. No questions regarding households' participation in the SLCP were asked in the first part of the questionnaire. Instead, questions were asked about how much land held by the non-participant households qualified for the SLCP and why they did not participate in the program. In the second part of the questionnaire regarding households' livelihood, questions were asked about the crops/trees planted on the households' land and the gross incomes per mu from the crops/trees without differentiating the enrolled forestland and the remaining farmland as the case of the SLCP-participant households. The remaining two parts of the questionnaire, i.e. the choice questions and the demographic information questions were the same with the questionnaire for the SLCP participant households.

3.5 Econometric Models for Choice Experiment

3.5.1 The Classic Conditional Logit Model

Choice Experiment is based on the characteristic theory of consumption which supposes that utility is derived from characteristics (attributes) of goods/services (Lancaster 1966) and the random utility theory which supposes that people make decisions to maximize the utility they derive from goods/services (McFadden 1974). The Conditional Logit Model (CLM), developed by McFadden (1974) who was rewarded the Nobel Prize of economics in 2000 for his contribution in choice modelling, is the classic and most widely used model for choice experiments studies. Assume that an individual is given a choice set (card) *C* to choose one of its alternatives, the utility of alternative *i* is supposed to be composed of a deterministic and observable component V_i and a random and unobservable error component ε_i.

$$U_i = V_i + \varepsilon_i \qquad (3.51)$$

When the individual compares alternative *i* with alternative *j* in the choice set *C*, he/she would choose alternative *i* if and only if larger utility can be derived from this alternative. So the probability of choosing alternative *i* is

$$\Pr(i \mid C) = \text{Prob}(V_i + \varepsilon_i > V_j + \varepsilon_j;\ i \neq j;\ \forall j \in C) \qquad (3.52)$$

When the random error terms ε_i and ε_j are independently and identically distributed following the Gumbel distribution, the probability of choosing *i* is (McFadden 1974; Hanley, Wright and Adamowicz 1998; Louviere, Hensher and Swait 2000):

$$\Pr(i) = \frac{\exp(\mu V_i)}{\sum_{j \in C} \exp(\mu V_j)}$$

(3.53)

where μ is a scale parameter which is assumed to 1, implying the constant error variance. The deterministic component V_i is usually presented as a linear function of the attributes vector X_i and the coefficients vector β'.

$$V_i = \beta' X_i \qquad (3.54)$$

Accordingly, Equation 3.53 can be rewritten as:

$$\Pr(i) = \frac{\exp(\beta' X_i)}{\sum_{j \in C} \exp(\beta' X_j)}$$

(3.55)

Under the assumption of Independent of Irrelevant Alternatives (IIA), which implies that the ratio of choice probability between two alternatives is not influenced by the introduction or removal of other alternatives, the coefficients vector *β'* in Equation 3.55 can be estimated by conditional logit regression procedures in statistical software packages. In this study, the special package "mlogit" of the statistical program *R* was used to conduct the conditional logit regression procedure (Croissant 2013).

The estimated coefficients in CLM do not have straightforward interpretations of the choice probabilities of any specific alternatives since the probability of choosing an alternative is conditional on the other alternatives in the choice set (represented by the denominator in Equation 3.55). Instead, the coefficients of CLM represent the changes in respondents' utility caused by a unit change in the attributes. A positive coefficient means the respondents prefer higher levels of the corresponding attribute and vice versa. Another useful interpretation of the coefficients is the marginal value, how much are the respondents willing to forgo for a unit increase in the non-monetary attributes.

Denote the coefficient of the monetary attribute as β_m, and the coefficients of non-monetary attributes as β_{nm}, the marginal value of non-monetary attributes can be calculated as (Hanley, Wright and Alvarez-Farizo 2006):

$$MV = \frac{\beta_{nm}}{\beta_m} \quad (3.56)$$

3.5.2 The Random Parameters Logit Model for Revealing the Heterogeneity in Respondents' Preferences

Despite its usefulness and wide application, the classic CLM has its limitations. Firstly, the CLM is restricted by the IIA assumption which does not always hold in real life. Secondly, the CLM assumes that the parameters/coefficients which represent respondents' preferences for the attributes are uniform for all people, so it is unable to account for the heterogeneity in respondents' preferences in choice experiments studies (Train 1998; Hanley, Wright and Alvarez-Farizo 2006; Ruto and Garrod 2009). The Random Parameter Logit Model (RPL) is an advanced model to overcome these limitations by allowing the parameters/coefficients of attributes in choice models to randomly vary over respondents but follow certain statistic distributions (Train 1998; McFadden and Train 2000; Greene and Hensher 2003; Hanley, Wright and Alvarez-Farizo 2006; Ruto and Garrod 2009; Hoyos 2010). The most adopted statistic distribution is the normal distribution which can be described by the mean and standard deviation. Therefore, instead of estimating one fixed coefficient for each attribute like the CLM, the RPL estimates two coefficients for each attribute, i.e. the mean coefficient and the standard deviation coefficient which together describe the distribution of the respondents' heterogeneous preferences for this attribute.

Following Train's (1998) study, Equation 3.55 is the probability of choosing alternative *i* when the coefficients vector β' is assumed to be homogenous for all respondents. Adding the subscripts *n* and *t* to represent the *n*th respondent and the *t*th choice set respectively, Equation 3.55 can be rewritten as:

$$P_{nit} = \frac{\exp(\beta' X_{nit})}{\sum_{j \in C} \exp(\beta' X_{njt})} \qquad (3.57)$$

The probability of the *n*th respondent's sequence of choices from all the choice sets is the product of the choice probability:

$$S_n = \prod_t P_{nit}(\beta') \qquad (3.58)$$

In the RPL, β' is not fixed but follows the normal distribution θ* characterized by the mean and standard deviation. Denote the probability density of the coefficients as $f(\beta'|\theta^*)$, the probability of the choice sequence which accounts for respondent's heterogeneous preferences is the integral of Equation 3.58 over all possible values of β' weighted by its probability density:

$$P_n(\theta^*) = \int S_n \; f(\beta'|\theta^*) d\beta \qquad (3.59)$$

The integral of Equation 3.59 does not have a closed form to be analytically calculated. Thus a simulated maximum likelihood estimate can be used to determine the coefficients distribution θ* (Train 1998; Ruto and Garrod 2009). Specifically, a number of values of β' are randomly drawn from a given distribution θ, and the probability of the choice sequence of the *n*th respondent, i.e. $P_n(\theta^*)$, is approximated by averaging all the simulated probabilities:

$$P_n'(\theta^*) = \frac{1}{R} \sum_{r=1}^{R} P_n(\beta^{r|\theta}) \qquad (3.60)$$

where R is the number of repetitions (draws), $\beta^{r|\theta}$ is the *r*th draw of β from the given distribution θ. Then the simulated log-likelihood of the choice sequences of all respondents under the coefficients distribution θ is:

$$SLL(\theta) = \sum_n ln[P_n'(\theta)] \tag{3.61}$$

Substitute Equations 3.57, 3.60 into Equation 3.61,

$$SLL(\theta) = \sum_n ln\left[\frac{1}{R}\sum_{r=1}^{R}\prod_t \frac{\exp(\beta^{r|\theta}X_{nit})}{\sum_{j\in C}\exp(\beta^{r|\theta}X_{njt})}\right]$$

(3.62)

Maximum Likelihood Estimate is applied to find the mean and standard deviation of the coefficients distribution θ* that maximize the simulated log-likelihood of respondents' choice sequences. If the estimated standard deviation coefficient is significant, there is significant heterogeneity in respondents' preferences for the attribute. In this study, the estimation of RPL was also conducted by the special package "mlogit" of the statistical program *R* (Croissant 2013).

3.6 Summary

This chapter explains and elaborates the research design, method and models used in this study. Non-market valuation was used to develop PES schemes for the water protection of the middle route of the South-to-North Water Transfer Project from both supply and demand perspectives. On the demand (consumer) perspective, a Contingent Valuation survey was conducted in four cities along the middle route project in order to investigate urban residents' willingness to pay higher water prices for water protection. The non-parametric model, the Single Bound Dichotomous Choice Model and the Double Bound Dichotomous Choice Model were applied to estimate respondents' mean WTP. An integrated procedure to combine the automatic stepwise regression and best subset regression techniques and manual adjustment was designed and developed in Contingent Valuation for model construction and refinement.

On the supply (provider) side of PES, a Choice Experiments survey was conducted in seven villages at the water supply area (around the Danjiangkou Reservoir) to reveal farmer households' preferences for the design of two water protection programs, namely the existing Sloping Land Conversion Program for reforestation and a hypothetical program for fertilizer reduction. In addition to the classic Conditional Logit Model, the advanced Random Parameters Logit Model was also applied in this study to further reveal the heterogeneity in farmer households' preferences. Furthermore, auxiliary questions were also asked in the choice experiments survey to investigate the effect of the SLCP on the livelihoods of the participant households. The results from the surveys and model estimation are discussed in detail in the following chapters.

Chapter 4
Public Willingness to Pay for Water Protection

The successful design of Payment for Ecosystem Services (PES) schemes requires knowledge and information from both the demand and supply sides. On the demand side, it is important to know whether the service users are willing to pay for the target service and factors that might influence their willingness to pay (WTP). This chapter presents the results of the Contingent Valuation survey in four cities along the middle route of the South-to-North Water Transfer Project (SNWTP) on urban residents' WTP for water protection.

The contents of this chapter are arranged as follows: Section 4.1 describes respondents' characteristics, environmental awareness, knowledge and opinions which help to explain their answers to the WTP question, i.e. whether they are willing to pay a proposed higher water price for water protection of the middle route of the SNWTP. Section 4.2 applies the relatively simple non-parametric model to provide preliminary estimates of respondents' mean WTP for water protection. Section 4.3 applies more sophisticated parametric models for each city to explain the probability of respondents' acceptance to a higher water price. Section 4.4 conducts a comparative analysis on the final parametric models of the four cities. Section 4.5 compares the WTP estimates of both parametric and non-parametric models and explores the effect of income disparity on the WTP for water protection. Lastly, Section 4.6 summarizes the major findings of this chapter.

4.1 Respondents' Characteristics, Environmental Awareness, Knowledge and Opinions

A total of 755 questionnaires were collected from the four cities, with 200 from Beijing, 247 from Tianjin, 98 from Shijiazhuang and 210 from Zhengzhou. Table 4.1 presents the characteristics of respondents in each city and a significance test of difference between them. The results show that significant differences were found in all characteristics except gender. This great heterogeneity in respondents indicates the necessity of conducting individual modelling analyses for each of the four cities.

Table 4.1 Characteristics of Respondents in Four Cities

Dif.: significance level of difference between the four cities, 0.001 ***, 0.01 **, 0.05 *

Characteristic	Beijing	Tianjin	Shijiazhuang	Zhengzhou	Dif.
Gender [a] (Male)	0.48	0.53	0.53	0.43	
Age					
30 and Below	35.5%	34.0%	34.7%	34.8%	***
31-40	21.5%	22.3%	24.5%	32.9%	
41-50	24.5%	23.5%	16.3%	21.0%	
51-60	8.5%	13.8%	9.2%	7.6%	
Above 60	9%	6.1%	14.3%	1.4%	
No Answer	1%	0.4%	1%	2.4%	
Education					
Middle School and Below	6.0%	15.4%	13.3%	12.9%	**
High School	21.0%	28.7%	29.6%	26.7%	
College and Higher	71.0%	50.6%	55.1%	55.2%	
No Answer	2.0%	2.3%	2.0%	5.2%	
Income (yuan/month) [b]					
Below 2500	30.5%	49.0%	76.5%	50.5%	***
2500-4000	26.0%	26.3%	11.2%	20.0%	
Above 4000	35.0%	9.7%	7.1%	16.7%	
No Answer	8.5%	15%	5.1%	12.9%	
Household Size	3.15	3.05	3.55	3.42	***
Job					
Public Sectors	40.5%	27.9%	19.4%	36.2%	***
Private Sectors	35.5%	42.5%	53.1%	35.2%	
Retired	10.5%	12.6%	15.3%	4.8%	
Unemployed	6.5%	10.1%	2.0%	4.8%	
No Answer	7%	6.9%	10.2%	19%	
Residence (year)					
Below 5	13.5%	4.0%	14.3%	12.9%	***
5-10	26.5%	5.3%	16.3%	21.4%	
10-20	16.5%	13.8%	18.4%	28.1%	
Over 20	42.5%	75.3%	49.0%	30.0%	
No Answer	1.0%	2.0%	2.0%	7.6%	
Visit [c]	0.24	0.11	0.10	0.09	***
Relatives [d]	0.21	0.17	0.17	0.10	*

[a] Gender is represented by a binary variable whereby female=0 and male=1.
[b] This variable refers to respondents' personal gross monthly income.
[c] This variable refers to whether the respondents had visited the water supply areas of the middle-route water transfer project. No=0, Yes=1
[d] This variable refers to whether the respondents have relatives or close friends in the water supply areas. No=0, Yes=1

Particular attention is paid to the difference in the income of respondents in the four cities. As shown in Table 4.1, while respondents at the lowest income level (Below 2500 yuan/month) accounted for the highest percentage in Shijiazhuang (77%), those at the highest level (Above 4000 yuan/month) accounted for the highest percentage in Beijing (35%). This is consistent with the fact that the annual disposal income per capita is lowest in Shijiazhuang and highest in Beijing (Table 3.1). The income levels shown in Table 4.1 were chosen because preliminary analysis found these levels helpful to produce better modelling results. The original income levels in the survey questionnaire (Appendix 1) ranged from “Below 1500 yuan/month” to “Over 20,000 yuan/month”.

Further assessment of the representativeness of the sample of residents is difficult due to the lack of comparable reference data. The available census data, without mentioning its lack of detailed categorization of respondents’ characteristics, include residents in both urban and rural areas under the administration of the city governments, but this study focused on urban residents since the water transfer project mainly aimed to provide drinking water for the urban areas in the north. So this survey actually targeted at different population to the census. Nevertheless, some extent of similarity can be found between the results of this survey and the census data. For example, the percentage of male residents in Tianjin was 52% in the census and 53% in this survey. The percentage of residents at high school education level in Beijing was 21% in both the census and this survey, and the average household size was 3.47 in Shijiazhuang and 3.55 in this survey. Additionally, some similar results of respondents’ characteristics can also be found between this survey and the literature (Du and Mendelsohn 2011; Guo *et al.* 2014). In general, it is fair to say that this survey has at least modestly represented the targeted urban residents in the four cities.

In addition to the respondents’ characteristics, other information was also collected in the survey regarding respondents’ environmental awareness, knowledge, their opinions about the water transfer project, the policy instrument of Ecological Compensation (EC) [39] and other water-related issues (Table 4.2). This information, together with respondents’ characteristics and the proposed increments in water price, was treated as explanatory variables which help to understand respondents’ answers to the WTP questions.

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[39] As explained in the literature review chapter, EC was treated as an interchangeable term with PES in this study. EC was use in the survey questionnaire of this study because it was the indigenous term used by the governments and mass media in China.

Table 4.2 Explanatory Variables of Respondents' Environmental Awareness, Knowledge and Opinions

Significance Level: 0.001 ***, 0.01 **, 0.05 *

Perceive-shortage: perception of water supply in the city. **Opinion-service**: opinion about the current tap water service. **Know-bill**: know their own water bills Yes=1, No=0. **Know-price**: know the current water price, Yes=1, No=0. **Heard-SNWTP**: have heard about the water transfer project, Yes=1, No=0. **Know-benefits**: know the potential benefits of the SNWTP, from 0 (know nothing) to 4 (know all the four major benefits). **Heard-mid-route**: have heard about the specific middle rout project, Yes=1, No=0. **Know-reservoir**: know the Danjiangkou Reservoir as the start of the middle route project, Yes=1, No=0. **Heard-EC**: have heard the policy of Ecological Compensation, **Understand-EC**: can correctly tell the general idea of EC, Yes=1, No=0. **Opinion-EC**: opinion about the idea of EC.

Explanatory Variable	Beijing	Tianjin	Shijiazhuang	Zhengzhou	Dif.
Perceive-shortage					
Abundant	35.5%	47.4%	29.6%	34.3%	
Moderate	27.5%	30.8%	45.9%	39.0%	***
Scarce	33.5%	19.8%	21.4%	19.0%	
No Answer	3.5%	2.0%	3.1%	7.7%	
Opinion-service					
Satisfactory	38.5%	47.4%	28.6%	32.9%	
Acceptable	43.0%	42.1%	50.0%	41.9%	***
Dissatisfactory	16.5%	9.3%	21.4%	22.4%	
No Answer	2.0%	1.2%	0.0%	2.9%	
Know-bill	0.48	0.55	0.62	0.43	**
Know-price	0.33	0.44	0.41	0.35	
Heard-SNWTP	0.96	0.94	0.95	0.92	
Know-benefits	1.87	1.87	1.39	1.59	***
Heard-mid-route	0.37	0.25	0.33	0.43	***
Know-reservoir	0.14	0.01	0.11	0.14	***
Heard-EC	0.24	0.19	0.13	0.26	*
Understand-EC	0.09	0.06	0.01	0.02	**
Opinion-EC					
Highly Agree	20.5%	13.4%	18.4%	12.9%	
Agree	49.5%	37.7%	60.2%	33.3%	
Not Sure	16.0%	19.4%	8.2%	20.5%	***
Disagree	7.5%	3.6%	5.1%	15.2%	
Highly Disagree	2.0%	2.8%	1.0%	7.1%	
No Answer	4.5%	23.1%	7.1%	11.0%	

In fact, apart from serving as the explanatory variables for modelling analysis, the information of respondents' environmental awareness, knowledge and opinions itself also provides useful and interesting findings. The survey results show that only 19%-34% of respondents in the four cities thought the water supply in their cities was scarce despite the severe water shortage in all the four cities. On the other hand, 75%-89% of respondents in the four cities felt that the current tap water service was satisfactory or acceptable. This interesting contrast of low awareness of water shortage and high satisfaction of water service implies that the city governments' endeavour to secure water supply may have overprotected the residents from realizing the severe water shortage problem of the four cities.

Furthermore, about half of the respondents in the four cities (43%-62%) knew approximately how much their water bills were, and only 33%-44% could tell the current water price, which indicate the necessity of providing the relevant information before asking the WTP questions to ensure that the respondents knew the implication of their answers to the proposed increments in water price.

Over 90% of respondents in the four cities had heard about the SNWTP before the survey, but substantially fewer respondents (25%-43%) had heard about the specific middle route of the SNWTP. Even fewer (1-14%) of them knew the Danjiangkou Reservoir as the major water supply area of the middle route project. With regard to the knowledge and opinions about EC, only 13%-26% of respondents in the four cities had heard about the EC policy, and very few of them (1%-9%) could correctly describe its general idea. After a brief introduction of EC by the interviewers in the survey, the minority of the respondents (6%-22%) showed clearly opposing attitudes (Disagree or Highly Disagree) while 46%-78% of them showed clearly supportive attitudes (Agree or Highly Agree).

The results above show that respondents in the four cities generally had quite limited knowledge about the middle route project and the EC policy. Implications of this finding will be discussed after the modelling analysis revealed the effect of this knowledge on respondents' WTP for water protection. Additionally, similar to the case of respondents' characteristics, significant differences were found in all the aforementioned awareness, knowledge and opinions (except Know-price and Heard-SNWTP) between respondents in different cities, which again implies the need of building individual models for respondents in each city.

4.2 Non-parametric Model Estimates of WTP for Water protection

As explained in the Methodology chapter, a non-parametric model (Haab and McConnell 2002; Carson and Hanemann 2005; Akram and Olmstead 2011) was used in this study to estimate the lower bound of respondents' mean WTP. The only information needed for this estimation was the percentages of *no* answer to different offered prices (i.e. increments in water price) [40]. This estimation also required a monotonic distribution of the percentages of *no* answer. When the original percentages of *no* answer from the survey results were not monotonically increasing with the offered price, a merging and smoothing procedure was applied to impose the restriction of monotonicity.

Figure 4.1 shows the original percentages of *no* answer in four cities. The data of Tianjin and Zhengzhou behaved very well in terms of monotonicity, thus no smoothing procedure was needed. When the offered price increased from 0.1 to 1.5 yuan/m^3, the percentage of *no* answer increased from 42% to 85% in Tianjin and from 48% to 93% in Zhengzhou. In general, respondents in Shijiazhuang did give more *no* answers to larger increments in water price, but the data was not perfectly monotonically distributed, which may be attributed to the relatively small number of respondents in this city.

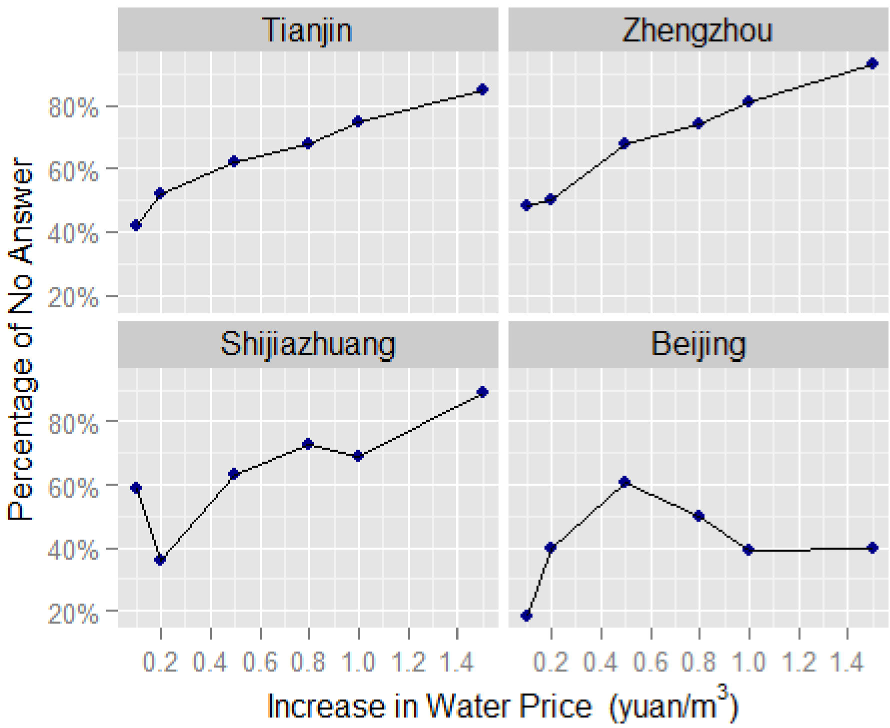

Figure 4.1 Original Percentages of *No* Answer in Four Cities

[40] A *no* answer meant that the respondent's WTP was less than the proposed increment in water price, thus the percentages of *no* answer to a series of increments in water price helped to construct the cumulative density function of WTP whereby the mean WTP was estimated.

The data of Beijing exhibited more violation of monotonicity when the offered price exceeded 0.5 yuan/m^3. However, this non-monotonicity does not necessarily imply that the data of Beijing was poor in quality. A possible explanation is that the increase in water price alone could not well explain the percentage of *no* answer in this city and there were other variables that strongly influenced respondents' answers. These influential variables cannot be revealed by the non-parametric model, but they will be investigated in the parametric models in the next section. To proceed with the non-parametric model, the non-monotonicity of the data of Shijiazhuang and Beijing was overcome by the smoothing procedure explained in Section 3.2.1.

Figure 4.2 shows the data of Shijiazhuang and Beijing before and after imposing the monotonicity. For Shijiazhuang, the original data points at the increments of 0.1 and 0.2 yuan/m^3 were merged as a new data point at 0.1 yuan/m^3, and the original data points at 0.8 and 1.0 yuan/m^3 were merged at a new data point at 0.8 yuan/m^3. For Beijing, the original data points at 0.5, 0.8, 1.0 and 1.5 yuan/m^3 were all merged at a new data point at 0.5 yuan/m^3.

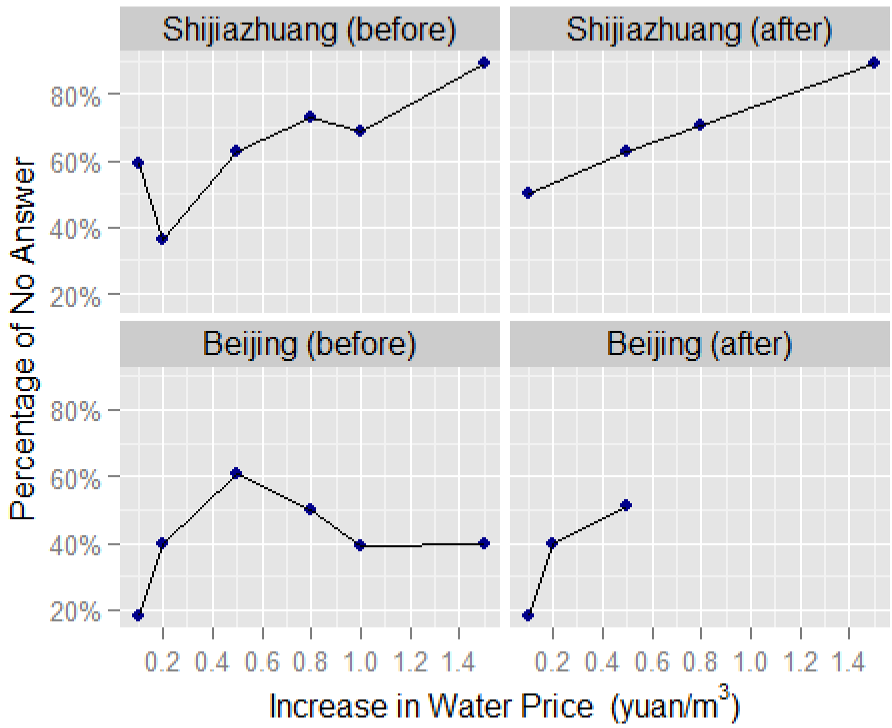

Figure 4.2 Imposing Monotonicity on the Data of Shijiazhuang and Beijing for Non-parametric Estimation

After ensuring the monotonicity of the datasets of all the four cities, the lower bound of respondents' mean WTP, its variance and 95% confidence intervals were estimated by the non-parametric model. The results are presented in Table 4.3.

Table 4.3 WTP Estimates of the Non-parametric Model (yuan/m^3)

Number of respondents: Beijing (200), Tianjin (247), Shijiazhuang (98) and Zhengzhou (210)

City	Mean WTP [a]	Variance	CI (L) [b]	CI (U)
Tianjin	0.44 (10.1%)	0.0027	0.44	0.45
Shijiazhuang	0.37 (10.1%)	0.0086	0.35	0.38
Zhengzhou	0.35 (14.5%)	0.0025	0.34	0.36
Beijing	0.29 (7.20%)	0.0003	0.29	0.29

[a] Values in the parentheses are the proportions of the mean WTP to the current water prices in the four cities.
[b] CI (L) and CI (U) are the lower and upper endpoints of the 95% confidence intervals.

The estimation results of the non-parametric model show that, on average, respondents in Tianjin were willing to pay the largest increase in water price (0.44 yuan/m^3) for water protection, while those in Beijing were willing to pay the lowest increase (0.29 yuan/m^3). Respondents in Shijiazhuang and Zhengzhou had similar mean WTP of 0.37 and 0.35 yuan/m^3, respectively. The variances of the estimation results were very trivial. Even the largest variance was only 0.0086 yuan/m^3 for the estimates of Shijiazhuang, where the number of respondents was smallest in the four cities.

Estimation of the non-parametric model was simple and direct. But cautioun is needed in using the results for further analysis, since this model did not take account of factors like respondents' income and their environmental knowledge which might strongly influence their WTP, and the smoothing procedure for imposing the monotonicity might also introduce bias in the WTP estimates. As a result, more sophisticated parametric logit models were applied in Section 4.3 to investigate respondents' WTP for water protection with influential factors. The WTP estimates of both non-parametric and parametric models are compared in Section 4.5.

4.3 Parametric Models for Estimating Public WTP for Water protection

This section focuses on individual analysis of parametric logit models for respondents in each of the four cities. For each city, three logit models, i.e. the initial full model containing all the explanatory variables, the best subset model determined by the automatic best subset regression procedure and the final stepwise regression model determined by the integrated procedure of automatic stepwise regression and manual adjustment, are compared to justify the choice of the final stepwise regression model for further analysis. Then the explanatory variables in the final stepwise model of each city are discussed in detail regarding their influence on respondents' answers to the WTP question.

4.3.1 Parametric WTP Models for Respondents in Beijing

Table 4.4 presents the estimation results of three models for respondents in Beijing. The initial full model with all the 20 explanatory variables[41] had a prediction error rate of 0.24. Its overall model significance was 0.02, which indicates that this model is significantly better than the *null model* (the regression model with no variable but only a constant). However, the majority of the 20 explanatory variables in the initial full model were not significant even at the 0.1 level, and the model contained only 124 observations (respondents) while a total of 200 observations were collected in the survey of Beijing.

The best subset regression model was determined by comparing all the 2^{20} = 1,048,576 regression models which included a subset of the 20 explanatory variables in the initial full model and choosing the model with the smallest AIC. Compared with the initial full model, the best subset model with 11 explanatory variables substantially reduced the AIC from 176.13 to 152.99 and improved the overall model significance from 0.02 to 4.34×10^{-5}, but the prediction error rate increased from 0.24 to 0.28. Despite these superiorities over the initial full model, the best subset model only contained slightly more observations (128) and 5 out of its 11 explanatory variables were still insignificant.

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[41] The variable Heard-SNWTP was removed from the initial full model because only 8 respondents had not heard about the water transfer project before the survey, and this number was too small for regression analysis.

Table 4.4 Parametric WTP Models for Respondents in Beijing

Significance Level: 0.001 ***, 0.01 **, 0.05 *, 0.1 °

Variable	Coefficient (Standard Error)		
	Initial Full Model	**Best Subset Model**	**Final Stepwise Model**
(Intercept)	4.01 (1.68) *	3.76 (1.22) **	2.49 (0.92) **
Perceive-shortage			
Moderate	-0.55 (0.76)	-0.32 (0.57)	
Scarce	-0.87 (0.76)	-0.66 (0.59)	
Opinion-service			
Acceptable	0.09 (0.55)		
Dissatisfactory	-0.15 (0.90)		
Know-bill	1.14 (0.66) °	0.68 (0.46)	
Know-price	0.24 (0.80)		
Know-benefits	0.34 (0.27)	0.33 (0.22)	0.33 (0.19) °
Heard-mid-route	0.88 (0.64)		
Know-reservoir	0.75 (0.93)		
Heard-EC	-3.07 (1.18) **	-1.44 (0.80) °	
Understand-EC	3.30 (1.42) *	2.09 (1.10) °	1.43 (0.81) °
Opinion-EC	-1.31 (0.36) ***	-0.92 (0.29) **	-0.71 (0.23) **
Price-increase	-1.60 (0.67) *	-1.25 (0.56) *	-0.92 (0.47) °
Household-size	-0.46 (0.21) *	-0.44 (0.17) *	-0.48 (0.16) **
Income (yuan/month)			
2500-4000	0.68 (0.79)	*Above 2500*	*Above 2500*
Above 4000	0.15 (0.86)	0.53 (0.52)	1.13 (0.44) **
Gender (Male)	0.09 (0.50)		
Age			
31-40	0.08 (0.73)	*Above 50*	
41-50	0.36 (0.70)	2.30 (1.17) *	
50-60	3.30 (1.71) °		
Above 60	2.92 (2.23)		
Education			
High School	0.73 (0.91)		
Middle School or Below	-1.94 (1.75)		
Job			
Private Sectors	-0.36 (0.63)	*Without Job*	
Retired & Unemployed	-1.93 (1.64)	-2.12 (1.21) °	
Residence (year)			
10-20	1.19 (0.89)		
5-10	-0.24 (0.68)		
Below 5	1.22 (0.95)		
Visit	1.04 (0.75)		
Relatives	-0.48 (0.74)		
Model Evaluation Indicator			
AIC	176.13	152.99	170.93
Prediction Error Rate	0.24 (124) [a]	0.27 (128)	0.24 (149)
Overall Significance	0.02	4.34×10^{-5}	5.34×10^{-8}

[a] Number in the parentheses is the number of observations (respondents) included in this model.

The final stepwise regression model selected six explanatory variables from the initial full model and increased the observations to 148. The 200-148=52 omitted observations were mainly caused by missing values of the response variable (26 respondents did not give a clear *yes/no* answer to the WTP question) and the explanatory variables of Income and Opinion-EC (17 respondents refused to give information about their income and 9 respondents chose to give no opinion about the idea of Ecological Compensation). Compared with the best subset model, the final stepwise regression model had a larger AIC due to the larger number of observations, but it had a smaller prediction error rate (0.24 versus 0.28) and considerably higher overall model significance (5.34×10^{-8} versus 4.34×10^{-5}). As a result, this final stepwise regression model was used as the final model for further analysis.

The improvement of model fitting from the initial full model to the best subset model and the final stepwise regression model justifies the model building and selection procedure adopted by this study. Moreover, it can be noted that the variables of Understand-EC, Opinion-EC, Price-increase and Household Size were all significant at least at the 0.1 level in all the three models, which reflects the consistency between them.

It is noteworthy that the variable Income in the initial full model was categorized into three levels, i.e. the reference level of “below 2500 yuan/month” (omitted in Table 4.4 for saving space) and the other two levels of 2500-4000 and above 4000 yuan/month, and neither of the two levels was significant in the initial full model. However, after merging the two levels, the new income level of “above 2500 yuan/month” became significant at the 0.01 level in the final stepwise model. This is an example of adjusting the categorization of explanatory variables for better revealing their effects on respondents’ *yes* answer to the WTP question. It can also be noticed that although the same adjustment of categorization was applied, the variable Income in the best subset model was not significant, which may be explained by the different number of observations in the two models. The same reason may also apply to other variables that showed different levels of significance in different models.

Figure 4.3 provides an intuitive visualization of the estimated coefficients of the six explanatory variables in the final stepwise regression model (the last column in Table 4.4). As explained in the Methodology chapter, the coefficients in logit models represent the changes in the logit (log-odds) of the *yes* answer that are caused by a unit change in the explanatory variables. And the exponents of the coefficients represent the odds ratios of *yes* answer between two groups of respondents who have a unit difference in the explanatory variables.

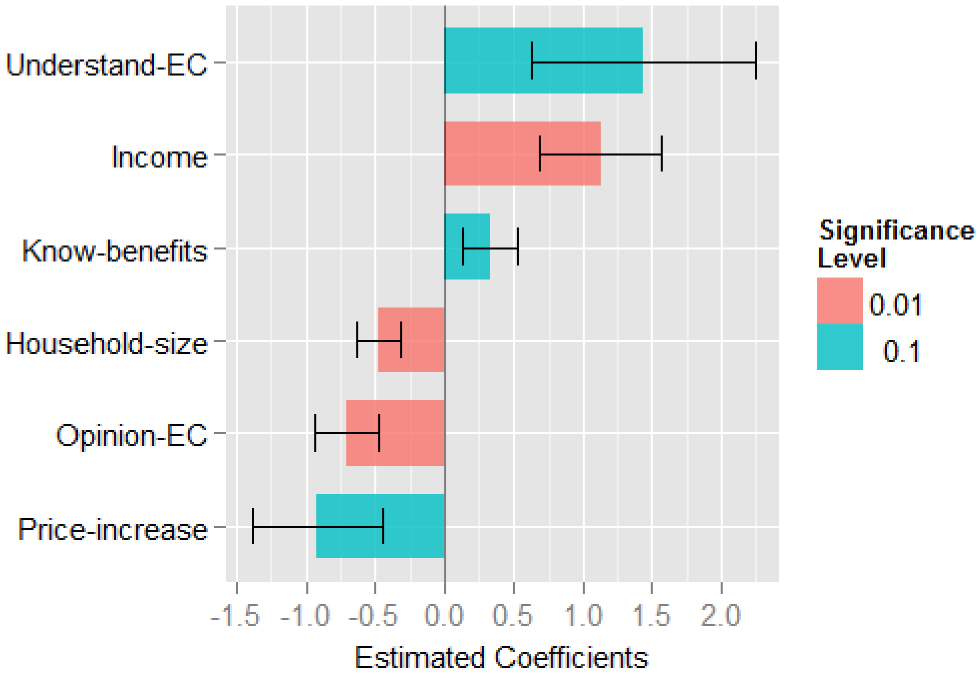

Figure 4.3 Explanatory Variables in the Final Model of Beijing

Colour bars represent the estimated coefficients in terms of logit (log-odds) of the probability of *yes* answer to the WTP question. Thin lines represent the estimated values ± standard errors.

The variables Understand-EC, Income and Know-benefits were found to have positive coefficients of 1.43, 1.13 and 0.33 respectively. That is to say, the odds of answering *yes* to the WTP question (i.e. accepting the proposed increase in water price) by respondents who could correctly describe the general idea of Ecological Compensation were $e^{1.43}$ = 4.18 times larger than the odds of respondents who could not. And the odds of respondents who received gross income of more than 2500 yuan/month in Beijing were $e^{1.13}$=3.10 times larger than those below that income level. Moreover, knowing each additional benefit of the SNWTP would make the odds of respondents' yes answer $e^{0.33}$=1.39 times larger. In other words, the odds of accepting a higher price by respondents who knew all the four major potential benefits of the water transfer project were $e^{0.33\times4}$=3.74 times larger than those who knew none of them. Among the three positive variables, Income (above 2500 yuan/month) was significant at the 0.01 level while the other two were only significant at the 0.1 level.

On the other hand, the variables Price-increase, Opinion-EC and Household-size were found to have negative coefficients of -0.92, -0.71 and -0.48 respectively. This indicates that an increase of 1 yuan/m^3 in the water price would cause a decline in the odds of *yes* answer by 60% ($1-e^{-0.92}=0.60$). With regard to respondents' opinion about the idea of Ecological Compensation (Opinion-EC), for the coding numbers from 1 to 5 which represent the opinion from Highly Agree to Highly Disagree, each increase in the number (i.e. being more opposed against EC) would decrease the odds by 49% ($1-e^{-0.71}= 0.51$). That is to say, respondents who highly disagreed with the idea of EC only had 5.8% ($e^{-0.71\times4}=0.058$) of the odds of accepting a higher price as those who highly agreed with EC had. Furthermore, each additional household member would lead to a decline in the odds of *yes* answer by 38% ($1-e^{-0.48}=0.38$). Among the three negative variables, Opinion-EC and Household Size were both significant at the 0.01 level while Price-increase was only significant at the 0.1 level (in fact, the exact p-value was 0.0503, which was very close to the 0.05 significance level).

Remembering that in the preceding section of the non-parametric model, the proportion of *no* answer to the WTP question in the survey of Beijing was not monotonically increasing with the rise in water price (Figure 4.1). The results of the estimated coefficients and significance levels of the six explanatory variables in this final model confirms the earlier explanation that the increase in water price alone could not well explain the percentage of *no* answer of respondents in Beijing and there were other variables that strongly influenced respondents' answers to the WTP question.

4.3.2 Parametric WTP Models for Respondents in Tianjin

Table 4.5 presents the estimation results of the initial full model, the best subset regression model and the final stepwise regression model for respondents in Tianjin.

Table 4.5 Parametric WTP Models for Respondent in Tianjin

Significance Level: 0.001 ***, 0.01 **, 0.05 *, 0.1 °

Variable	Coefficient (Standard Error)		
	Initial Full Model	Best Subset Model	Final Stepwise Model
(Intercept)	2.12 (2.13)	0.79 (1.14)	0.11 (0.80)
Perceive-shortage			
Moderate	1.62 (0.81) *	*Not Abundant*	
Scarce	1.11 (1.07)	0.81 (0.56)	
Opinion-service			
Acceptable	-1.87 (1.01) °	-1.31 (0.70) °	*Numeric* [a]
Dissatisfactory	-4.10 (1.71) *	-2.68 (1.22) *	-1.01 (0.34) **
Know-bill	-0.03 (0.79)		
Know-price	0.73 (0.74)	0.81 (0.52)	
Know-benefits	0.24 (0.30)	0.32 (0.22)	
Heard-mid-route	0.60 (0.71)		0.84 (0.46) °
Heard-EC	1.95 (1.04) °	1.49 (0.66) *	1.37 (0.59) *
Understand-EC	0.28 (1.49)		
Opinion-EC	-0.70 (0.47)	-0.57 (0.35)	
Price-increase	-1.86 (0.75) *	-1.50 (0.58) **	-1.80 (0.50) ***
Household-size	-0.37 (0.34)		
Income (yuan/month)			
2500-4000	0.79 (0.83)	0.49 (0.58)	*Numeric*
Above 4000	2.28 (1.23) °	2.15 (0.85) *	0.91 (0.33) **
Gender (Male)	-0.44 (0.68)	-0.73 (0.51)	
Age			
31-40	0.85 (0.81)		
41-50	-0.84 (1.20)		*Above 50*
50-60 & Above 60	1.96 (1.39)		1.62 (0.71) *
Job			
Private Sectors	-0.42 (0.69)		
Retired	-3.57 (1.71) *	*Without Job*	*Without Job*
Unemployed	-0.34 (1.65)	-1.18 (0.88)	-2.67 (0.84) **
Education			
High School	-0.37 (0.81)		
Middle School or Below	-1.09 (1.38)		
Residence			
10-20	-1.33 (1.04)	*Less than 20*	
5-10	-0.27 (1.38)	-0.76 (0.67)	
Below 5	-1.14 (2.13)		
Visit	-1.39 (1.17)		
Relatives	1.36 (1.07)		1.03 (0.57) °
Model Evaluation Indicator			
AIC	149.77	129.99	161.90
Prediction Error Rate [b]	0.18 (109)	0.26 (111)	0.24 (155)
Overall Significance	0.13×10^{-2}	9.35×10^{-6}	1.20×10^{-10}

[a] *Numeric* refers to numeric variable with linear effect.
[b] Number in the parentheses is the number of observations (respondents).

Respondents in Tianjin seemed more reluctant to give their opinions and information in the survey, which caused a large number of missing values in the dataset. For example, 57 (23.2%) respondents chose to give no opinion about the general idea of Ecological Compensation (Opinion-EC) whereas only 9 (4.5%) respondents in Beijing did so. As a result, the initial full model with all the 19 explanatory variables[42] contained only 109 observations while the survey actually collected a total of 247 observations. Nevertheless, the initial full model still exhibited some extent of ability to explain respondents' answers to the WTP question given its prediction error rate of 0.18 and overall model significance of 1.30×10^{-3}. In comparison, the best subset model of the Tianjin survey with 11 explanatory variables and similar observations (111) reduced the AIC from 149.77 to 129.99 and raised the overall model significance from 1.30×10^{-3} to 9.35×10^{-6}, but the prediction error rate rose from 0.18 to 0.26.

The final stepwise model selected 8 out of the 19 explanatory variables of the initial full model and substantially increased the observations from 109 to 155. The 92 omitted observations were caused by missing values of the response variable (48 respondents did not give a clear yes/no answer to the WTP question) and explanatory variables that showed significant effects on respondents' answers to the WTP question but involved private information that some respondents refused to give such as Income (37 missing values) and Job (17 missing values). Despite having a larger AIC (161.90) than the other two models due to the substantial increase in observations, the final stepwise model maintained a moderate prediction error rate of 0.24. This means that the final stepwise model could correctly predicted 155 × (1-0.24) =118 respondents' answers to the WTP question whereas the initial full model could only provide 109 × (1-0.18) = 89 correct predictions. More importantly, the overall model significance of the final stepwise model was much higher than the other two models (1.20×10^{-10}). In spite of the considerable difference in the goodness of fit, the variables Opinion-service, Heard-EC, Price-increase, Income, and Job were significant at least at the 0.1 level in all the three models, which reflects the underlying consistency between the three models.

Noticing that the Income variable was categorized into three levels (the reference level of below 2500 yuan/month is not listed in Table 4.5) in the

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[42] The variable of Heard-SNWTP and Understand-EC were removed for a similar reason explained in Footnote 41.

initial full model but only one of the levels (above 4000 yuan/month) was significant at the 0.1 level. In the best subset model which had less explanatory variables and better goodness of fit, the income level of “above 4000 yuan/month” became significant at the 0.05 level. Then in the final stepwise regression model with even less variables, better goodness of fit and more observations, the variable Income was treated as a numeric variable (with linear effects) and became significant at the 0.01 level. This is an example of improving model fitting and better revealing variables’ effects on respondents’ answers to the WTP question by removing unnecessary explanatory variables and adjusting the coding of variables. More examples can be easily found on other variables (such as Price-increase, of which the significance level was 0.05, 0.01 and 0.001 respectively in the three models) and in the results of other cities. Similar justification will not be repeated in later discussion.

Figure 4.4 illustrates the eight explanatory variables in the final stepwise model for the respondents in Tianjin. The variables Age (above 50), Heard-EC, Relatives, Income and Heard-mid-route were found to be positively influential on respondents’ *yes* answer to the WTP question with the coefficients of 1.62, 1.37, 1.03, 0.91 and 0.84 respectively. That is to say, the odds of accepting an increase in water price by respondents older than 50 were 5.05 ($e^{1.62}$) times larger than the odds of younger respondents. Those who had heard about Ecological Compensation were more likely to accept an increase in water price and the odds of *yes* answer were 3.94 ($e^{1.37}$) times larger.

Respondents who had relatives or close friends living in the water source area had the acceptance odds 2.8 ($e^{1.03}$) times larger. Compared with respondents whose gross income was below 2500 yuan/month, the acceptance odds of respondents who earned 2500-4000 yuan/month and more than 4000 yuan/month were 2.48 ($e^{0.91}$) and 6.17 ($e^{0.91\times2}$) times larger respectively. Additionally, respondents who had heard about the specific middle route of the SNWTP had the acceptance odds 2.32($e^{0.84}$) times larger. For the five positive variables, Income was at the highest significance level of 0.01, Age (above 50) and Heard-EC were both at the 0.05 significance level while Relatives and Heard-mid-route were only significant at the 0.1 level.

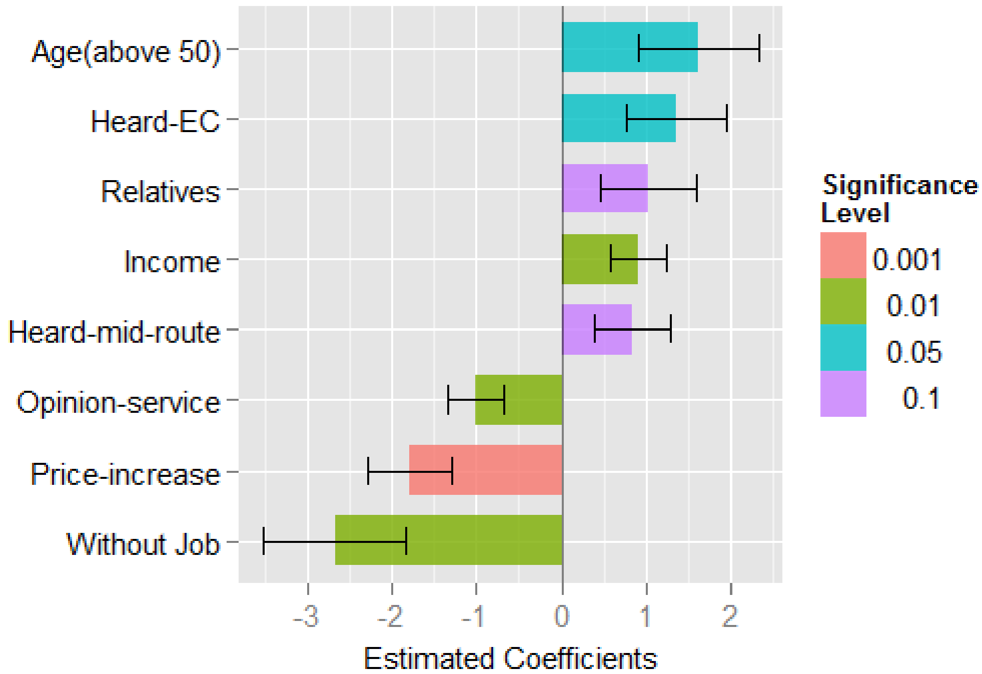

Figure 4.4 Explanatory Variables in the Final Model of Tianjin

Without Job is the merged category of the variable of Job, referring to respondents who were retired or unemployed.

The variable Job (retired & unemployed, i.e. “Without Job” in Figure 4.4), Price-increase and Opinion-service were found to be negatively influential on respondents’ *yes* answer to the WTP question with the coefficients of -2.67, -1.80 and -1.01 respectively. This means that the odds of accepting a higher water price by respondents in retirement or unemployment were only 6.9% ($e^{-2.67}$) of the odds of respondents who had a job. For an increase of 1 yuan/m^3 in the water price, the acceptance odds would decline by 83% (1 - $e^{-1.80}$). Compared with respondents who felt satisfied about the current tap water service, those who thought it acceptable and dissatisfactory were less likely to accept an increase in water price and the odds of *yes* answer declined by 64% (1-$e^{-1.01}$) and 87% (1-$e^{-1.01*2}$) respectively.

The finding of smaller odds of accepting a higher water price by respondents who were less satisfied about the current tap water service seems unexpected in the first place since the water transfer project is assumed to improve the tap water quality in the northern cities, so respondents should be more willing to pay a higher water price if they were not satisfied about the current tap water service. However, further analysis of the survey results found that among the 30 respondents in Tianjin who had given the reasons for their dissatisfaction about the tap water service, 25 of them mentioned water quality issues (turbidity, odour and taste), but 28 of them did not know the water transfer project could improve tap water quality in the northern cities. In other words, these respondents were less willing to pay a higher water price probably because they did not want to pay additional money for a service that (they thought) could not solve their water quality problem.

Lastly, among the three negative variables, Job and Opinion-service were both significant at the 0.01 level, and Price-increase was highly significant at the 0.001 level, which corresponds with the findings in the section of non-parametric model that the data of Tianjin survey behaved quite well in terms of monotonicity (Figure 4.1).

4.3.3 Parametric WTP Models for Respondents in Shijiazhuang

Only 98 questionnaires were collected in Shijiazhuang because only two interviewers were successfully recruited to conduct the survey in this city. As shown below, less substantial improvement was achieved in model fitting for the dataset of this city compared with Beijing and Tianjin, yet the modelling analysis revealed some useful and interesting results.

Table 4.6 presents the estimation results of the three models for respondents in Shijiazhuang. In spite of having a decent prediction error rate of 0.17, the initial full model of the Shijiazhuang survey with all the 19 explanatory variables[43] contained only 60 observations and the overall model significance was merely 0.04. In comparison, the best subset model with 12 variables reduced the AIC from 96.06 to 77.05 and improved the overall model significance to 7.45×10^{-4}, but the prediction error rate rose to 0.23 with slightly more observations (62). The final stepwise model selected 7 out of the 19 explanatory variables in the initial full model and increased the observations from 60 to 72. The 26 omitted observations were mainly caused by missing values of the response variable (13 respondents did not give a clear yes/no answer to the WTP question) and the explanatory variables of Opinion-EC (7 missing values) and Income (5 missing values). Due to the increase in the total observations, the AIC of the final stepwise model was larger than the best subset model but still smaller than the initial final model. The overall model significance of the final stepwise model (1.27×10^{-3}) was also between that of the other two models.

[43] The variable of Heard-SNWTP and Understand-EC were removed for similar reason explained in Footnote 41.

Table 4.6 Parametric WTP Models for Respondents in Shijiazhuang

Significance Level: 0.001 ***, 0.01 **, 0.05 *, 0.1 °

Variable	Coefficient (Standard Error)		
	Initial Full Model	**Best Subset Model**	**Final Stepwise Model**
(Intercept)	3.98 (3.86)	1.86 (2.47)	0.99 (1.22)
Perceive-shortage			
Moderate	5.69 (2.81) *	*Not Abundant*	*Not Abundant*
Scarce	5.99 (3.37) °	4.14 (1.71) *	0.59 (0.66)
Opinion-service			
Acceptable	-0.13 (1.42)		
Dissatisfactory	-2.13 (2.18)		
Know-bill	1.17 (1.32)	1.63 (1.03)	
Know-price	0.39 (1.85)		
Know-benefits	-0.90 (1.01)	-0.31 (0.63)	
Heard-mid-route	-3.54 (2.22)	-3.20 (1.36) *	-1.75 (0.87) *
Know-reservoir	5.50 (2.74) °	4.00 (1.94) *	2.46 (1.13) *
Heard-EC	-0.31 (2.20)		
Opinion-EC	-2.53 (1.87)	-1.70 (1.03) °	-0.58 (0.47)
Price-increase	-2.72 (1.45) °	-2.57 (1.18) *	-2.20 (0.86) *
Household-size	0.28 (0.52)		
Income (yuan/month)			
Above 2500	-1.92 (1.93)	-0.35 (1.22)	1.52 (0.79) °
Gender (Male)	-0.88 (1.32)		
Age			
31-40	0.78 (1.41)		
41-50	-1.25 (1.88)		
50-60 & Above 60	0.41 (2.80)		
Job			
Private Sectors	-1.95 (2.05)	-2.12 (1.35)	
Retired & Unemployed	-3.74 (2.51)	-2.01 (1.65)	
Education			
High School	-0.80 (1.61)		
Middle School or Below	1.30 (2.23)		
Residence			
10-20	-2.69 (2.00)	-1.84 (1.30)	
5-10	1.46 (1.93)	1.40 (1.24)	*5-10 year* 2.34 (1.03) *
Below 5	-3.54 (2.74)	-1.50 (1.82)	
Visit	4.10 (2.84)	3.09 (1.77) °	
Relatives	2.94 (1.59) °	2.26 (1.14) *	
Model Evaluation Indicator			
AIC	96.06	77.05	87.53
Prediction Error Rate [a]	0.17 (60)	0.23 (62)	0.21 (72)
Overall Significance	0.04	7.45×10^{-4}	1.27×10^{-3}

[a] Number in the parentheses is the number of observations (respondents).

As mentioned above, the improvement in model fitting from the initial full model to the final stepwise model was less substantial for the dataset of Shijiazhuang than the case of Beijing and Tianjin. This could be attributed to the relatively small number of the total observations in this city. Nevertheless, the prediction error rate (0.21) of the final stepwise model indicates that it could make 57 correct predictions of respondents' answer to the WTP question, while the initial full model and the best subset model could just make 50 and 48 correct predictions respectively. Since the final stepwise model better accorded with the Principle of Parsimony (i.e. achieving satisfactory model fitting with fewest variables), it was adopted as the final model for further analysis. On the other hand, a certain degree of consistency did exist in the three models as the variables Know-reservoir and Price-increase were both significant at least at the 0.1 level in all the three models.

Figure 4.5 illustrates the seven explanatory variables in the final stepwise model for respondents in Shijiazhuang. The variables Know-reservoir, Residence (5-10), Income (above 2500 yuan/month) and Perceive-shortage (perception of water shortage) were found to have positive coefficients of 2.46, 2.34, 1.52 and 0.59 respectively. This indicates that respondents who knew the Danjiangkou Reservoir as the start (and major water supply area) of the middle route project were more likely to accept the increase in water price and their acceptance odds were 11.70 ($e^{2.46}$) times larger than the odds of respondents who did not know.

Interestingly, respondents who had lived in Shijiazhuang for 5-10 years had the odds ($e^{2.34}$) of accepting a higher price 10.38 times larger than the odds of respondents who had lived in the city for either a shorter or longer time. Perhaps this was because those short-term and temporary (less than 5 year) residents were less interested in paying a higher water price for future benefits of the water resource protection, while those who had lived in the city for more than 10 years had witnessed the substantial increase in water price during the past two decades [44], so they were more averse to any further increase.

[44] The water price in Shijiazhuang was 1.03 yuan/m^3 in 2000, 2.93 yuan/m^3 in 2007 and 3.63 yuan/m^3 at present.

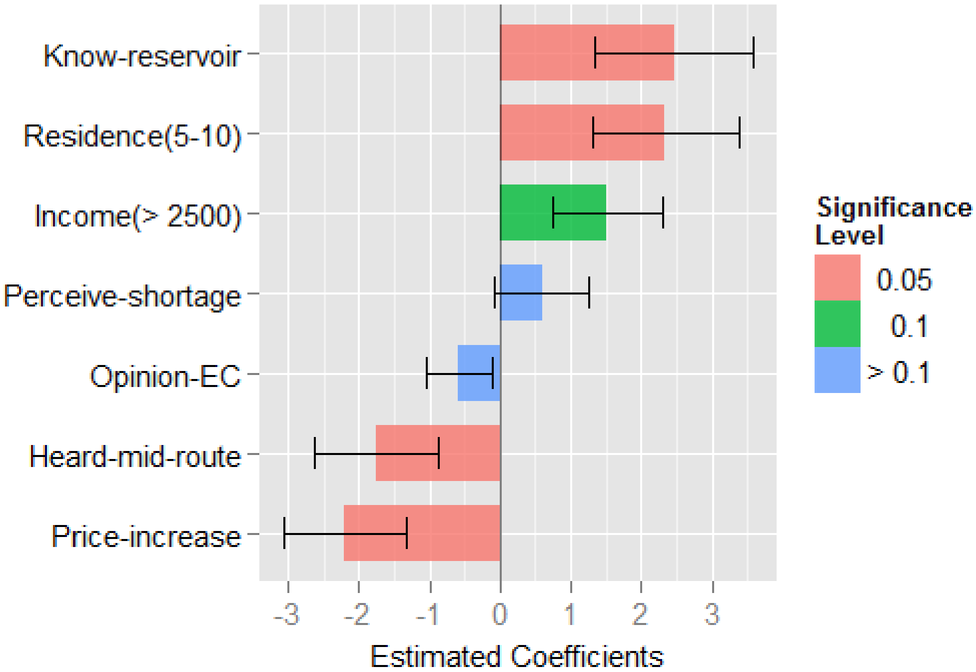

Figure 4.5 Explanatory Variables in the Final Model of Shijiazhuang

The error bar of the variable *P-shortage* stretches across the boundary line of x=0, which means that within the range of the estimated mean ± standard error, the coefficient of this variable is possible to be a minus value. This is an intuitive visualization of the low significance level of this variable[45].

Compared with respondents whose income was less than 2500 yuan/month, those with higher income were more willing to accept a higher water price with the odds 4.57 ($e^{1.52}$) times larger. While the variables Know-reservoir and Residence were both significant at the 0.05 level, Income was significant at the 0.1 level (in fact, the exact p-value of Income was 0.055, which was much closer to 0.05 than to 0.1). The variable Perceive-shortage was below the 0.1 significance level but still retained in the model for its contribution to the overall model fitting. Its positive coefficient and low significance level means that compared with respondents who thought the water supply in Shijiazhuang was Abundant (the reference level which is not shown in Table 4.6), respondents who thought it was Moderate or Scarce might be more likely to give a yes answer to the WTP question and the odds

[45] The variable Opinion-EC was also below the 0.1 significance level but its error bar does not stretch across the boundary of x=0. This is because it has a smaller p-value than the variable of Perceive-shortage (0.22 versus 0.37).

could be 1.80 ($e^{0.59}$) times larger, but the difference would not be statistically significant.

With regard to the negative variables to respondents' acceptance to a higher water price, Price-increase had the coefficient of -2.20 at the 0.05 significance level, indicating that an increase of 1 yuan/m^3 in the water price led to a decrease in the odds of *yes* answer by 89% ($1-e^{-2.20}$). The variable Heard-mid-route was found to have a negative coefficient of -1.75 at the 0.05 significance level, which implies that respondents who had heard about the middle route project had smaller odds (17%, i.e. $e^{-1.75}$) of accepting a higher water price. This is an unexpected result since it would be more reasonable to assume that more knowledge about the water transfer project would make respondents more supportive to the proposal of paying a higher water price for protecting water resources. A fact that may explain this unexpected result is that the northernmost part of the middle route project was completed in 2008 in order to transfer water from Shijiazhuang to Beijing for securing the water supply for the 2008 Olympic Games and later for drought in the summer of the following years. That is to say, instead of benefiting (receiving water) from the middle route project, Shijiazhuang was actually contributing water to the project when the survey was conducted. Respondents who knew this information might therefore be more averse to the increase in water price.

Additionally, the variable Opinion-EC had the coefficient of -0.58 with low significance level (the exact p-value was 0.22), which indicates that for the coding numbers from 1 to 5 which represent the opinions from Highly Agree to Highly Disagree with the idea of Ecological Compensation, each increase in the coding number might led to a decline in the odds of *yes* answer by 44% ($1-e^{-0.58}$), but the difference was not statistically significant. Similar to the variable Perceive-shortage, this variable was not significant but retained in the model because of its contribute to the overall model fitting for the dataset of Shijiazhuang with relatively small number of respondents.

4.3.4 Parametric WTP Models for Respondents in Zhengzhou

Table 4.7 presents the estimation results of the three models for respondents in Zhengzhou. The initial full model with all the 19 explanatory variables had a decent prediction error rate of 0.17 and overall model significance of 1.96×10^{-4}, but it contained only 104 complete observations though 210 questionnaires were actually collected in this city. The best subset model which contained 7 variables and similar observations (108) reduced the AIC from 137.79 to 108.55 and raised the overall model significance to 2.29×10^{-9} with slightly higher prediction error rate of 0.18.

Table 4.7 Parametric WTP Models for Respondents in Zhengzhou

Significance Level: 0.001 ***, 0.01 **, 0.05 *, 0.1 °

Variable	Coefficient (Standard Error)		
	Initial Full Model	**Best Subset Model**	**Final Stepwise Model**
(Intercept)	2.62 (2.22)	1.87 (1.31)	0.34 (0.96)
Perceive-shortage			
Moderate	-1.19 (0.97)	*Not Abundant*	
Scarce	-0.22 (1.38)	-1.17 (0.61) °	
Opinion-service			
Acceptable	-0.14 (0.89)		
Dissatisfactory	-0.36 (1.34)		
Know-bill	-0.37 (0.80)		
Know-price	-0.90 (0.92)		
Know-benefits	0.54 (0.35)	0.35 (0.24)	0.52 (0.22) *
Heard-mid-route	-0.09 (0.81)		
Know-reservoir	1.83 (1.09) °		
Heard-EC	0.28 (0.84)		
Opinion-EC	-0.93 (0.42) *	-0.59 (0.28) *	-0.49 (0.22) *
Price-increase	-3.88 (1.09) ***	-3.30 (0.73) ***	-2.86 (0.64) ***
Household-size	0.18 (0.29)		
Income (yuan/month)			
2500-4000	1.03 (0.99)	*Numeric*	*Numeric*
Above 4000	1.40 (1.05)	0.78 (0.38) *	1.04 (0.34) **
Gender (Male)	-0.91 (0.79)		-0.98 (0.52) °
Age			
31-40	0.14 (0.90)		
41-50	1,32 (1.22)		
50-60 & Above 60	3.37 (2.81)		
Job			
Private Sectors	1.09 (1.04)	0.65 (0.69)	
Retired	-1.96 (3.04)	0.55 (1.39)	
Unemployed	1.46 (1.77)	0.75 (1.46)	
Education			
High School	-0.36 (1.07)	*No college*	
Middle School or Below	-0.49 (1.48)	-0.33 (0.73)	
Residence			
10-20	0.22 (0.93)		
5-10	0.48 (0.94)		
Below 5	1.04 (1.33)		
Visit	-0.29 (1.56)		
Relatives	-1.39 (1.37)		
Model Evaluation Indicator			
AIC	137.79	108.55	120.68
Prediction Error Rate [a]	0.17 (104)	0.18 (108)	0.18 (130)
Overall Significance	1.96×10^{-4}	2.29×10^{-9}	1.41×10^{-12}

[a] Number in the parentheses is the number of observations (respondents).

The final stepwise model selected 5 out of the 19 explanatory variables from the initial full model and included 130 observations. The 80 omitted observations were largely caused by missing values in the response variable (43 respondents did not give a clear yes/no answer to the WTP question) and the explanatory variables of Income (27 missing values) and Opinion-EC (23 missing values). As a results of the increase in total observations, the final stepwise model had a larger AIC (120.68) than the best subset model (yet still smaller than the initial full model). However, the final stepwise model maintained the prediction error rate at 0.18, which means it could correctly predict 108 respondents' answers to the WTP question while the other two models could only provide 86 and 89 correct predictions respectively. More importantly, the overall model significance of the final stepwise model was as impressively high as 1.41×10^{-12}. Meanwhile, the variables Opinion-EC and Price-increase were significant in all the three models at the 0.05 and 0.001 level respectively, reflecting the consistency between the three models.

Figure 4.6 illustrates the five explanatory variables in the final stepwise model for respondents in Zhengzhou. Two of the five variables, Income and Know-benefits were found to have positive coefficients of 1.04 and 0.52 at the significance levels of 0.01 and 0.05 respectively. That is to say, compared with respondents who earned less than *2500* yuan/month, those who earned 2500-4000 yuan/month had 2.83 ($e^{1.04}$) times larger odds of accepting a higher water price, and those who earned more than 4000 yuan/month had 8.00 ($e^{1.04\times2}$) times larger odds to do so.

Moreover, knowing each additional benefit of the SNWTP would make the respondents' odds of accepting the increase in water price 1.68 ($e^{0.52}$) times larger. In other words, respondents who knew all the four benefits of the SNWTP had ($e^{0.52\times4}$) 8.00 times larger odds to accept a higher water price than respondents who knew nothing about it at all. Interestingly, the positive effect of knowing all the four benefits of the SNWTP was equivalent to the effect of earning over 4000 yuan/month, which would both make the odds of yes answer (to the WTP question) 8 times larger. This result reflects the important role of non-economic factors such as environmental knowledge in shaping respondents' WTP for water protection.

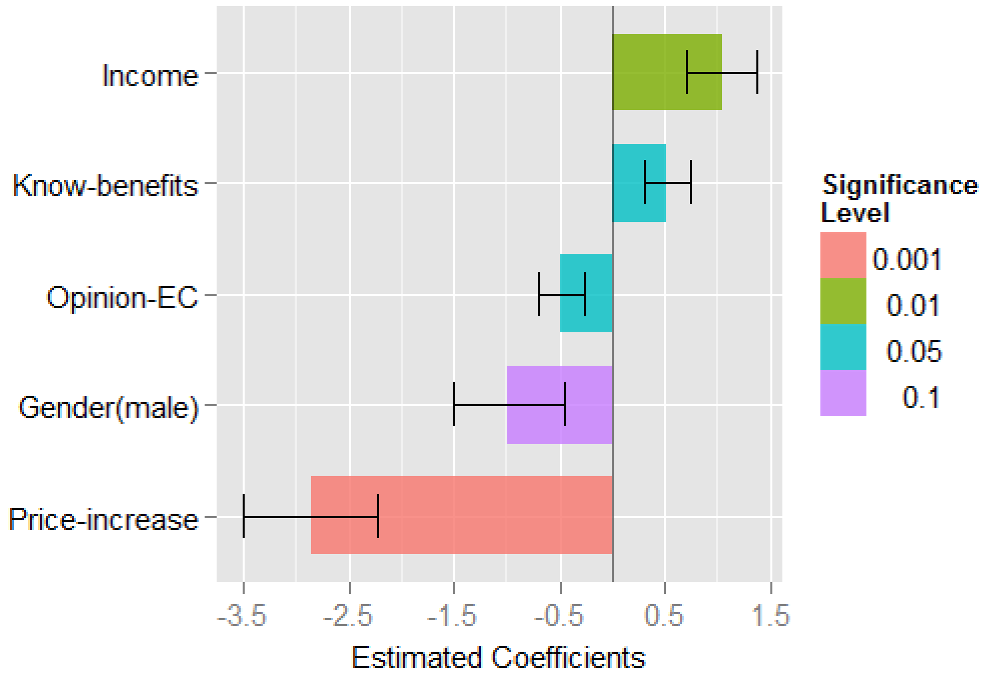

Figure 4.6 Explanatory Variables of the Final Model of Zhengzhou

On the other hand, three of the five variables in the final stepwise model, Price-increase, Gender (male) and Opinion-EC, were found to have negative coefficients of -2.86, -0.98 and -0.49 at the significance levels of 0.001, 0.1 and 0.05 respectively. This means for an increase of 1 yuan/m^3 in the water price, the odds of respondents' *yes* answer to the WTP question would significantly decline by 94% (1-$e^{-2.86}$). Male respondents seemed less likely to accept a higher water price and the odds of their yes answer could be as low as 38% of the odds of female respondents, but this difference was just significant at the 0.1 level. With regard to the variable Opinion-EC, for the coding numbers from 1 to 5 which represent the opinions from Highly Agree to Highly Disagree with the idea of Ecological Compensation, each increase in the coding number would lead to a decline in the odds *of yes* answer by 39% (1-$e^{-0.49}$). In other words, the odds of accepting a higher price by respondents who highly disagreed with the idea of EC would be as low as 14% ($e^{-0.49\times4}$) of the odds of respondents who highly agreed with it.

It can be noted that the variable Price-increase played a dominant role in the final stepwise model of Zhengzhou both in terms of the magnitude (the absolute value, represented by the length of the colour bar in Figure 4.6) and the significance level (the exact p-value was as high as 8.37×10^{-6}) of its coefficient. This was the only case in all the four cities, which implies that respondents in Zhengzhou seemed most sensitive to the increase in water price. Additionally, the dominant effect of Price-increase in this parametric model (i.e. the final stepwise model) was also in agreement with the result of the non-parametric model that the proportion of *no* answer to the WTP questions exhibited a high degree of monotonicity with the increase in water price (see Figure 4.1).

4.4 Comparison of the Final Parametric Models of Four Cities

After detailed analysis and discussion on the parametric models of each city in the preceding section, this section conducts a comparative analysis of the final parametric models (i.e. the final stepwise regression models) of the four cities (Table 4.8) in order to provide a holistic view of factors (variables) that influenced respondents' acceptance to paying a higher water price for water protection.

Firstly, money-related factors were respondents' concerns in all the four cities. The proposed increase in water price and respondents' monthly gross income (highlighted in purple shaded cells in Table 4.8) were the only two explanatory variables that were included in the final models of all the four cities. Respondents in Beijing were least sensitive to the increase in water price while respondents in Zhengzhou were most sensitive to it. For an increase of 1 yuan/m^3 in the water price, the odds of accepting a higher water price would decline by 60% at the 0.1 significance level in Beijing whilst the odds would decline by 94% at the 0.001 significance level in Zhengzhou.

Moreover, significant differences in the odds of accepting a higher water price were found between respondents at the three income levels (below 2500, 2500-4000 and above 4000 yuan/month) in Tianjin and Zhengzhou, but no significant difference was found between respondents receiving 2500-4000 yuan/month and those receiving more than 4000 yuan/month in Beijing and Shijiazhuang. The difference in the odds of accepting a higher water price between respondents earning more than 4000 yuan/month and those earning less than 2500 yuan/month was 8.00 times in Zhengzhou (the largest) and 3.10 times in Beijing (the smallest), which again indicates that respondents in Zhengzhou showed the highest sensitiveness to money-related factors when answering the WTP question.

The policy implication here is that applying differentiated increments in water price to respondents at different income levels may be a feasible way to raise funds for water resource protection. Furthermore, since the current minimum threshold of personal income tax in China (3500 yuan/month) is just within the range of the medium income level in this study (2500-4000 yuan/month), it may serve as a sensible cut point for differentiated increase in water price which nicely fits the model estimation results of this study and the current socio-economic and policy settings in China.

Table 4.8 Final Parametric WTP Models of Four Cities

Significance Level: 0.001 ***, 0.01 **, 0.05 *, 0.1 °

Variables	Coefficients			
	Beijing	**Tianjin**	**Shijiazhuang**	**Zhengzhou**
(Intercept)	2.49 **	0.11	0.99	0.34
Price-increase	-0.92 °	-1.80 ***	-2.20 *	-2.86 ***
Income	*Above 2500* 1.13 **	*Numeric* 0.91 **	*Above 2500* 1.52 °	*Numeric* 1.04 **
Know-benefits	0.33 °			0.52 *
Heard-mid-route		0.84 °	-1.75 *	
Know-reservoir			2.46 *	
Heard-EC		1.37 *		
Understand-EC	1.43 °			
Opinion-EC	-0.71 **		-0.58	-0.49*
Household-size	-0.48 **			
Job (without job)		-2.67 **		
Age (above 50)		1.62 *		
Gender (male)				-0.98 °
Residence (5-10)			2.34 *	
Relatives		1.03 °		
Opinion-service		-1.01 **		
Perceive-shortage			0.59	
Model Evaluation Indicator [a]				
Prediction ER [b]	0.24	0.24	0.21	0.18
Overall Significance	5.34×10^{-8}	1.20×10^{-10}	1.27×10^{-3}	1.41×10^{-12}

[a] AIC is not included here since it is not applicable to compare models for entirely different populations (i.e. respondents in different cities)

[b] Prediction error rate

Secondly, respondents with more knowledge of the water transfer project (variables highlighted in blue shaded cells of Table 4.8) were more likely to accept a higher water price, though the specific influential variables differed in the four cities. While more knowledge of the benefits of the SNWTP led to larger odds of accepting a higher water price in Beijing and Zhengzhou, knowledge of the specific middle route project and the Danjiangkou Reservoir exhibited significantly positive influence in Tianjin and Shijiazhuang. An exception was the variable Heard-mid-route in the final model of Shijiazhuang which had a negative coefficient. As explained in Section 4.3.3, this might be attributed to the fact that Shijiazhuang was providing water to Beijing rather than receiving water from the middle route project when this survey was conducted. In other words, respondents were less likely to accept a higher water price if they felt no benefits gained from the water transfer project. This is a reasonable finding and it supports the argument that respondents' perception/knowledge of the water transfer project played an important role in forming their attitudes to the proposed PES scheme for water protection.

Linking the findings of modelling analysis and the descriptive analysis results of respondents' environmental knowledge provides even more insights for policy makers. Only 34% of the 755 respondents in the four cities had heard about the specific middle route of the SNWTP, and even fewer (9.2%) of them knew the Danjiangkou Reservoir. As many as 44% respondents did not know that the SNWTP would provide water to their cities and 66% of them were unaware that the project could also improve the tap water quality. Obviously, respondents in the four cities in general had very limited knowledge about the water transfer project. If policy makers and advocators of the PES scheme for water protection make better efforts to disseminate relevant knowledge and information, they should have better chance to gain more support from residents in the northern cities.

Thirdly, respondents' understanding and attitudes to the idea of Ecological Compensation (variables highlighted in green shaded cells in Table 4.8) were also important factors that influenced their answers to the WTP question. In Beijing and Zhengzhou, the decline in the odds of yes answer caused by highly opposed attitude to the idea of EC could offset the effect of earning more than 2500 yuan/month. In Beijing, the positive effect of correct understanding of EC (coefficient: 1.43) on respondents' yes answer to the WTP question could even offset the negative effect of an increase of 1 yuan/m^3 in the water price (coefficient: -0.92). In fact, Beijing is the only city where the number of respondents who could correctly describe the general idea of EC was large enough to include the variable Understand-EC in regression models. In Tianjin, respondents who had heard about EC (not necessarily able to correctly describe its meaning) already showed significantly larger odds of accepting a higher water price.

Furthermore, descriptive analysis shows that respondents in the four cities were still unfamiliar with the EC as only 21% of them had heard about EC and as few as 5% of them could correctly describe its general idea. Encouragingly, however, 58% of them expressed clear supportive attitude after a brief introduction of EC in the survey. These descriptive results and the modelling results above suggest that more efforts from policy makers and PES advocators are needed to promote the concept and idea of EC among residents in the northern cities, which can be promising to increase public WTP for water protection.

Interestingly, a multi-option question was asked in the survey (before introducing the idea of EC) about who should undertake the cost of water protection. About 17% of respondents included water users in the northern cities in their answers (and 2% of respondents chose this option as the only answer). In contrast, 60% of respondents believed the central government should undertake at least part of the cost, 34% of them included local governments of the northern cities in their answers and 38% of them included local governments in the water source area. That is to say, respondents placed high expectation on “the government”, especially the central government, to play the leading role in funding the water protection. Accordingly, a multi-source funding (PES) scheme may be more feasible and acceptable to residents in the northern cities. It should be noted that 34% of respondents actually answered *yes* to the WTP question in the later stage of the survey, which is double the abovementioned percentage of respondents who believed that water users should undertake at least part of the water protection cost [46]. It seems even a brief introduction of EC during the survey had changed some respondents’ attitudes to the idea of paying for water protection.

Lastly, demographic variables other than income (highlighted in tan shaded cells in Table 4.8) did not show universal influence on respondents’ answers to the WTP question as none of them appeared in two or more final models

[46] Not to mention that another 17% respondents just answered “not sure” instead of clear “no” to the WTP question, and some respondents answered “no” not because they refused to pay anything but because the proposed increment in water price was too high for them. Therefore, the actual percentage of respondents who were willing to contribute to water protection should be larger than 34%.

of the four cities. In fact, some of those demographic variables were money-related issues. In Beijing, respondents with larger household sizes were less likely to accept an increase in water price, which could be attributed to higher living cost of larger households. In Tianjin, respondents without jobs (retired or unemployed) were less willing to pay a higher water price, which could reasonably relate to their economic conditions. In Zhengzhou, male respondents were also less likely to give a *yes* answer to the WTP question, perhaps due to generally heavier responsibilities of males in supporting their households' living. It can be noted that the demographic variable Education did not exhibit significant influence on respondents' answers to the WTP questions in any of the four cities (thus it is not listed in Table 4.8). Additional correlation analysis also found there was little correlation between respondents' education level and their knowledge/attitudes about the SNWTP and EC [47]. These results implies that environmental campaigns or other public education efforts are needed to disseminate knowledge of the water transfer project and the idea of paying for water protection to which the current school education seemed little helpful.

4.5 Respondents' Mean WTP for Water Resource Protection

After determining the final parametric models for each city, the estimated model coefficients (parameters) and the sample means of the explanatory variables in the final models were used to calculate respondents' mean WTP for water protection. In order to explore the uncertainty of the calculation results [48], the 95% confidence interval of the mean WTP was determined by a Monte Carlo simulation method which randomly drew *N* arrays of coefficient values to simulate the multivariate normal distribution of the estimated model coefficients. Then a simulated mean WTP was calculated with each array of coefficients, so *N* simulated mean WTP generated from the *N* random draws constructed a distribution of the mean WTP whereby the 95% confidence interval was located by the 2.5% and 97.5% quantile values. Due to the randomness of draws, each simulation would actually

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[47] The correlation was between 0.05-0.2. In fact, correlation analysis was conducted between all the explanatory variables and no strong correlation was found. So modelling analysis in this study focused on the main effects of those variables and excluded the interaction effect.

[48] The model coefficients used for calculating the mean WTP are estimated values with standard errors which will consequently cause uncertainty (variance) in the calculation of the mean WTP.

generate a different confidence interval. If the number of random draws *N* is not sufficiently large, the simulation results could be substantially different between each random draw. In order to obtain stable simulation results of the confidence intervals, a wide range of random draws from 1000 to 1,000,000 were tested in this study. Figure 4.7 illustrate the effect of the number of random draws on the simulation results.

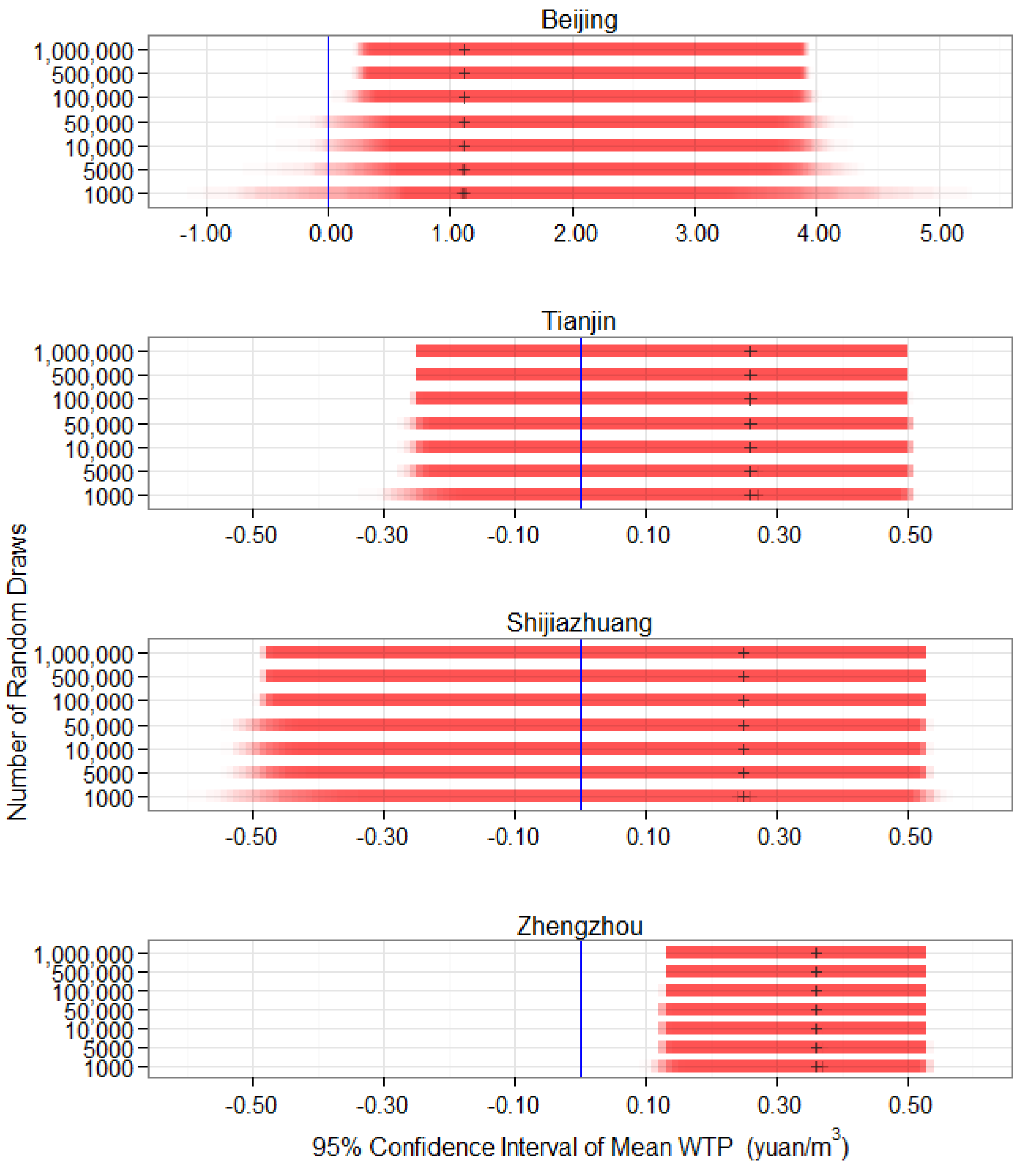

Figure 4.7 Effect of Random Draws on Simulated Confidence Intervals of the Mean WTP

100 times of simulation were performed for each number of random draws, and a colour bar in 1% transparency was plotted for each simulation result. Thus more solid colour indicates more overlaps between the simulation results, namely more stability of the simulation. The cross marks (also in 1% transparency) indicate the medians in the distribution of simulated mean WTP.

In general, the simulation results of the four cities all become quite stable when the number of random draws reached 500,000 and over, though 100,000 random draws were already sufficient for Zhengzhou. The mean WTP of respondents in Beijing had much larger confidence interval than the other cities (the horizontal axis of the sub-graph of Beijing in Figure 4.7 is about ten times larger in scale), which might be largely attributed to the earlier finding that Beijing was the only city where the variable of Price-increase in the final model was less significant than the 0.05 level (Table 4.8) [49]. In contrast, the mean WTP of respondents in Zhengzhou had the narrowest confidence interval, which could be explained by the highest model fitting and the highest significance level of the variable of Price-increase in the final model of Zhengzhou (Table 4.8) [50]. Based on the testing results, the final 95% confidence intervals of respondents' mean WTP were determined by the average 2.5% and 97.5% quantile values of 100 times of simulation with 1,000,000 random draws.

As explained in the Methodology chapter, parametric models that use one dichotomous (yes/no) question to elicit respondents' WTP (as discussed in the previous section) is usually called Single Bound Dichotomous Choice Model. An improvement on the single bound model is the Double Bound Dichotomous Choice Model. For applying the double bound model, a follow-up dichotomous choice question was asked in the survey. If the respondents answered yes to the first WTP question, a higher increment of water price was offered to them in the second WTP question, otherwise a lower increment was offered. In this way, more precise information could be obtained about respondents' WTP and thus refinement could be achieved in the model estimates. Table 4.9 presents the estimation results of double bound parametric models of the four cities. For the convenience of comparison, the estimation results of the single bound models (i.e. the same results presented in Table 4.8 but in a more compact form) are also presented in this table.

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[49] The coefficient of Price-increase is the only denominator in the calculation function of the mean WTP, thus the low significance of this variable (which means large standard error) is prone to cause large variance in the estimates of the mean WTP.

[50] Although Price-increase was both significant at the 0.001 level in the final models of Tianjin and Zhengzhou, the exact p-value of the variable was 3.55×10^{-4} and 8.37×10^{-6} respectively in the two cities.

Table 4.9 Comparison of Single Bound and Double Bound Models

Significance Level: 0.001 ***, 0.01 **, 0.05 *, 0.1 ◦

City/Variable	Coefficient (Standard Error)	
	Single Bound Model	**Double Bound Model**
Beijing		
(Intercept)	2.49 (0.92) **	2.55 (0.75) ***
Price-increase	-0.92 (0.47) ◦	-2.20 (0.26) ***
Opinion-EC	-0.71 (0.23) **	-0.72 (0.20) ***
Household-size	-0.48 (0.16) **	-0.33 (0.12) **
Know-benefits	0.33 (0.19) ◦	0.39 (0.17) *
Income	1.13 (0.44) **	1.11 (0.39) **
Understand-EC	1.43 (0.81) ◦	0.64 (0.60)
Tianjin		
(Intercept)	0.11 (0.80)	0.11 (0.79)
Job	-2.67 (0.84) **	-2.11 (0.75) **
Price-increase	-1.80 (0.50) ***	-1.95 (0.32) ***
Opinion-service	-1.01 (0.34) **	-0.90 (0.34) **
Know-mid-route	0.84 (0.46) ◦	0.84 (0.43) ◦
Income	0.91 (0.33) **	0.80 (0.30) **
Relatives	1.03 (0.57) ◦	1.59 (0.53) **
Heard-EC	1.37 (0.59) *	1.08 (0.55) *
Age	1.62 (0.71) *	1.33 (0.66) *
Shijiazhuang		
(Intercept)	0.99 (1.22)	2.78 (1.18) *
Price-increase	-2.20 (0.86) *	-3.12 (0.57) ***
Know-mid-route	-1.75 (0.87) *	-1.34 (0.69) ◦
Opinion-EC	-0.58 (0.47)	-1.09 (0.51) *
Perceive-shortage	0.59 (0.66)	0.49 (0.58)
Income	1.52 (0.79) ◦	0.94 (0.68)
Residence	2.34 (1.03) *	2.28 (0.91) *
Know-reservoir	2.46 (1.13) *	1.43 (0.87)
Zhengzhou		
(Intercept)	0.34 (0.96)	0.31 (0.83)
Price-increase	-2.86 (0.64) ***	-1.95 (0.40) ***
Gender (male)	-0.98 (0.52) ◦	-0.35 (0.44)
Opinion-EC	-0.49 (0.22) *	-0.44 (0.19) *
Know-benefits	0.52 (0.22) *	0.20 (0.18)
Income	1.04 (0.34) **	0.73 (0.28) **

The double bound and single bound models were similar regarding the signs (positive/negative) of variable coefficients, but the double bound models generated different estimates of the magnitudes of coefficients and substantially improved the significance level of some variables' coefficients, especially for the proposed increase in water price. For example, the variable Price-increase was only significant at the 0.1 level in the single bound model in Beijing but was at the 0.001 significance level in the double bound model. This is understandable since the double bound model actually doubled the observations of residents' responses to the increase in water price by introducing the second WTP question. As a result of the higher significance level of the estimated coefficients, the double bound model was able to generate stable simulation results of confidence intervals with 100,000 random draws (illustrated in Figure 4.8).

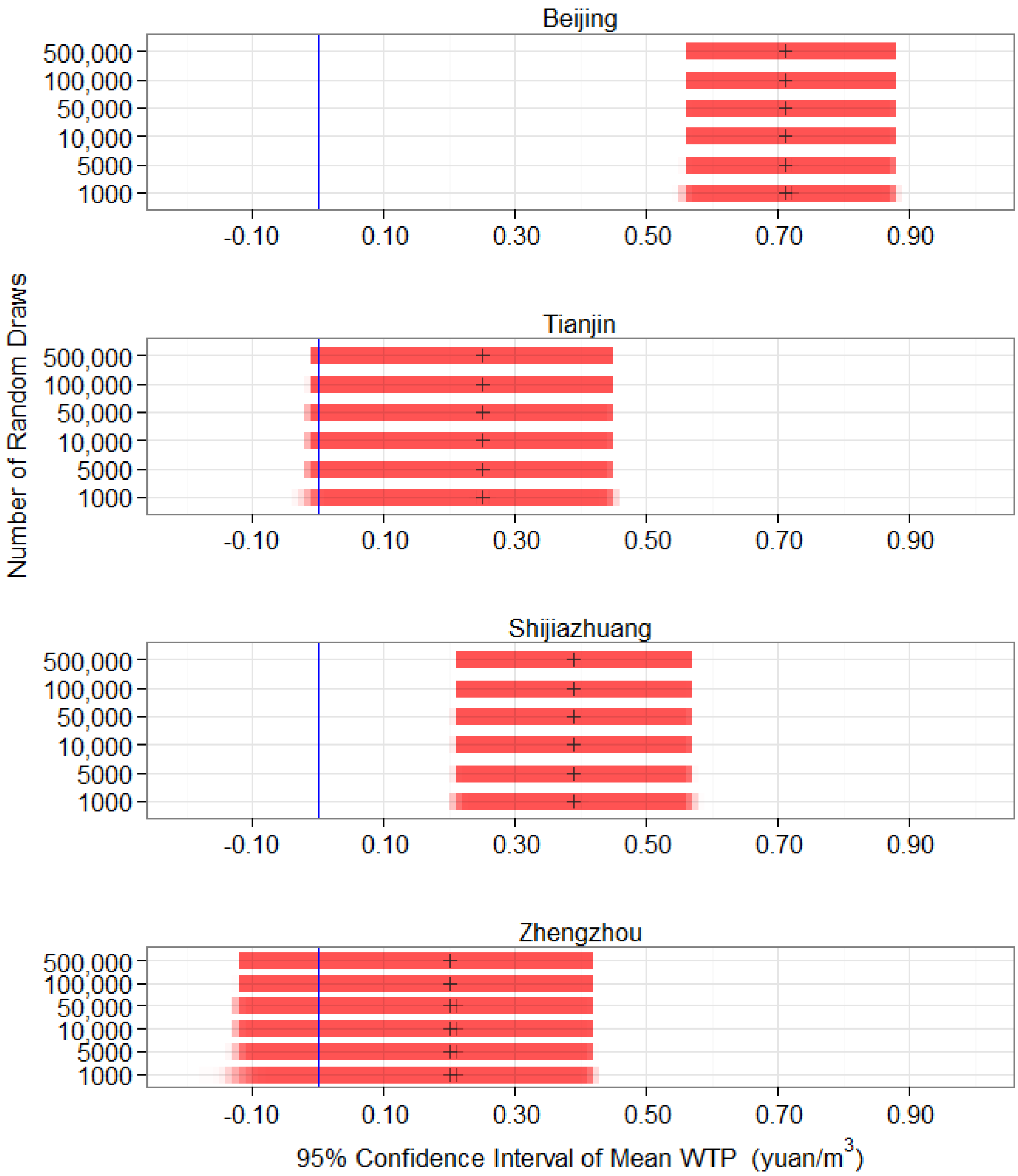

Figure 4.8 Simulated Confidence Intervals of the Mean WTP (Double Bound Parametric Model)

Table 4.10 presents the estimates of respondents' mean WTP by the single bound parametric model, double bound parametric model and the non-parametric model. One merit of the parametric models is that they are convenient to calculate the mean WTP of specific groups of respondents with regard to particular explanatory variables. Therefore, in addition to the mean WTP of the whole sample of respondents in each city, this study also conducts disaggregate analysis of the mean WTP of respondents at different income levels in order to investigate the effect of income disparity on the WTP for water protection.

Table 4.10 Estimates of Respondents' Mean WTP by Different Models

Values in parentheses are the 95% confidence intervals of the mean WTP (yuan/m^3). Results highlighted in olive green shaded cells are the estimates of the sample of respondents in each city. As no significant differences were found between respondents earning 2500-4000 yuan/month and those earning more than 4000 yuan/month in their answers to the WTP question, respondents in Beijing and Shijiazhuang were only divided into two groups.

City	Single Bound Parametric Model	Double Bound Parametric Model	Non-parametric Model
Beijing	1.13 (0.28, 3.90)	0.71 (0.56, 0.88)	0.29 (0.29, 0.29)
Below 2500	0.27 (-2.07, 1.65)	0.36 (0.06, 0.65)	
Above 2500	1.51 (0.14, 6.10)	0.86 (0.68, 1.06)	
Tianjin	0.26 (-0.25, 0.50)	0.25 (-0.01, 0.45)	0.44 (0.44, 0.45)
Below 2500	-0.01 (-0.81, 0.33)	0.04 (-0.32, 0.30)	
2500-4000	0.50 (0.10, 0.78)	0.45 (0.18, 0.69)	
Above 4000	1.00 (0.44, 1.80)	0.86 (0.37, 1.37)	
Shijiazhuang	0.25 (-0.48, 0.53)	0.39 (0.21, 0.57)	0.37 (0.35-0.38)
Below 2500	0.12 (-0.90, 0.43)	0.33 (0.11, 0.53)	
Above 2500	0.81 (0.09, 2.25)	0.63 (0.25, 1.05)	
Zhengzhou	0.36 (0.13, 0.53)	0.20 (-0.12, 0.42)	0.35 (0.34-0.36)
Below 2500	0.14 (-0.23, 0.36)	-0.01 (-0.49, 0.28)	
2500-4000	0.50 (0.28, 0.70)	0.36 (0.07, 0.60)	
Above 4000	0.87 (0.52, 1.32)	0.73 (0.29, 1.25)	

For the respondents in Beijing, the estimation of the single bound model shows that, on average, they were willing to pay an increase of 1.13 yuan/m^3 in water price for protecting the water resources of the middle route of the SNWTP and the confidence interval of this mean WTP was 0.28-3.90 yuan/m^3. This was an excessively large interval and the upper bound estimate was unreliable since 3.90 yuan/m^3 was far beyond the highest increase that was proposed to respondents in the survey (1.50 yuan/m^3).

In contrast, the double bound model of Beijing substantially narrowed down the confidence interval of the WTP estimate to 0.56-0.88 yuan/m^3 and provided a smaller estimated mean WTP of 0.71 yuan/m^3, which was the largest mean WTP in the four cities. This was quite different from the result of the non-parametric model that the mean WTP of respondents in Beijing was 0.29 yuan/m^3 as the smallest in the four cities. An explanation to this difference is that the non-parametric model was applied onto the dataset of Beijing after a smoothing procedure in order to overcome the non-monotonicity of the original data (illustrated in Figure 4.2), which caused considerable underestimate of the mean WTP [51].

Additionally, disaggregate analysis with the double bound model also shows that respondents receiving less than 2500 yuan/month in Beijing had the mean WTP of 0.36 (0.06, 0.65) yuan/m^3 while those above that income level had the mean WTP of 0.86 (0.68, 1.06) yuan/m^3. The difference in the mean WTP was statistically significant since there was no overlap between the 95% confidence intervals of these two estimates.

For the respondents in Tianjin, the estimated mean WTP of the single bound model was 0.26 (-0.25, 0.50) yuan/m^3, and the double bound model provided a similar result with a narrower confidence interval, 0.25 (-0.01, 0.45) yuan/m^3. This similarity is consistent with the result that the significance levels of coefficients in the double bound model of Tianjin did not improve much from the single bound model (Table 4.9). On the other hand, the estimated mean WTP of the non-parametric model (0.44 yuan/m^3) was close to the upper bound of the confidence intervals of the estimated WTP by the two parametric models, which reflects some degree of

[51] The non-parametric model calculated the mean WTP with the sum of the products of the increments in water price and the differences between the percentages of no answer to two consecutive increments. The smoothing procedure merged data points where non-monotonicity occurred, which reduced the number of products in the summation function and thus provided an underestimate of the mean WTP.

consistency in parametric and non-parametric models. But the non-parametric model made an overestimate here probably because it did not take account of influential variables of respondents' WTP except for the proposed increase in water price.

Interestingly, the lower bound of the confidence intervals of mean WTP in Tianjin was below zero, indicating that some respondents actually looked forward to a decrease in the water price instead of paying a higher water price for water protection. Disaggregated analysis with the double bound model revealed that on average respondents receiving less than 2500 yuan/month in Tianjin were only willing to pay a trivial increase of 0.04 (-0.32, 0.30) yuan/m^3. In comparison, the mean WTP of respondents at the other two income levels (2500-4000 and above 4000 yuan/month) were 0.45 (0.18, 0.69) and 0.86 (0.37, 1.37) yuan/m^3 respectively. That is to say, respondents who desired a decrease in water price all understandably fell in the lowest income group. The income disparity did cause significant difference in respondents' mean WTP for water protection at least between those receiving less than 2500 yuan/month and those receiving more than 4000 yuan/month as the confidence intervals of the mean WTP did not overlap with each other [52].

For respondents in Shijiazhuang, the mean WTP estimated by the single bound model was 0.25 (-0.48, 0.53) yuan/m^3. The double bound model considerably narrowed down the confidence interval on the lower bound and provided a larger estimate of the mean WTP as 0.39 (0.21, 0.57) yuan/m^3, which was close to the estimate of the non-parametric model (0.37 yuan/m^3). Disaggregated analysis with the double bound model found that respondents with less than 2500 yuan/month in Shijiazhuang had the mean WTP of 0.33 (0.11, 0.53) yuan/m^3 while those above that income level had a mean WTP of 0.63 (0.25, 1.05) yuan/m^3. But the difference between two income levels might not be statistically significant because there was some extent of overlap between the two confidence intervals.

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[52] It should be noted that although no overlap between two confidence intervals means there was significant difference between the two estimated WTP, the presence of overlap does not necessarily mean the opposite. If the estimated WTP follows a normal distribution, the significance of difference can be tested by standard statistical test. However, this is not the case for the parametric models. Therefore, the significance of difference in the mean WTP of respondents at the low (less than 2500) and medium (2500-4000) income levels cannot be tested here.

For the respondents in Zhengzhou, the single bound model provided an estimate of the mean WTP as 0.36 (0.13, 0.53) yuan/m^3, which was close to the estimate of the non-parametric model (0.35 yuan/m^3) This is consistent with the previous finding that Zhengzhou was the only city where the variable Price-increase played a dominate role in the single bound models in terms of both the magnitude and significance (Table 4.8) [53].

Unlike the case of the other three cities, the WTP estimate of the double bound model of Zhengzhou, 0.20 (-0.12, 0.42) yuan/m^3, did not show the superiority over the estimate of the single bound model given its wider confidence interval. This can be attributed to the result that explanatory variables in the double bound model of Zhengzhou did not exhibit higher significance than the single bound model (Table 4.9). On the contrary, the variables of Gender and Know-benefits become insignificant in the double bound model. A possible explanation is that when the respondents of Zhengzhou considered the second WTP question, the influence of the two variables became much weaker than the other three variables in the model, i.e. Price-increase, Opinion-EC and Income since the proposed increase in water price and income were directly related to respondents' financial conditions and their opinions about the idea of Ecological Compensation directly justified their answers to the WTP question.

Given the narrower confidence interval and greater consistence with the result of the non-parametric model, the estimate of the single bound model was adopted for further analysis of the dataset of Zhengzhou. Disaggregated analysis with the single bound model found that the mean WTP of respondents at the three income levels (less than 2500, 2500-4000 and more than 4000 yuan/month) in Zhengzhou were 0.14 (-0.23, 0.36), 0.50 (0.28, 0.70) and 0.87 (0.52, 1.32) yuan/m^3 respectively. That is to say, some respondents at the lowest income level in Zhengzhou actually desire a decrease in the water price, and the effect of income disparity on the mean WTP was at least significant between respondents earning less than 2500 yuan/month and those earning more than 4000 yuan/month according to the confidence intervals of the estimation results.

Comparatively, the mean WTP of respondents in Beijing, Tianjin, Shijiazhuang and Zhengzhou were 0.71 (0.56, 0.88), 0.25 (-0.01, 0.45), 0.39

[53] Since Price-increase was the only variable used in the non-parametric model, the parametric models would be more likely to produce a similar estimate to the non-parametric model when the variable of Price-increase was overwhelmingly influential.

(0.21, 0.57) and 0.36 (0.13, 0.53) yuan/m^3 respectively [54]. The confidence intervals of these estimates indicated that respondents in Beijing had a significantly larger mean WTP than respondents in the other three cities. This may largely be attributed to the previous finding that there were fewer respondents at relatively low income level and more respondents at relatively higher level Beijing (Table 4.1).

It is also informative to compare the mean WTP of respondents at the same income level in different cities. As Table 4.10 shows, respondents earning less than 2500 yuan/month in Beijing showed a larger mean WTP than their counterparts in other cities, but there were considerable overlaps between the estimated confidence intervals. Interestingly, respondents earning more than 4000 yuan/month in Beijing, Tianjin and Zhengzhou had similar mean WTP around 0.86 yuan/m^3, which were all significantly larger than the mean WTP of respondents earning less than 2500 yuan/month in these cities. In other words, respondents' WTP was more related to their income level than which city they were in. The policy implication here is that instead of adopting a uniform increment of water price in each city according to the estimated mean WTP of all respondents in each city, it might be better to adopt differentiated increments for respondents at different income levels which applied to all cities (or with minor adjustment in each city). Such a fundraising mechanism would resemble the current personal income tax in China.

4.6 Summary

This chapter presents the research results of the Contingent Valuation surveys in four cities on public WTP for water protection. The final stepwise regression model showed considerable superiority than the initial full model and best subset regression model in terms of goodness of fit and model simplicity, thus it was adopted as the final model to explain respondents' answers to the WTP question. In general, respondents' willingness to pay a higher water price was significantly influenced by money-related factors (the proposed increments in water price and income), respondents' knowledge about the water transfer project, their understanding and attitudes to the idea of Ecological Compensation. Demographic variables such as household size

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[54] As explained above, the estimate of the single bound model was adopted as the final result for Zhengzhou whereas the estimates of the double bound model were adopted for the other three cities.

were also influential in individual cities, but they did not exhibit universal influence in the four cities.

Respondents' mean WTP for water protection was calculated by the single bound parametric model, the double bound parametric model and the non-parametric model. The estimation results of different models showed some degree of consistency given the overlaps of their estimated confidence intervals. Generally, the double bound parametric model exhibited the superiority of less uncertainty (narrower confidence interval) in the estimation results than the single bound parametric model for all the four cities except Zhengzhou. And the two parametric models surpassed the non-parametric model in the ability of taking account of more influential factors of respondents' WTP and exploring the effect of income disparity on the WTP. But when the proposed increase in water price was the dominant variable in the parametric models (like the case of Zhengzhou), parametric and non-parametric models could generate close results.

On average, respondents in Beijing, Tianjin, Shijiazhuang and Zhengzhou were willing to pay the increase of 0.71, 0.25, 0.39 and 0.36 yuan/m^3 in the water price respectively for water protection. In each city except for Shijiazhuang, respondents receiving more than 4000 yuan/month had significantly larger mean WTP than those receiving less than 2500 yuan/month. In Tianjin and Zhengzhou, some respondents receiving less than 2500 yuan/month actually look forward to a decrease in water price.

Major policy suggestions that can be offered based on the results of this chapter are as follows. Firstly, if policy makers and PES practitioners make better efforts to disseminate knowledge about the water transfer project and promote the idea of Ecological Compensation among residents in the northern cities, they may have better chance to raise more funds for water protection. Secondly, a multi-source funding scheme involving both the government and water users should be more feasible since respondents in the four cities placed high expectation on the government, especially the central government, to play the leading role in funding the water protection. Thirdly, compared with a uniform increment of water price in each city, differentiated increments in water price for respondents at different income levels could be better given the significant higher mean WTP of respondents at the relatively high income level. Moreover, the current start point of the personal income tax in China (3500 yuan/month) could be a useful benchmark for a water protection PES scheme with differentiated payment levels.

Chapter 5
Farmer Households' Preferences for the Design of Water Protection Programs

The previous chapter investigates urban residents' WTP for water protection from the consumer perspective of PES. This chapter focuses on the supply side of PES and presents the research results of the Choice Experiment survey in seven villages around the Danjiangkou Reservoir (i.e. the water supply area of the middle route of the South-to-North Water Transfer Project) on farmer households' preferences for the design of water protection programs. Two water protection programs are discussed in this chapter, i.e. the existing Sloping Land Conversion Program (SLCP) for reforestation on sloping farmland and a hypothetical program for reducing the use of Nitrogen and Phosphate fertilizers in flat farmland that is not currently covered by the SLCP [55].

The contents of this chapter are arranged as follows: Section 5.1 describes the characteristics of the interviewed farmer households. Section 5.2 presents survey results regarding households' participation in the SLCP, Section 5.3 examines the effect of SLCP on livelihoods of farmer households. Section 5.4 discusses the choice modelling results of farmer households' preferences for the design of water protection programs. Section 5.5 further explores the heterogeneity in farmer households preferences and Section 5.6 summarizes major findings of this chapter.

5.1 Characteristics of Farmer Households

A total of 246 farmer households in two groups were interviewed in this survey, i.e. those who have participated in the SLCP (161 households) and those who have qualified sloping land for the SLCP but did not participate (85 households). Table 5.1 presents the demographic and socio-economic characteristics of the two groups of households.

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[55] The SLCP only enrols land with gradient larger than 25 degrees which is vulnerable to soil erosion.

Table 5.1 Characteristics of Farmer Households

Gender, Age and Education Level refer to the characteristics of the heads of households. Total Land and Enrolled/Qualified Land were recorded in mu [56], Household Income refers to gross income (yuan/year). The P-value indicates the significance of the difference between the two groups of households in terms of the corresponding characteristic.

Characteristics	Participants of SLCP	Non-participants	P-value
Gender			
Male	71%	73%	0.83
Female	29%	27%	
Age			
Below 30	6.8%	1.2%	
30 - 40	18.6%	12.9%	
40 - 50	45.3%	50.6%	0.27
50 - 60	18.6%	23.5%	
Above 60	9.9%	11.8%	
No answer	0.6%	0	
Education Level			
Below Primary School	13.0%	5.9%	
Primary School	23.0%	34.1%	
Middle School	42.9%	47.1%	0.08
High School	18.0%	11.8%	
College or above	1.2%	1.2%	
No answer	1.9%	0.0%	
Household Size			
Mean	4.5	4.3	0.37
Standard Deviation	1.5	1.4	
Members in village			
Mean	2.5	2.7	0.23
Standard Deviation	1.2	1.2	
Total Land			
Mean	15.8	16.5	0.03
Standard Deviation	19.8	15.6	
Enrolled/Qualified Land [57]			
Mean	12.0	11.4	0.70
Standard Deviation	16.9	14.0	
Household Income			
Mean	23,430	26,510	0.53
Standard Deviation	24,784	27,468	

[56] "mu" is the unit of land commonly used in China which is equal to 1/15 hectare.

[57] It should be noted that several households in both groups were holding much larger land (around 100 mu) than most households and thus substantially enlarged the average enrolled/qualified land. The medians of enrolled/qualified land were both 7 mu for the two groups of households.

5.1.1 The Difference between SLCP Participant and Non-participant Households

In general, the two groups of households had similar characteristics. In both groups, over 70% of the heads of households were male, about half of them aged 40-50 and nearly half of them attended middle school as the highest education. On average, households in both groups had 4-5 family members, and 2-3 of them were living in the villages while the others were working or studying outside the villages.

The average land held by the SLCP participating households was 15.8 mu (1.05 hectare) [58], which was slightly less than the average land held by the non-participating households, 16.5 mu (1.10 hectare). Interestingly, the average sloping land enrolled in the SLCP by the participating households and the average qualified sloping land held by the non-participating households were close, i.e. 12.0 and 11.4 mu respectively. This implied that the two groups of households were also similar in terms of the topographic characteristics (e.g. gradient) of their land. The average gross household income [59] of the SCLP participants was 23,430 yuan/year, which is smaller than the income of the non-participating households, 26,510 yuan/year. It should be noted that, in both groups of households, the standard deviations of total land, enrolled/qualified land and household income were quite large compared with the mean values, which indicates large disparities in landholding and income within each group.

Particular attention was paid to whether there was significant difference between the two groups of households that may cause systematic biases in later comparative analyses of this chapter. For the three characteristics recorded as categorical variables (gender, age and education level), the Chi-square test was applied to examine whether the distributions of these characteristics of the heads of households were dependent on which group

[58] In China, land is state or community-owned, but is usually contracted to farmers. According to the national law on land contracting, the tenure is 30 years for farmland, 30-50 years for grassland and 30-70 years for forestland. Thus the SLCP which converts sloping farmland to forests actually provides an opportunity to extend the tenure of farmers' land contracts.

[59] The data of household income here are calculated results of households' income from multiple sources. Detailed discussion on household income is conducted in Section 5.3.

they belonged to. For the rest of the characteristics recorded as numeric variables, the Shapiro-Wilk Normality Test (Verzani 2004) showed that they did not follow normal distributions in both groups, thus the commonly used t-test was not applicable here. Instead, the Mann-Whitney-Wilcoxon Test [60] (Dalgaard 2008) was applied to test the significance of difference in the means of the characteristics between the two groups of households.

As Table 5.1 shows, no significant difference was found in the characteristics of households in the two groups, except for the total land (P-value=0.03). Nevertheless, the difference in the means of total land between the two groups of households was rather slight in magnitude (0.7 mu) despite its significance in statistics. In contrast, the difference in the means of household income in the two groups seemed not negligible (3,080 yuan/year), yet was still insignificant in statistics due to the large standard deviations in each group. The similarity in the demographic and socio-economic characteristics is helpful to the comparability of the two groups of households and hence, any difference found in later analyses between the two groups is more likely to be attributed to their participation (or not) in the SLCP instead of the characteristics of the households themselves.

5.1.2 Representativeness of the Sample Households

Another important issue is the representativeness of the sample households. Assessing this representativeness is difficult due to the lack of census data of the surveyed villages or the water source areas [61]. In fact, even if the census data is available, it may not be a proper reference to be compared with the survey results as this survey has been targeted at a specific population of farmer households, i.e. those who have sloping land qualified for the SLCP (either participants or non-participants). It is also difficult to find comparable information of farmer households' characteristics from literature since existing SLCP studies have overlooked many regions implementing the program, such as the water source areas of the middle-route water transfer project [62]. Nevertheless, the following information has been found to

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[60] This is a non-parametric test assuming no normal distribution of two independent samples (i.e. two groups of farmer households).

[61] The access to census data is very limited in China. Generally, only a few data at the provincial or municipality level are published which do not differentiate urban and rural residents.

[62] A detailed literature review on existing SLCP studies can be referred to in Section 2.3.

give some hints of the representativeness of the sample households of this study.

As reported in the official news website of Danjiangkou City (named after the reservoir) where the surveyed villages in this study were located [63], the statistic department of the city sampled 100 SCLP participating households in ten villages (names and locations not specified) in 2012 which is the same year of the survey of this study (Chen 2013). In that sample of 100 households, the average household size was 4.3, which is close to the result of this study (4.5); the average enrolled land of households was 6.9 mu, which is similar to the median of households' enrolled land in this study (see Footnote 57); and the net income per capita was 5021 yuan/year. Multiplying the net income per capita by the average household size of 4.3 yields an estimate of the average net household income of 21,590 yuan/year, which is moderately below the survey result of the average gross household income of this study (23,430 yuan/year). Speaking overall, the sample households in this study exhibited similar characteristics to the sample households in the survey of the statistic department of Danjingkou City, which probably implies a decent representativeness of the farmer households in villages around the Danjiangkou Reservoir.

5.2 Farmer Households' Participation in Sloping Land Conversion Program

Some qualitative questions were asked in this survey before the quantitative choice modelling questions in order to provide information of farmer households' participation in the SLCP, their land use decisions after the expiration of their SLCP contracts and the reasons why some farmer households had sloping land qualified for the SLCP but did not participate in the program.

5.2.1 What was the most important reason for farmer households' participation in the SLCP?

161 farmer households who have participated in the Sloping Land Conversion Program (SLCP) were interviewed in this study. The earliest year of the farmers' participation in the SLCP was 2000, when the program extended its pilot project from three province to 17 provinces, and the latest

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[63] In China, "city" usually refers to an administrative region that includes both urban and rural areas.

year of participation was 2012 when this survey was conducted. Most of the enrolled farmers were long-term participants as 90% of them entered the program before 2005. 82% of these participant households enrolled at least half of their total land in the SLCP.

A critical and interesting question is what was the most important reason for the households to participate in the SLCP. In the survey, a question including the following options was presented to the respondents [64].

A. The payment of the program is higher than the income from farming on the enrolled land.
B. Forestland can yield higher income than farmland.
C. There is not sufficient labour in my household to manage farmland.
D. Participating in the program can extend the tenure of the enrolled land.
E. The program is strongly encouraged by the government.
F. Many households in my village have participated in this program.

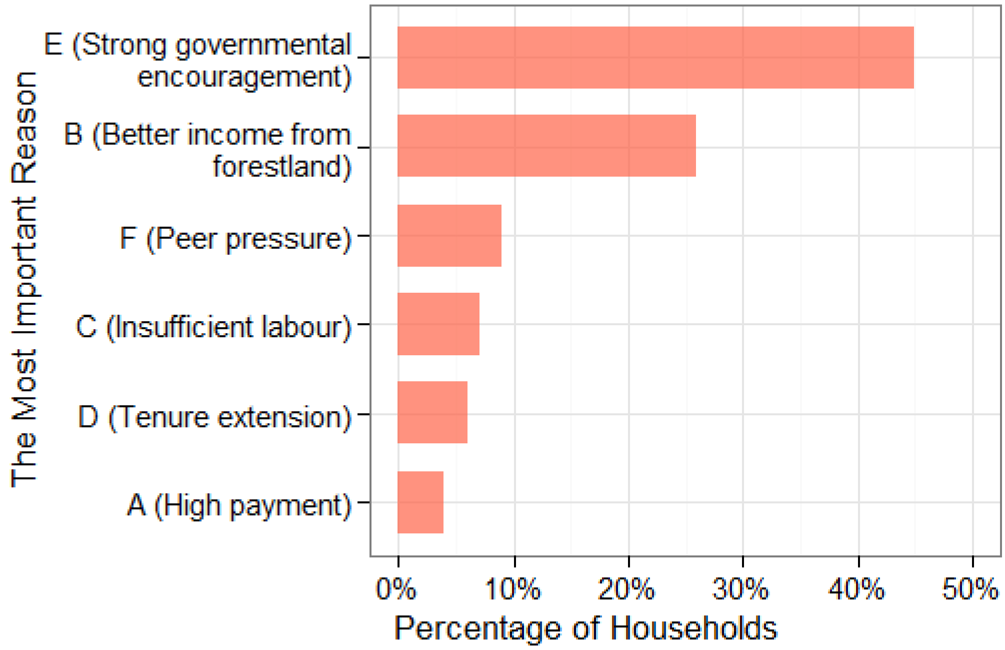

Figure 5.1 The Most Important Reason for Participation in the SLCP

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64 Another option of "Other reasons" was also given to the respondents and a blank was left in the questionnaire for respondents to specify their most important reason. Since no respondent chose this option, it is not mentioned in the main text.

The survey result (Figure 5.1) showed that the most important reasons were: E (strong governmental encouragement) and B (better income from forestland), which were chosen by 45% and 26% of the SLCP-participating households respectively. In addition to the strong influence from the government, “peer pressure” was also an important driver as 9% (the third largest percent) of households chose option F (“many households in my village have participated in this program”). Noticeably, option A (High payment) was chosen by the smallest percentage (4%) of households, indicating that few households thought the payment of the SLCP was higher than the income from farming on the sloping land.

5.2.2 Have the SLCP-participant households enrolled all their qualified sloping land in the program? If not, why?

The survey found that 23% (37) of the SLCP participating households retained part of their qualified sloping land for growing crops, which on average accounted for 39% of these partially-participating households’ total land. An open-ended question was asked to the households about the reason for their partial participation. Surprisingly, 50% of these partially participating households reported that there were quotas of total enrolled land for their villages (assigned by the local forestry department), so they could not enrol all their qualified land even if they would like to.

This quotas assignment issue is rarely mentioned by literature, and it is against the common impression that local officers have to persuade and even force farmers to join in the program instead of limiting the amount of land that can be enrolled (Xu *et al.* 2010). However, assigning quotas for each village does reflect a typical top-down administration style in the implementation of SLCP(Bennett 2008). In fact, it is possible that the assignment of quotas of enrolled land was actually an enforcement measure at the beginning of SLCP in the early 2000s, but with the farmer households’ increasing acceptance to this program due to the aforementioned reasons, such as higher income from forestland than farmland, the quotas then became a barrier to enrolling more sloping land in the villages.

“The needs of growing subsistence crops” was another major reason for farmer households’ partial participation in the SLCP (mentioned by 18% of the partially participating households). Other reasons reflecting very particular circumstances of households are not reported here.

5.2.3 Will farmer households keep the converted forestland after the expiration of their SLCP contracts?

The "permanence" of effect on land use behaviours, i.e. whether land managers keep their environment-benefiting land use behaviours after the payments cease, is considered as a criterion to evaluate the success of PES programs (Engel, Pagiola and Wunder 2008; Wunder, Engel and Pagiola 2008). The literature review in Section 2.3 also indicates that the farmers' post-program land use decision is one of the most important research issues in SLCP studies.

Table 5.2 Reasons for Keeping Forestland after the Expiry of SLCP Contracts

112 households' SLCP contracts had expired, and 96 of them were still keeping the forest in the enrolled land.

Reason for Keeping Forestland	Percentage
Higher income from fruit trees than crops	45%
Timber trees not ready for sale	15%
Inadequate labour to grow crops	9%
Difficulties to clean up the trees for growing crops	9%
Opportunity of off-farm income	4%
Sufficient non-enrolled land to grow subsistence crops	2%
Not allowed to convert forestland back to farmland	2%
Looking forward to extending the SLCP contract	1%
No answer	13%
Number of households	96

When this survey was conducted, the SLCP contracts of 112 (70%) of the 161 participating households had expired [65]. In those 112 farmers, 96 (86%) households were still keeping the forestland after the SLCP contracts expired. With regard to the reasons for keeping forestland (Table 5.2) , 45% of the 96 households mentioned "higher income from fruit trees than crops", which is in agreement with the abovementioned result that "higher income from forestland (than farmland)" was the second most chosen reason for their participation in the SLCP (Figure 5.1). Other major reasons included

[65] The current SLCP contracts are 5 or 8 years.

“timber trees not ready for sale” (15%), “inadequate labour to grow crops” (9%)[66] and “difficulties to clean up the trees for growing crops” (9%).

On the other hand, 49 (30%) of the 161 participating households were still under the SLCP contracts, and 39 (80%) of these 49 households did not have the plan to convert the forestland back to farmland. Generally, they reported similar reasons as the aforementioned households who were still keeping forest in the enrolled sloping land after the expiration of SLCP contracts. Additionally, one benefit of converting farmland to forestland was mentioned by several farmers was that trees needed less tending time than crops, so they could save time to earn additional income from off-farm work or simply have more leisure time (especially for the old farmers). The willingness to protect the environment was also mentioned by several farmers.

The analysis above shows that 135 (84%) out of the 161 SLCP participating households were keeping or would keep forestland after the expiry of their SLCP contracts. This result provides an evidence of the ability of the SLCP to generate considerable extent of permanent effect on farmers’ land use behaviours. However, it is noted that some households are prone to changing the land cover when their timber trees are mature for sale, and those who did not re-cultivate forestland because of inadequate labour may also change their decisions if family members working away from the villages come back for farming. Therefore, the possibility of farmers’ converting forestland back to farmland is not negligible if the SLCP ceases when the current duration expires.

5.2.4 Are farmer households willing to continue with the SLCP under the current contract?

86 (53%) out of the 161 participating households answered *yes* when they were asked whether they were willing to continue with the SLCP if the contract conditions remain the same. 27 (17%) households answered *no* while 48 (30%) of them gave no answer. All these 48 no-answer households had already fulfilled their SLCP contracts but did not convert their forestland back to farmland, so they might be willing to accept a renewal of the SLCP with better conditions. For those who did not want to continue with the SLCP under the current conditions, one of their major reasons was stated to be

[66] Generally, this is because nowadays most young people in rural China leave their villages to find jobs in cities and towns, and farmers staying in villages are aging.

"less income from trees than crops". Interestingly, this was contrary to the experiences of some other farmers who considered forestland more profitable as mentioned above. These crops-favouring households also mentioned the lack of techniques for increasing the production rate of fruit trees and more fluctuation in the prices of fruits than in crops. Additionally, dissatisfaction about the program payments was another major reason for being reluctant to renew the SLCP.

Although the majority of households showed willingness to renew their SLCP contracts, this did not mean they were totally satisfied about the current program. 75 out of the 161 participating households provided suggestions on the improvement of SLCP. 45 (60%) of them asked for a higher payment, 9 (12%) of them complained about the limited quotas of enrolled land and 6 (10%) of them reported payments not duly and fully delivered (one of them mentioned corruption). Moreover, extending the tenure of the program, technical assistance in planting and tending of fruit trees and marketing assistance in fruits sale were also mentioned by farmers.

5.2.5 What are the non-participating farmer households' reasons for not participating the SLCP?

As mentioned above, 85 farmer households who have qualified sloping land but did not participate in the SLCP were also interviewed in this study. On average, each of the non-participants household had 11.4 mu (0.76 hectare) qualified sloping land (Table 5.1), which is close to the average enrolled land of the participant households and accounted for 60% of the non-participating households' total land.

Given the high percentage of qualified sloping land held by the non-participating households, a natural question is why they did not participate in the SLCP. Surprisingly, the most mentioned reasons by the farmers were "not aware of the program at the time of implementation" (46%) and "no quota of enrolled land was assigned to them" (32%). This result together with the above finding that over half of the participating households did not enrol all their qualified sloping land because of limited quotas suggests that the potential of enrolling more sloping land in the SLCP could be substantial in these villages. 72 out of the 85 non-participating households answered an open-ended question about what adjustment/improvement of the SLCP could persuade them to take part in the program. 33% of them mentioned "raising the program payments to avoid decrease in income", but no farmers specified the desired level of payments. 31% of them said they "are willing to participate as long as quotas of enrolled land are assigned to them", which supports the above argument of SLCP's potential to expand in the villages. Moreover, 13% of the households asked for better information about the program and 7% asked for longer contract tenure.

5.3 The SLCP's Effect on Farmer Households' Livelihood

As reviewed in Section 2.3, the socio-economic effect of SLCP is one of the major research issues in existing SLCP studies. Apparently, hardly any real success can be achieved if a PES scheme like SLCP makes participants' livelihood worse off after taking part in the program. This study has examined the effect of SLCP on farmer households' livelihood from three aspects, i.e. comparison of the income per mu from crops before the SLCP and from trees after the program, comparison of households' income from all their sloping land before and after joining in the SLCP, and comparison of the total income (including both on-farm and off-farm income) of SLCP-participating and non-participating farmers.

5.3.1 Comparison of Income per mu from Trees and Crops

Table 5.3 lists the major species of trees the interviewed households planted on the enrolled sloping land after joining in the SLCP and major crops before the program, gross income per mu generated by the trees/crops, percentage of households planting the trees/crops and percentage of households receiving income from the trees/crops[67]. The comparison between income per mu from trees and crops is visualized by Figure 5.2.

As shown in Table 5.3, 63% of famers planted orange trees on their enrolled sloping land which generated the highest gross income (916 yuan/mu/year) among all the trees and crops. It is noticeable that farmers' gross income from orange trees exhibited a considerably wide range from 400 to 2000 yuan/mu/year. This huge difference explains why some farmers asked for technique assistance in cultivating and tendering fruit trees. Other major trees planted on the enrolled sloping land included poplar, chestnut, peach walnut and fir. As trees take years to mature for producing fruits, nuts or timber, some farmers had not received income from their trees at the time of survey, which was particularly the case for timber trees like poplar and fir.

[67] Some households' trees had not matured for sale or producing fruits, and some households grew crops only for their own consumption. In these cases, the households received no income from the trees or crops.

Table 5.3 Gross Income per mu from Major Trees and Crops

Percent-HH1: percentage of households planting the trees or crops. **Percent-HH2**: percentage of households receiving income from the trees or crops. As many households planted multiple trees/crops, the percentages here do not sum to unity.

Tree/Crop	Mean [a] (yuan/year)	5% - 95% Percentiles	Percent-HH1 [b]	Percent-HH2
Enrolled Forestland				
Orange	916 (430)	400 – 2000	63%	61%
Poplar	470 (191)	175 – 800	16%	10%
Chestnut	661 (237)	385 – 960	12%	9%
Peach	733 (187)	510 – 980	8%	7%
Walnut	514 (267)	216 – 932	9%	6%
Fir	511 (270)	247 – 667	11%	2%
Former Farmland				
Sesame	381 (150)	241 - 652	45%	45%
Wheat	394 (222)	200 - 900	43%	38%
Rapeseed	399 (226)	212 - 710	31%	29%
Maize	546 (449)	138 - 1625	34%	22%
Peanut	587 (354)	200 - 1190	15%	14%

[a] Values in parentheses are standard deviations

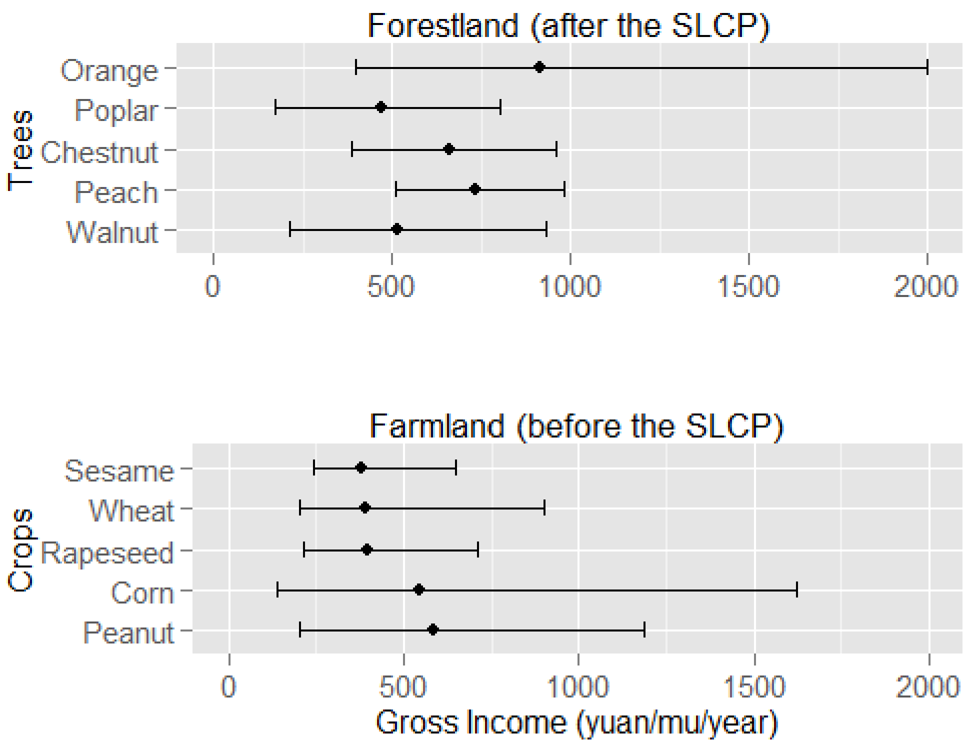

Figure 5.2 Comparison of Gross Income from Trees and Crops

Points represent the mean values while the slim bars represent the quantile range of 5%-95%.

Before the SLCP, major crops grown on the sloping land included sesame, wheat, rapeseed, corn and peanut. Some farmers grew crops like wheat and corn just for their households' own consumption rather than selling for money. In general, crops grown on the sloping land generated lower income than trees planted after the SLCP. Maize and peanut were relatively high-income crops (546 and 587 yuan/mu/year respectively), but still generate significantly lower income than orange trees [68]. This result is consistent with the above finding that 26% (the second largest percentage) of farmers chose "forestland can yield higher income than farmland" as the most important reason for their participation in the SLCP.

The payment from the SLCP, 230 yuan/mu/year, was lower [69] than the mean gross income from all the major crops but larger than the lower bound of 5% quantile values (except for sesame). That is to say, the income of a few of households from crops before the SLCP was lower than the payment from the SLCP, which is in agreement with the finding above that 4% of farmers attributed their participation in SLCP to the reason that "the payment from the program is higher than the income from farming in the enrolled land before".

5.3.2 Comparison of Households' income from Sloping Land before and after the SLCP

As most households planted multiple crops/trees on their sloping land, another aspect to assess the SLCP's effect on their livelihood is comparing their aggregate income from the sloping land before and after the SLCP. On average, the SLCP participant households received 5,365 yuan/year from crops on the sloping farmland before the SLCP. The income disparity between households was substantial given the large standard deviation of 9953 yuan/year. In fact, while about 10% of the households grew crops only for their own consumption and received no income, a few of them earned more than 20,000 yuan/year. Comparatively, households' average income

[68] The significance of difference here was tested by the non-parametric Mann-Whitney-Wilcoxon Test for two independent samples assuming no normal distribution. Moreover, although the average gross income of maize and peanut in the former farmland seemed higher than trees like poplar and walnut (Table 5.3), tests showed that the differences were not significant. On the other hand, however, chestnut and peach did generate significantly higher gross income than sesame, wheat and rapeseed.

[69] However, It should be noted that the payments from the SLCP can be considered as net income for farmers.

from trees after the SLCP was 7,727 (with the standard deviation of 10,882) yuan/year, which was significantly higher than their average income from crops before the program [70].

The distribution of households' income from the sloping land before and after the SLCP is illustrated in Figure 5.3. Generally speaking, more households were at the relatively high income levels after the SLCP than before. For example, 32% of farmers earned more than 10,000 yuan/year after the SLCP while only 14% did so before the program. When comparing each household's income from the sloping land before and after the SLCP, the analysis showed that 71% of households were not earning less after joining in the SLCP. When the payments from the SLCP were counted, the corresponding percentage increased to 75%, and farmers' average income from the enrolled land after the SLCP increased to 8,008 yuan/year.

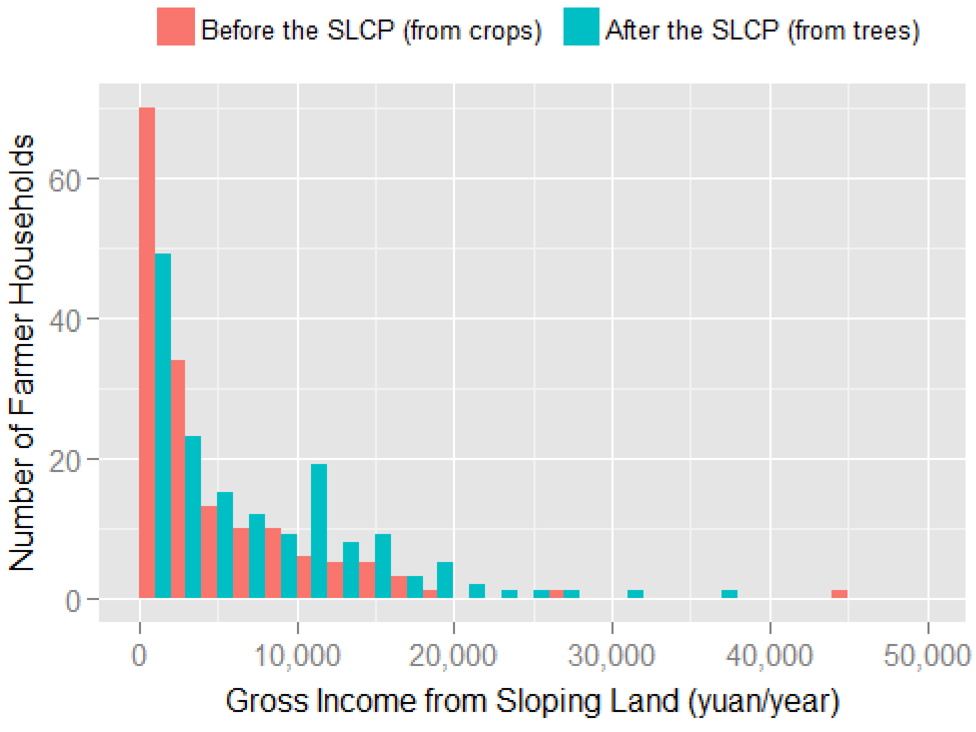

Figure 5.3 Distribution of Farmers' Income from Sloping Land

Each bar (in the same colour) represents an income range of 2,000 yuan/year. Accordingly, each five red/green-blue bars represent an income range of 10,000 yuan/year.

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[70] The significance here was tested by the non-parametric Wilcoxon Signed-Rank Test for two matched datasets (same farmers, before/after the SLCP) assuming no normal distribution of farmers' income.

5.3.3 Comparison of the Total Income of SLCP Participant and Non-participant Households

The analysis in Sections 5.3.1 and 5.3.2 indicates that trees planted on the sloping land generally produced higher income per mu than crops, and the SLCP participant households generally received higher income from the sloping land after joining in the SLCP. These results seemingly suggest that the SLCP is able to improve participants' livelihood. However, caution is needed in making this argument. It should be noted that the majority of the households entered the SLCP before 2005, which means the information of their income from crops before the SLCP was largely based on grain prices quite a few years ago, while the information of their income from trees after the SLCP was based on recent prices of forestry products (e.g. fruits, timber). This temporal disparity in the income information may cause some extent of bias in comparative analysis above, given the economic development and accompanied rising commodity prices in China. In order to overcome this potential bias and better understand SLCP's effect on participants' livelihood, further comparison was made between the total income of SLCP participant and non-participant households. The similarity in the characteristics of the two groups of households (see Section 5.1.1) ensures the validity of this comparison.

Most of the interviewed farmer households had multiple income sources, including trees in forestland, crops in farmland, livestock, agricultural products processing, part-time off-farm work, small businesses, money sent back by family members working in cities and towns and so on. For the convenience of comparing the two groups of households, income from forestland and farmland were classified as "land income", while income from all the other sources were classified as "other income". Table 5.1 presents the composition of the total income of the two groups of farmer households.

On average, the total income of the SLCP participant households was 23,430 yuan/year. While 11,500 yuan/year came from the enrolled forestland (8008 yuan/year) and retained farmland (3,487 yuan/year), approximately another half, 11,940 yuan/year came from other sources. The average percentage of households' income from enrolled forestland in the total income was 41.5%. That is to say, the forestland enrolled in the SLCP was an important income source but not the dominate one of the participant households. However, the disparity of households' reliance on the enrolled forestland was great, while about 12% of households received no income from the enrolled forestland, 11% of them relied on the enrolled forestland as the only income source.

Table 5.4 Total Income of Two Groups of Farmer Households

Income Source	Mean (Sd)	Median	5%-95% Percentiles
SLCP Participant Households			
Land income	11,500 (20,367)	7,650	0 - 30,860
Enrolled Forestland [a]	8,008 (11,079)	5,000	0 - 20,000
Retained Farmland	3,487 (15,988)	200	0 - 8,800
Other income	11,940 (14,497)	8,500	0 - 40,000
Total Income	*23,430 (24,784)*	*18,600*	*4,730 - 52,000*
Non-participant Households			
Land income	19,340 (28,378)	9,725	1,320 - 65,560
Other income	7,166 (8482)	4,500	0 - 24,700
Total Income	*26,510 (27468)*	*18,000*	*3,940 - 65,840*

[a] The reported income here includes both income from trees and payments from the SLCP if the households were still under the program.

In contrast, the average total income of the non-participant households was 26,510 yuan/year, in which 19,340 yuan/year came from land and 7,166 yuan/year came from other sources. Interestingly, the survey found that 81% of the non-participant households also planted orange trees even without payments from the SLCP due to the relatively high profitability. The Mann-Whitney-Wilcoxon Test for assessing the significance of difference between the two groups of households indicated that while the non-participant households received significantly higher land income than the participant households, their income from other sources was significantly lower than the participant households. As a result, the difference in the total income of the two groups of households was not statistically significant.

The higher land income of the non-participant households could partly be explained by the slightly but significantly larger total land held by them (see Section 5.1.1). That is to say, the lower land income of the participant households should not be entirely attributed to their participation in SLCP. The insignificant difference in total income between the two groups of households indicates that participation in the SLCP at least did not make famer households significantly worse off because their potential income increase from other income sources could largely offset their possible income loss from land.

5.4 Choice Modelling Results of Farmers Households' Preferences for the Design of Water Protection Programs

As explained in the Methodology chapter, farmer households' preferences for the design of water protection programs (including the existing SLCP and a hypothetical fertilizer reduction program) were modelled in terms of households' preferences for three defined attributes of the two programs and households' trade-offs between the three attributes in choosing the preferred program design. With regard to the SLCP, the three defined attributes were the annual payment (200, 300 and 400 yuan/year/mu), the contract length (5, 10 and 15 years) and the maximum percentage of commercial trees allowed to be planted on the enrolled land (0%, 50% and 100%) [71]. Each household was given three choice cards, each of which had three policy scenarios and each scenario was a combination of the three attributes at different levels. The households were asked to choose the preferred policy scenario from each choice card, so their preferences and trade-offs for the three attributes can be revealed by econometric models. As one of the attributes is the annual payment, the marginal values of the other two non-monetary attributes, i.e. the ratios of the coefficients of the non-monetary attributes to the coefficient of the annual payment, revealed how much farmer households were willing to trade (forgo) for a unit change in the contract length and the maximum percentage of commercial trees to be planted on the enrolled sloping land.

With regard to the hypothetical fertilizer reduction program, the three attributes of the hypothetical fertilizer reduction program were the annual payment (300, 400 and 500 yuan/year/mu), the contract length (2, 5 and 8 years) and the reduction rate of the fertilizers (25%, 50% and 75%). Similarly, each household was asked to choose the preferred policy scenario (design) from each of the three choice cards.

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[71] "Commercial trees" (e.g. fruit trees) refer to trees that can generate relatively high economic profits but less ecological benefits than "ecological trees". The specific species of trees under the two categories are designated by the Chinese National Bureau of Forestry.

5.4.1 Farmer Households' Preferences for the Design of SLCP

5.4.1.1 Marginal Values of Contract Length and Commercial Trees

As introduced in the Methodology chapter, the Conditional Logit Model (CLM), which is the classic and most widely used choice model, was applied in this study to reveal farmer households' preferences and trade-offs between three attributes of the SLCP. Table 5.6 presents the CLM estimation results of the two groups of households and the pooled sample of all households. The coefficients of variables (attributes) in the CLM represent the change in farmer households' utility (an ordinal variable describing their satisfaction to different policy scenarios) that is associated with a unit change in the corresponding attributes. The signs of the coefficients indicate whether farmer households prefer (positive signs) or dislike (negative signs) an increase in the attributes.

Table 5.5 Conditional Logit Model of Farmer Households' Preferences for the Design of SLCP

Significance Level: 0.001 ***, 0.01 **, 0.05 *

Variable	Coefficient (Standard Error)		
	SLCP-participants	**Non-participants**	**All Households**
Annual Payment [a]	0.047 (0.006) ***	0.033 (0.008) ***	0.042 (0.005) ***
Contract-length	0.033 (0.012) **	0.038 (0.017) *	0.035 (0.010) ***
P-com-trees [b]	0.044 (0.012) ***	0.069 (0.016) ***	0.053 (0.010) ***
Log-likelihood	-489.57	-262.78	-754.40
Marginal Value of the Attributes			
Contract-length (yuan/year) [c]	6.97 (1.95, 12.45)	11.37 (1.67, 25.39)	8.27 (3.80, 13.20)
P-com-trees (yuan/10%)	9.41 (4.48, 15.15)	20.78 (10.66, 41.82)	12.54 (8.02, 18.04)

[a] For the convenience of presenting the results, Annual Payment was input in models in the unit of 10 yuan/mu, so the coefficient here represents the change in farmers' utility for every increase of 10 yuan/year/mu in the program payment.
[b] The maximum percentage of commercial trees was input in models in the unit of 10% for the convenience of presenting the results
[c] Values in the parentheses are the 95% confidence intervals of the estimates.

As Table 5.5 shows, all the three attributes of SLCP are with positive and significant coefficients in the models of the three samples of households, which means farmer households significantly preferred higher payments, longer contracts and less restriction on the planting of commercial trees. The magnitudes of coefficients in the CLM are relatively small (below 0.1) simply because of the units of attributes used in the modelling process. For example, If the unit of annual payment was changed from 10 yuan/year/mu to 100 yuan/year/mu, the coefficient of annual payment in the model of all households would increase from 0.042 to 0.42. However, the unit of 10 yuan/year/mu is more convenient for policy interpretation as the current annual payment of the SLCP is 230 yuan/mu/year.

The marginal values of contract length and the maximum percentage of commercial trees are also presented in Table 5.5. The SLCP-participant households were found to be willing to forgo 6.97 yuan/mu/year for every extra contract year at least within the range of 5-15 years[72] and 9.41 yuan/mu/year for each 10% more commercial trees allowed to be planted on the enrolled sloping land within the full range of 0%-100% (i.e. from complete restriction to no restriction at all). In contrast, the non-participant households were willing to forgo 11.37 yuan/mu/year for every extra contract year and 20.78 yuan/mu/year for each extra 10% commercial trees. With regard to the pooled sample of all farmers, the marginal values of contract length and the maximum percentage of commercial trees were 8.27 and 12.54 yuan/mu/year respectively.

Noticeably, non-participant households were willing to forgo almost twice the payment as the participant households would do for an extra year of contract length or the permission of 10% more commercial trees. This substantial difference between the two groups of households may be attributed to the strong interests of the non-participant households in joining in the SLCP. As reported in previous sections, the two groups of farmer households had a similar amount of sloping land qualified for the SLCP and many households in both groups planted orange trees as an important income source, but the participant farmers could receive extra income from the SLCP payments. Moreover, many non-participant households did not join in the program, not because they had no intention but because no quotas of enrolled land was assigned to them. Therefore, the attractiveness of receiving extra income from the SLCP with no need to change much of the current land use activities might have lowered the non-participants'

[72] This is the range of contract length that were presented to farmers in the survey. Any evaluation involving shorter or longer contract length requires extrapolation, which is less reliable than evaluation within the range.

expectation for the program payments (i.e. they were willing to forgo more money for extra contract years and higher percentage of commercial trees).

The uncertainties/distributions of the marginal value estimates are described by the 95% confidence intervals shown in Table 5.5 and illustrated in Figure 5.4. It can be noted that the marginal values estimates of non-participant households exhibit more dispersed distributions (in green shade) than the estimates of SLCP-participant households (in red shade). This can be attributed to the larger standard errors of the estimated coefficients in the model of non-participant households (see Table 5.5).

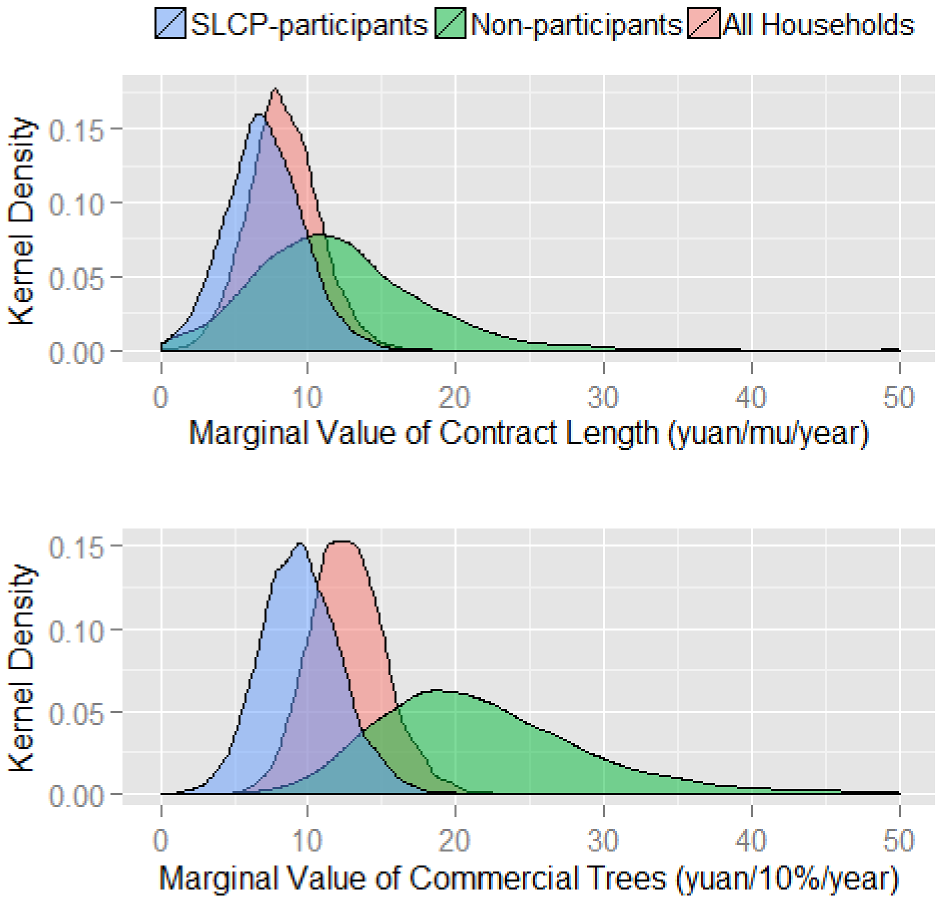

Figure 5.4 Distribution of Marginal Value Estimates of the SLCP

5.4.1.2 Farmer Households' Preferences for Longer SLCP Contracts

It is common to find preferences for higher payments and less restrictions on land use activities in the literature on farmer households' willingness to participate in agri-environmental schemes (Ruto and Garrod 2009; Chen *et al.* 2009a; Espinosa-Goded, Barreiro-Hurle and Ruto 2010; Christensen *et* *al.* 2011; Beharry-Borg *et al.* 2013). However, it is rarely reported in the literature that farmer households preferred longer contracts and would forgo certain payments for extra contract years as found in this study. Doubts may arise on whether the farmer households simply chose the policy scenarios with the largest aggregate payments (i.e. the product of the Annual Payment and Contract-length) or they just considered the aggregate payments and the maximum percentage of commercial trees in their choices instead of truly preferring longer contracts. In order to clarify these doubts, further analyses are conducted from the following two aspects.

Firstly, a descriptive statistical analysis of farmer households' choices in the survey (Table 5.6) shows that the policy scenarios with the largest aggregate payment in the three choice cards (highlighted in bold) were chosen by 57%, 30% and 31% households respectively, which were far from dominant. Obviously, the aggregate payment was not the decisive factor of households' choices of preferred design of SLCP.

Table 5.6 Farmer Households' Choices for Policy Scenarios of SLCP

In the real survey, Aggregate Payment (yuan/mu) did not actually appear in the choice cards presented to farmers, and policy scenarios were neither listed in descending nor ascending order to avoid any ordering effect on farmers' choices.

Annual Payment (yuan/mu)	Contract-length (year)	P-com-trees	Aggregate Payment	Households' Choice
Choice Card A				
400	15	50%	**6000**	**57%**
300	10	100%	3000	33%
200	5	0	1000	9%
Choice Card B				
300	15	0%	**4500**	**30%**
400	5	100%	2000	49%
200	10	50%	2000	21%
Choice Card C				
400	10	0%	**4000**	**31%**
200	15	100%	3000	31%
300	5	50%	1500	38%

Secondly, two modified conditional logit models were constructed to examine the modelling effect of contract length and aggregate payment. The first modified model (Modified CLM-1) replaced the annual payment and contract length in the original CLM with the aggregate payment and the second modified model (Modified CLM-2) removed contract length from the original CLM. The modelling results (Table 5.7) show that both of the two modified models exhibit significantly lower goodness of fit than the original CLM, especially for the pooled sample of all households. That is to say, including contract length in the choice model can significantly improve the model's ability to explain farmer households' preferences for the policy scenarios of SLCP, and considering the contract length and annual payment as two separate variables is a significantly better strategy to understand farmers' choice than using the aggregate payment in the model.

Table 5.7 Modelling Effect of Contract-length and Aggregate Payment

Significance Level: 0.001 ***, 0.01 **, 0.05 *

Variable	Coefficient (Standard Error)		
	SLCP-participants	**Non-participants**	**All Households**
Modified CLM-1			
Aggregate Payment	0.002 (0.000) ***	0.002 (0.000) ***	0.002 (0.000) ***
P-com-trees	0.054 (0.012) ***	0.077 (0.017) ***	0.062 (0.010) ***
Log-likelihood [a]	-502.92	-265.30	-769.38
LR-test with CLM [b]	2.37×10^{-7}	0.02	4.41×10^{-8}
Modified CLM-2			
Annual Payment	0.045 (0.006) ***	0.030 (0.008) ***	0.040 (0.005) ***
P-com-trees	0.037 (0.012) ***	0.063 (0.016) ***	0.046 (0.009) ***
Log-likelihood	-493.23	-265.39	-760.81
LR-test with CLM	0.007	0.02	3.44×10^{-4}

[a] Log-likelihood indicates the goodness of fit of the model. Larger log-likelihoods indicate better model fitting. The log-likelihoods of the original CLM for the SLCP-participants, non-participants and the pooled sample of all households are -489.57, -262.78, -754.40 respectively, which are all larger than that of the modified models.

[b] Values in this row are the p-values of likelihood ratio test. P-values less than 0.05 mean that the original CLM has significantly better fitting than the modified models.

The analyses from the above two aspects indicate that substantial farmer households did not prefer the policy scenarios with the largest aggregate payment and contract length significantly contributed to the model fitting as a separate variable. This implies that farmers households did take account of contract length as a significant variable in making their choices and the result of their preferences for longer contracts revealed by the CLM is valid[73]. In fact, longer contracts of agri-environmental schemes could both have the benefit of generating stable income and the drawback of reducing the flexibility of land use activities. The preferences for longer contracts revealed by this study indicates that the interviewed farmer households put more weight on the positive side of long-term SLCP than its drawback. This finding has important policy implications that will be discussed in the next chapter.

5.4.2 Farmer Households' Preferences for the Design of Fertilizer Reduction Program

In addition to the existing SLCP, this study also investigated farmer households' preferences for the design of a hypothetical water protection program for reducing the use of Nitrogen and Phosphate fertilizers on the flat farmland that cannot be covered by the SLCP. As presented in Table 5.8, farmer households showed significant preferences for higher annual payments, longer contracts and understandably significant dislike of higher percentages of fertilizer reduction.

Table 5.8 Conditional Logit Model of Farmer Households' Preferences for the Design of Fertilizer Reduction Program

Significance Level: 0.001 ***, 0.01 **, 0.05 *

Variable	Coefficient (Standard Error)		
	SLCP-participants	**Non-participants**	**All Households**
Annual Payment [a]	0.045 (0.006) ***	0.047 (0.008) ***	0.046 (0.005) ***
Contract-length	0.147 (0.021) ***	0.073 (0.028) **	0.120 (0.017) ***
P-ferti-reduce [b]	-0.069 (0.025) **	-0.087 (0.033) **	-0.075 (0.020) ***
Log-likelihood	-452.09	-252.13	-706.5
Marginal Value of the Attribute			
Contract-length (yuan/year) [c]	32.51 (21.95, 47.98)	15.37 (3.66, 31.66)	26.45 (18.28, 36.96)
P- fert-reduce (yuan/10%)	-15.19 (-30.23, -4.03)	-18.45 (-37.96, -4.39)	-16.39 (-27.54, -7.42)

[a] Annual Payment was input in the model in the unit of 10 yuan/mu.
[b] Percentage of fertilizer reduction was input in models in the unit of 10%.
[c] Values in the parentheses are the 95% confidence intervals.

[73] Similar analysis will not be repeated for the fertilizer reduction program.

With regard to the marginal values of contract length and fertilizer reduction rate, the SLCP-participant households were willing to forgo 32.51 yuan/mu/year for every extra contract year within the range of 2-8 years, but they would require 15.19 yuan/mu/year for reducing the use of each 10% of fertilizers within the range of 25% to 75%. Comparatively, the non-participant households would forgo only about half of the annual payment (15.37 yuan/mu/year) as the participants did for every extra contract, and they required more money (18.45 yuan/mu/year) than the participants for reducing the use of each 10% of fertilizers. When the two groups of households were pooled together for analysis, they were willing to trade every extra contract year for 26.45 yuan/mu/year and each 10% lower fertilizer reduction rate for 16.39 yuan/mu/year. Figure 5.5 illustrates the distribution of the marginal value estimates for the attributes of contract length and fertilizer reduction rate.

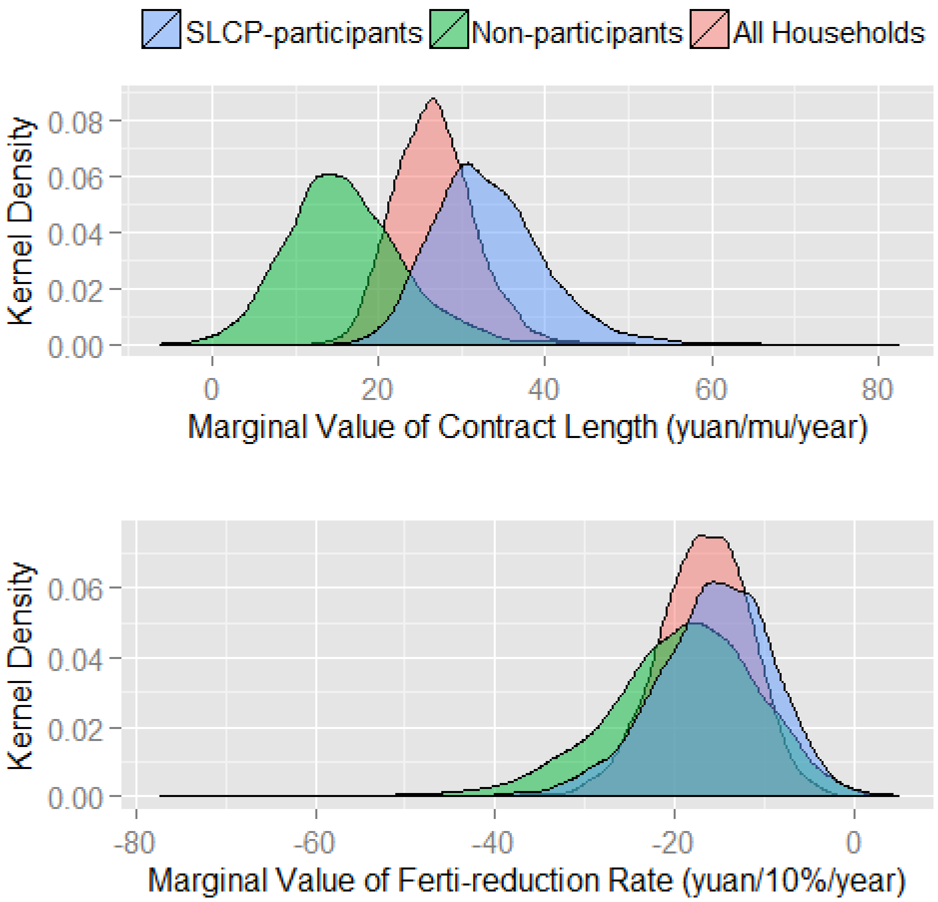

Figure 5.5 Distribution of Marginal Values Estimates of the Fertilizer Reduction Program

Interestingly, while the non-participant households were willing to forgo more money for extra contract years and the permission of planting more commercial trees when choosing the preferred design of SLCP, they would forgo less money for extra contract years and require more money for higher fertilizer reduction rates when choosing the preferred design of the fertilizer reduction program. In other words, the non-participant households showed relatively less interests in reducing the use of fertilizers in the flat farmland. This may be explained by the earlier finding mentioned in Section 5.3 that the non-participant households were more reliant on income from their land, thus the fertilizer reduction program may impose a larger effect on their livelihood.

5.5 Heterogeneity in Farmer Households' Preferences for the Design of Water Protection Programs

5.5.1 Estimation Results of the Random Parameters Logit Model

In Section 5.4, the classic Conditional Logit Model (CLM) is applied to reveal farmer households' preferences for the design of water protection programs. In the CLM, farmer households' preferences for each program attribute is represented by one estimated coefficient, which implies that all households in the sample had homogeneous preferences. This was useful simplification for modelling but not necessarily true in practice. In order to take account of the heterogeneity in farmer households' preferences, the advanced Random Parameters Logit Model (RPL) is applied in this section.

The RPL estimates a statistic distribution for the coefficient of each attribute, so the coefficient representing farmer households' preferences for the attribute is allowed to vary among households and follow the estimated distribution. Normal distribution represented by mean and standard deviation was mostly used in literature (Train 1998; Hanley, Wright and Alvarez-Farizo 2006; Ruto and Garrod 2009; Espinosa-Goded, Barreiro-Hurle and Ruto 2010) and thus was applied in this study. However, farmer households' preferences for the monetary attribute was usually assumed to be uniform among households for the convenience of calculating the marginal values of non-monetary attributes.

5.5.1.1 Farmer Households' Heterogeneous Preferences for the Design of SLCP

Table 5.9 presents the RPL estimates of farmer households' preferences for the design of SLCP. The attributes of contract length and maximum percentage of commercial trees in the RPL have two coefficients, i.e. the mean and standard deviation of the normal distributions that describe farmer households' heterogeneous preferences for the two attributes. If the standard deviation coefficient is significant, it means that there is significant heterogeneity in farmers' preferences for the attribute. When the standard deviation coefficient is relatively large compared with the mean coefficient (in terms of the absolute value), it implies that some households showed opposite preferences for the attribute to what is indicated by the mean coefficient [74]. The likelihood ratio test (LR-test with CLM) showed that the RPL significantly improves the model fitting than the CLM for all the three samples of farmer households, especially for the pooled sample of all farmers (with the p-value of 4.07×10^{-7}).

Table 5.9 Radom Parameters Logit Model of Farmers Households' Preference for the Design of SLCP

Significance Level: 0.001 ***, 0.01 **, 0.05 *, 0.1 $^{\circ}$

Variable	Coefficient (Standard Error)		
	SLCP-Participants	Non-participants	All Households
Annual Payment	0.055 (0.007) ***	0.035 (0.009) ***	0.048 (0.006) ***
Mean-Contract-length	0.033 (0.015) *	0.035 (0.018) *	0.034 (0.012) **
Mean-P-com-tree	0.054 (0.017) **	0.079 (0.022) ***	0.064 (0.013) ***
Sd-Contract-length [a]	0.109 (0.034) **	0.019 (0.143)	0.086 (0.029) **
Sd- P-com-trees	0.131 (0.033) ***	0.137 (0.042) **	0.134 (0.026) ***
Log-likelihood	-478.39	-257.94	-739.69
LR-test with CLM [b]	1.40×10^{-5}	0.003	4.07×10^{-7}
Marginal Value of the Attribute			
Contract-length [c] (yuan/year)	6.02 (0.63, 12.15)	9.91 (0.00, 26.02)	7.19 (2.45, 12.64)
P-com-trees (yuan/10%)	9.98 (3.87, 17.04)	22.45 (10.16, 47.36)	13.35 (7.84, 19.98)

[a] This refers to the standard deviation coefficient of the attribute of contract length.
[b] Values in this row are the p-values of the likelihood ratio test for assessing the significance of improvement in model fitting from the Conditional Logit Model to the Random Parameters Logit Model.
[c] Values in the parentheses are the 95% confidence intervals.

74 This is because for a normal distribution, a relatively large standard deviation (compared with the mean) implies that the distribution disperses on both sides of the x axis. So there are both positive and negative values in this distribution no matter that the mean is on the positive or negative side.

For the SLCP-participant farmer households (Table 5.9), the standard deviation coefficients of contract length and the maximum percentage of commercial trees (Sd-Contract-length and Sd-P-com-trees) are significant at the 0.01 and 0.001 level respectively, which means participant households showed significant heterogeneity in their preferences for the two attributes. Specifically, the SLCP-participants' heterogeneous preferences for contract length can be described by a normal distribution with the mean of 0.033 (the coefficient of Mean-Contract-length) and standard deviation of 0.109 (the coefficient of Sd-Contract-length). In such a normal distribution, the probability of having a negative value is 38%. That is to say, although the SLCP-participant households preferred longer contracts on average (as the mean coefficient of 0.033 indicates), 38% of them had different preferences to the majority and preferred shorter contracts.

Furthermore, the SLCP-participant households' preferences for the maximum percentage of commercial trees can be described by a normal distribution with the mean of 0.054 and standard deviation of 0.131, which implies 34% of them showed different preferences to the majority and preferred lower percentage of commercial trees allowed to be planted on the sloping land. This preference for stricter restriction on commercial trees seems strange, a possible explanation is that some households were actually indifferent to this restriction and chose the policy scenarios with stricter restriction but higher annual payment and longer contracts (such as the first policy scenario in Choice Card B and Choice Card C in Table 5.6), which made them appear to favour stricter restrictions on commercial trees.

The marginal values of attributes in the RPL were calculated based on the mean coefficients of the two non-monetary attributes and the coefficient of annual payment. On average, the SLCP-participant households willing to forgo 6.02 yuan/mu/year for every extra contract year and 9.98 yuan/mu/year for the permission of each 10% commercial trees. These estimates are close to the estimates of the CLM (6.97 and 9.41 yuan/mu/year respectively), which reflects the consistency between the two models.

As for the non-participant farmer households, no significant heterogeneity was found in their preferences for contract length since the standard deviation coefficient (Sd-Contract-length) in the RPL is not significant (Table 5.9). That is to say, households in this group showed homogenous preferences for longer contracts. In contrast, non-participant households showed heterogeneous preferences for the maximum percentage of commercial trees (at the 0.01 significance level), which can be described by a normal distribution with the mean of 0.079 and standard deviation of 0.137. This means 28% of them showed preferences for stricter restrictions on the planting of commercial trees, which indicates lower heterogeneity than the SLCP-participant households with the corresponding percentage of 34%. Similar to the case of the SLCP-participant households, the marginal value estimates of the non-participant households by the RPL are similar to the estimates by the CLM. On average, farmer households in this group were willing to trade every extra contract year for 9.91 yuan/mu/year and the planting permission of each 10% commercial trees for 22.45 yuan/mu/year.

When the two groups of households were pooled together, the RPL estimates show that farmer households' preferences for contract length and the maximum percentage of commercial trees were both significantly heterogeneous and could be described by a normal distribution with the mean of 0.034 and standard deviation of 0.086 and another normal distribution with the mean of 0.064 and standard deviation of 0.134 respectively. This means while they preferred longer contracts and less restriction on commercial trees on average, 34% of them showed preference for shorter contracts and 32% of them preferred stricter restrictions on commercial trees. Moreover, the marginal values of an extra contract year and the permission of 10% more commercial trees are 7.19 and 13.35 yuan/mu/year respectively, which are similar to the estimates of the CLM (8.27 and 12.54 yuan/mu/year).

5.5.1.2 Farmer Households' Heterogeneous Preferences for the Design of Fertilizer Reduction Program

Table 5.10 presents the RPL estimates of farmer households' preferences for the design of the hypothetical fertilizer reduction program. It can be noted that the standard deviation coefficients of fertilizer reduction rate in the models of all the three samples of farmer households are insignificant, which indicates that all households had homogeneous preferences for lower requirement of reducing the use of fertilizers. The non-participant (of SLCP) households also showed homogenous preferences for longer contracts. Since this group of households did not show significant heterogeneity in their preferences for both the attributes of contract length and fertilizer reduction rate, the RPL of this group of households did not exhibit significant improvement in model fitting than the CLM as shown by the likelihood ratio test (p-value=0.45).

In contrast, the SLCP-participant households showed significantly heterogeneous preferences for contract length which can be described by a normal distribution with the mean of 0.171 and standard deviation of 0.199. This means 20% of households in this group preferred shorter contracts while the whole group preferred longer contracts on average. For the pooled sample of all farmer households, the heterogeneity in their preferences for contract length is at the 0.001 significance level and can be described by a normal distribution with the mean of 0.138 and standard deviation of 0.178, which indicates 22% of the pooled sample of all households preferred shorter contracts.

Table 5.10 Radom Parameters Logit Model of Farmer Households' Preference for the Design of Fertilizer Reduction Program

Significance Level: 0.001 ***, 0.01 **, 0.05 *

Variable	Coefficient (Standard Error)		
	SLCP-Participants	**Non-participants**	**All Households**
Annual Payment	0.049 (0.007) ***	0.049 (0.009) ***	0.049 (0.005) ***
Mean-Contract-length	0.171 (0.026) ***	0.080 (0.031) *	0.138 (0.020) ***
Mean-P-fert-reduce	-0.075 (0.028) **	-0.088 (0.037) *	-0.079 (0.022) ***
Sd-Contract-length	0.199 (0.051) ***	0.127 (0.080)	0.178 (0.042) ***
Sd-P-fert-reduce	0.018 (0.454)	0.010 (1.002)	0.018 (0.373)
Log-likelihood	-446.17	-251.33	-700.17
LR-test with CLM	0.003	0.45	0.002
Marginal Value of the Attribute			
Contract-length (yuan/year)	34.84 (23.27, 51.42)	16.39 (3.83, 33.43)	28.21 (19.52, 39.34)
P-fert-reduce (yuan/10%)	-15.26 (-30.75, -3.93)	-18.04 (-38.56, -3.22)	-16.18 (-27.62, -7.02)

The marginal value estimates of the RPL for the fertilizer reduction program are similar to the estimates of the CLM. The SLCP-participant households were willing to forgo more money for extra contract years (34.84 in contrast with 16.39 yuan/mu/year) and required less money (15.26 in contrast with 18.04 yuan/mu/year) for achieving higher fertilizers reduction rate. For the pooled sample of all farmer households, the marginal values of contract length and fertilizer reduction rate are 28.21 and -16.18 yuan/mu/year respectively, while the estimates by the CLM were 26.45 and -16.39 yuan/mu/year respectively.

5.5.2 Factors Causing Heterogeneity in Farmer Households' Preferences for the Design of Water Protection Programs

The Random Parameters Logit Model (RPL) provides useful information of the distribution of farmer households' heterogeneous preferences for the design of water protection programs. However, it does not explain what factors might have caused the revealed heterogeneity. A possible method to understand the source of farmer households' heterogeneous preferences is to introduce their characteristics into the RPL through interactions with the program attributes. Special interests are focused on the heterogeneous preferences for contract length as farmer households' overall preferences for longer contracts is a special finding of this study, and it would be interesting to know which types of households showed significantly greater or less interests in longer contracts. Table 5.11 presents the estimation results of RPL with interaction terms between farmer households' characteristics and the contract length of SLCP [75].

For the SLCP-participant households, education, the percentage of enrolled land in their total land and total income were significant factors causing the heterogeneity in households' preferences for contract length. The heads of households who had at least completed middle school education showed significantly greater interests in longer contracts (at the 0.01 significance level), which may be attributed to their better knowledge and skills to receive income from trees on the sloping land and other sources. Households with higher total income were also significantly more willing to accept longer contracts (at the 0.01 significance level). It is possible that these well-off households received higher income after joining in the SLCP and thus had more positive attitudes to this program, or they were less sensitive to the change in opportunity cost (e.g. crops prices) of converting farmland to forestland and appreciated SLCP more for the benefit of stable income and less labour input needed for trees than crops.

On the other hand, households who enrolled higher percentages of their total land in the SLCP were significantly less willing to accept longer contracts (at the 0.001 significance level), probably because they would like to retain more flexibility in land use and preferred more diversified land management. Interestingly, the standard deviation coefficient of contract

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[75] The RPL with interaction terms between farmers' characteristics and the maximum percentage of commercial trees did not generate satisfactory estimation results and thus is not reported here.

length (Sd-Contract-length) is no longer significant after introducing the interaction terms between farmer households' characteristics and contract length in the RPL for the SLCP-participant households. That is to say, the heterogeneity of this group of households' preferences for the contract length of SLCP has been well captured by these interaction terms.

Table 5.11 Heterogeneity in Farmer Households' Preference for the Contract length of SLCP

Significance Level: 0.001 ***, 0.01 **, 0.05 *, 0.1 °

Variable	Coefficient (Standard Error)		
	SLCP-Participants	**Non-participants**	**All Households**
Annual Payment	0.055 (0.008) ***	0.035 (0.009) ***	0.048 (0.006) ***
Mean-Contract-length	0.186 (0.066) **	-0.040 (0.092)	0.108 (0.051) *
Mean-P-com-trees	0.058 (0.017) ***	0.081 (0.022) ***	0.066 (0.013) ***
Sd-Contract-length	0.065 (0.046)	0.005 (0.505)	0.066 (0.034) °
Sd-P-com-trees	0.127 (0.034) ***	0.138 (0.043) **	0.133 (0.026) ***
Log-likelihood	-444.87	-251.33	-711.92
Interaction Terms with Contract Length			
Gender (female)	0.005 (0.034)	0.026 (0.043)	0.003 (0.026)
Age	0.030 (0.033)	-0.014 (0.047)	0.022 (0.025)
Education	0.084 (0.032) **	-0.018 (0.047)	0.043 (0.025) °
Family Size	-0.013 (0.009)	0.009 (0.016)	-0.007 (0.008)
Hiring Labour [a]	0.031 (0.033)	0.017 (0.052)	0.025 (0.027)
Total Land	-0.021 (0.037)	-0.082 (0.058)	-0.017 (0.030)
P-enrolled/qualified [b]	-0.214 (0.065) ***	0.130 (0.083)	-0.086 (0.045) °
Total Income	0.128 (0.041) **	0.050 (0.055)	0.090 (0.031) **
P-land-income [c]	-0.071 (0.051)	-0.038 (0.073)	-0.078 (0.039) *

[a] This is a binary variable indicating whether the households hired labour for farming.
[b] This variable refers to the percentage of the households' sloping land enrolled (for SLCP-participants) or qualified (for non-participants) in their total land.
[c] This variable refers to the percentage of the households' land income in their total income.

For the non-participant households, no significant heterogeneity was found by the original RPL in their preferences for contract length (Table 5.9). Introducing the interaction terms does not change this finding and none of the interaction terms are significant in this new model either. However, the RPL with interaction terms performs relatively well for the pooled sample of all households. Similar to the case of the SLCP-participant households, education and total income were positive factors of the preferences for longer SLCP contracts while the percentage of enrolled/qualified land in the total land was a negative factor, but the effect of education and percentage of enrolled/qualified land decreased to the 0.1 significance level due to the integration of the two groups of households.

Additionally, percentage of land income in households' total income (P-land-income) was a significantly negative factor at the 0.05 significance level, indicating that households who were more reliant on land income had significantly less interest in longer contract. This is probably because greater reliance on land income made farmer households more sensitive to the changing market prices of crops and forest products, so they preferred greater flexibility in land use and thus chose shorter SLCP contracts. After introducing the interaction terms in the RPL, the standard deviation coefficient of contract length is only significant at the 0.1 level while it is at the 0.01 significance level in the original RPL. That is to say, the interaction terms has largely but not completely captured the heterogeneity of households' preference for the contract length of SLCP.

Table 5.12 presents the estimation results of RPL with interaction terms between households' characteristics and the contract length of the hypothetical fertilizer reduction program. Unlike the case of SLCP, the standard deviation coefficients of contract length in the models of the SLCP-participant households and the pooled sample of all households are still significant after introducing the interaction terms [76]. That is to say, the interaction terms with households' characteristics cannot well capture all the heterogeneity in households' preferences for contract length of this hypothetical program. Nevertheless, it is found that female heads of households in the group of SLCP-participants showed significantly less interest in longer contracts, education is a significantly positive factor of the non-participant households' preferences for longer contracts and both gender and education are significant factors causing the heterogeneity in the pooled sample of all households' preferences for contract length. These results are useful information for future studies on farmer households' heterogeneous preferences for the design of fertilizer reduction programs.

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[76] The standard deviation coefficient of contract length in the original RPL of the non-participant households is not significant (Table 5.10), so the insignificance of this coefficient in the new RPL (Table 5.12) can hardly be attributed to the introduction of the interaction terms.

Table 5.12 Heterogeneity in Farmer Households' Preference for the Contract length of Fertilizer Reduction Program

Significance Level: 0.001 ***, 0.01 **, 0.05 *, 0.1 °

Variable	Coefficient (Standard Error)		
	SLCP-Participants	Non-participants	All Households
Annual Payment	0.050 (0.007) ***	0.049 (0.009) ***	0.049 (0.005) ***
Mean-Contract-length	0.341 (0.125) **	0.191 (0.152)	0.275 (0.091) **
Mean-P-fert-reduce	-0.074 (0.028) **	-0.088 (0.037) *	-0.079 (0.022) ***
Sd-Contract-length	0.171 (0.057) **	0.056 (0.155)	0.156 (0.046) ***
Sd-P-fert-reduce	0.001 (1.120)	0.006 (1.511)	0.004 (0.803)
Log-likelihood	-428.67	-244.63	-680.99
Interaction Terms with Contract Length			
Gender (female)	-0.031 (0.056) *	-0.046 (0.069)	-0.090 (0.042) *
Age	0.074 (0.058)	0.009 (0.074)	0.038 (0.045)
Education	0.043 (0.054)	0.164 (0.080) *	0.103 (0.043) *
Family Size	-0.021 (0.017)	-0.011 (0.023)	-0.017 (0.013)
Hiring Labour	0.002 (0.056)	0.103 (0.082)	0.038 (0.044)
Total Land	-0.005 (0.066)	-0.004 (0.087)	-0.001 (0.050)
P-enrolled/qualified	-0.132 (0.117)	-0.161 (0.128)	-0.106 (0.082)
Total Income	0.087 (0.069)	-0.068 (0.078)	0.009 (0.049)
P-land-income	-0.009 (0.085)	-0.083 (0.114)	-0.084 (0.65)

5.6 Summary

This chapter presents the research findings of the Choice Experiment survey in seven villages around the Danjiangkou Reservoir on farmer households' preferences for the design of water protection programs. For the existing Sloping Land Conversion Program (SLCP), the estimation results of the classic Conditional Logit Model show that farmer households in general preferred higher payment, longer contracts and higher percentage of commercial trees allowed to be planted on the enrolled sloping land. The finding of preferences for longer contracts is different from the results of most choice modelling studies on agri-environmental programs, which may be attributed to the relatively positive effect of SLCP on farmer households' livelihood.

Analysis of farmer households' trade-offs between defined program attributes of the SLCP found that households who had not participated in the

SLCP were willing to forgo twice as much payment as the households who had participated in the SLCP did for every extra contract year and the permission of planting each 10% more commercial trees. When the two groups of farmer households were pooled together for the analysis, they were willing to forgo about 8 yuan/mu/year for every extra contract year and 13 yuan/mu/year for the each 10% more commercial trees.

With regard to the hypothetical program for reducing the use of fertilizers on flat farmland, farmer households in general preferred higher payment, longer contracts and lower fertilizer reduction rate. Unlike the case of SLCP, the non-participant households showed less interest in this hypothetical program as they were willing to forgo only about half of the payment as the SLCP-participant households did for every extra contract year and required more payment for reducing their fertilizer use by each 10%. When the two groups of households were pooled together for analysis, they were willing to trade each extra contract year for about 26 yuan/mu/year but required 16 yuan/mu/year for reducing the use of fertilizers by each 10%.

The Random Parameters Logit Model was applied in this study to reveal the heterogeneity in farmer households' preferences for the design of water protection programs. The modelling results indicate that there was significant heterogeneity in the SLCP-participant households' preferences for both contract length and the maximum percentage of commercial trees. Although, on average, households in this group preferred longer contracts and the permission of higher percentage of commercial trees, 38% of them showed contrary preferences for shorter contracts and 34% of them did not prefer higher percentage of commercial trees. The non-participant households only showed significant heterogeneity in their preferences for commercial trees and 28% of them did not prefer the permission of higher percentage of commercial trees. For the hypothetical fertilizer reduction program, both of the two groups of households show homogeneous preferences for lower fertilizer reduction rates. The non-participant households showed homogeneous preferences for longer contracts as well. But the SLCP-participant households showed significantly heterogeneous preferences for contract length and 20% of them preferred shorter contracts.

In order to understand the source of farmer households' heterogeneous preferences for the design of water protection programs, interaction terms between farmer households' characteristics and the variable of contract length were introduced into the random parameters logit models. The results indicate that introducing the interaction terms can well capture the heterogeneity in the SLCP-participant households' preferences for the contract length of SLCP. While education level of the heads of households and households' total income are significantly positive factors of the preferences for longer contracts, larger percentage of enrolled land in households' total land could lead to significantly less interests in longer contracts. Additionally, the percentage of land income in households' total income is also a significantly negative factor of the preferences for longer contract in the pooled sample of all households. In contrast, the interactions terms with households' characteristics cannot well explain their heterogeneous preferences for the contract length of the hypothetical fertilizer reduction program, which needs more studies in the future.

In addition to the choice modelling questions, some auxiliary questions were also asked in the farmer households survey which provides useful information for better understanding the implementation of SLCP in the surveyed villages. The survey results show that the most important two reasons for farmer households' participation in the SLCP were strong promotion of the program by the government and the prospect of higher income from forestland than farmland. On the other hand, households with qualified land did not participate in the SLCP mainly because of unawareness of the program or limited quotas of enrolled land assigned to their villages. In fact, limited quotas of enrolled land was also the major reason why some of the participant households only enrolled part of their qualified land in the SLCP. These results indicate the potential for extending the SLCP in these villages in the future.

The analysis of the effect of SLCP on farmer households' livelihood found that the participant households generally received higher income from the sloping land after joining in the SLCP as a result of higher income per mu generated by trees (especially orange trees) than crops. Further comparison of the participant and non-participant households found that the difference in the average total income of the two groups of households was not significant. The participant households were less reliant on land income because, as some households stated, managing forestland needed less tending time than farmland and thus they had better chance to receive income from other sources. Overall, a conservative argument is that participation in the SLCP at least did not make farmer households' livelihood significantly worse off.

Chapter 6
Discussion and Implications

Chapters 4 and 5 have discussed the modelling results of residents' Willingness to Pay for water protection from the demand side of PES and farmers' preferences for different designs of water protection programs from the supply side, respectively. This chapter focuses on the implications derived from the research findings of the two preceding chapters. Comparing the total WTP of all water users in the four northern cities and the budget of the central government's water protection plan, Section 6.1 assesses the financial feasibility of establishing a water protection PES scheme by levying higher water prices in northern cities. Section 6.2 focuses on improving the contractual design of the Sloping Land Conversion Program in the water supply area with the findings of farmers' preferences for program attributes. Section 6.3 summaries the major results and arguments of this chapter.

6.1 Financial Feasibility of PES for Water Protection

6.1.1 Aggregate WTP for Water Protection

One of the major purposes of this research is to assess the financial feasibility of establishing a water protection PES scheme by levying higher water fees in the northern cities along the middle route of the South-to-North Water Transfer Project. The Contingent Valuation study in Chapter 4 has provided the estimates of urban residents' mean WTP for water protection in terms of an increase in water price. With the data of daily water consumption per capita and the residential population of water consumers in the four cities, the annual WTP per capita and the aggregate annual WTP of all water users can be calculated (see Table 6.1). The aggregate WTP can be compared with the cost of water protection in the water supply area as estimated by the Plan of Water Pollution Control and Soil Conservation in Danjiangkou Reservoir and Upstream Areas[77]. The percentage that annual WTP per capita accounts for residents' annual disposable income per capita is useful information to indicate the potential impact of the proposed PES scheme on residents' income. Additionally, the annual WTP per household

[77] As introduced in the Introduction chapter, this plan was issued in 2006 by the Chinese central government to guide the water protection in the water supply area.

for water protection was calculated using the mean household size of the four cities for comparison with the results of similar studies in the literature.

Table 6.1 The Aggregate WTP for Water Protection

Rows highlighted in olive green shading present the calculation results of aggregate WTP. Secondary data of water consumption per capita, annual disposable income per capita and the numbers of residential water users were obtained from the online database of the National Bureau of Statistics of China.

City	Beijing	Tianjin	Shijiazhuang	Zhengzhou
Mean WTP (yuan/m^3) [a]	0.71 (4.00)	0.25 (4.40)	0.39 (3.63)	0.36 (2.40)
Increase in % of the current water price	17.8%	5.7%	10.7%	15.0%
Water consumption Per Capita (m^3/day) [b]	0.173	0.129	0.124	0.109
Annual WTP per capita (yuan)	44.73	11.75	17.72	14.27
Annual Disposable Income per capita (yuan)	32,903	26,921	20,534	21,612
Annual WTP as % of individual disposable income	0.14%	0.04%	0.09%	0.07%
Average Household Size	3.15	3.06	3.55	3.42
Annual WTP per household (yuan)	140.91	35.96	62.89	48.80
Residential population of water users (million)	17.41	6.15	1.88	4.28
Annual city WTP (million yuan)	778.69	72.33	33.31	61.07
Total WTP	945.09 million yuan/year			

[a] Values in parentheses are the current water prices in the four cities.
[b] As the data of Shijiazhuang and Zhengzhou are not available, the data of Hebei and Henan Province where these two cities are located were used for aggregate calculation.

As shown in Table 6.1, the annual WTP per capita of residents in Beijing, Tianjin, Shijiazhuang and Zhengzhou are 44.73, 11.75, 17.72 and 14.27 yuan which account for 0.14%, 0.04%, 0.09% and 0.07% of the annual disposal income per capita in the four cities, respectively. Accordingly, the aggregate WTP of all water users in the four cities would be about 778.69, 72.33, 33.31, 61.07 million yuan/year respectively, leading to a total WTP of 945.09 million yuan/year. It can be noted that Beijing could contribute substantially more funding for water protection than the other three cities due to the largest mean WTP per capita, largest water consumption per capita and population of tap water users.

The calculation of aggregate WTP above is relatively conservative for deriving policy implications for the future. Firstly, the population of water users adopted in the calculation were the data of 2011 since the Contingent Valuation survey was conducted in the January and February of 2012. In fact, with the growth of total population, expansion of urbanization and improvement of water service infrastructure, the population of water users in these four cities is growing fast. For example, the population of water users increased by 0.43 million in Beijing and 0.34 million in Tianjin from 2011 to 2012. Secondly, as the water consumption data of Shijiazhuang and Zhengzhou are not available, the data of Hebei and Henan Province have been used in this calculation. The actual water consumption data could be larger than the provincial average level as the two cities are provincial capitals which are more developed than other cities in the provinces and usually consumed more water per capita. Larger estimates of total WTP could be derived with larger population of water users and water consumption.

6.1.2 Comparison with the results of Similar Studies

Table 6.2 lists the estimates of annual households' WTP for water quality improvement in the recent Contingent Valuation studies in China.

Table 6.2 WTP for Water Quality Improvement in Similar Studies

Surface water quality is classified into Grade I to V in China, and Grade I refers to the highest level of water quality. Water used for tap water processing should be at Grade III or above. The objective of the *Plan of Water Pollution Control and Soil Conservation in Danjiangkou Reservoir and Upstream Areas* is to maintain the water quality in the reservoir at Grade II.

Study	Time of Survey	Valued Services	Annual WTP (yuan) [a]
Wang *et al.* (2013a)	2007	Rural households' WTP for improving water quality of two major local rivers from Grade IV to Grade III, Yunnan Province, Southwest China	888 (5%)

Wang *et al.* (2013b)	2007	Rural and urban households' WTP for improving water quality of Puzhehei Lake from Grade III to Grade II, Yunnan Province, Southwest China	360 (3%)
Zhao *et al.* (2013)	2008	Urban households' WTP for restoring ecosystem services of an urban river in Shanghai, East China [b]	243
Zhang (2011)	2008	Urban households' WTP for improving water quality of Tai Lake (reaching at least Grade IV), East China	141 (0.7%)
Jiang, Jin and Lin (2011)	2009	Urban households' WTP for ensuring water quality of upstream Min River at Grade III, Fujian Province, Southeast China	53
Shang *et al.* (2012)	2011	Urban households' WTP for improving river network [c], Shanghai, East China	226

[a] Values in parentheses are the percentages of annual WTP in households' income.
[b] The restoration aims to ensure three types of ecosystem services, i.e. landscape and recreational use, habitat for fish and wildlife and flood control. No specific grade of water quality was mentioned in this study.
[c] The proposed services included raising connectivity of rivers, improving water quality (but no specific quality grade was mentioned) and building riparian zone for recreation.

Overall, this study provided more conservative estimates (36-141 yuan/year in the four cities) than similar studies in the literature (53-888 yuan/year). A possible reason is that this study did not ask respondents' WTP in terms of a lump-sum (as those studies did) but an increase in water price. In this study, the current water price and average water consumption per capita in the cities were provided as a clear benchmark for the respondents to consider their WTP[78]. In contrast, none of the studies asking respondents whether they were willing to pay a lump-sum of money for better water quality provided such a benchmark to let respondents know the implication of their WTP answers. Therefore, better provision of information and the convenience of comparing the offered increase in water price and the current water price might have made respondents in this study take more realistic and serious consideration and give more conservative estimates of annual WTP.

[78] This information was especially important when some respondents were actually not aware of the current water price and their annual water fees.

Interestingly, in the studies listed in Table 6.2, Jiang, Jin and Lin (2011) was the only study that investigated respondents' WTP in terms of an increase in water price (as this study did), and their result (53 yuan/year) was the lowest among the given studies and was closest to the results of this study. This finding just supports the above explanation.

6.1.2 Total WTP versus Total Cost of Water Protection

The budget of implementing the central government's Plan of Water Pollution Control and Soil Conservation in Danjiangkou Reservoir and Upstream Areas during 2011-2020 was estimated to be 12.44 billion yuan (£1.24 billion). Implementing the SLCP to convert 30.98 thousand hectares of sloping land to forests in the water supply area [79] was integrated into the water protection plan, but the 8.375 billion yuan of SLCP funds were not included in the aforementioned budget since the SLCP had started implementation before the water protection plan was made and its funds were allocated separately by the central government. So, the overall cost of water protection was 20.82 billion yuan (approximately £2.08 billion annually) for 10 years.

As calculated above, the total WTP of all residents in the four cities amounted to 945.09 million yuan per year. That is to say, in the period of 10 years, the potential funds raised from water users could be 76% of the budget of the aforementioned central government's water protection plan, 113% of the SLCP funds and 45% of the total cost of water protection. Given that there will be far more than four cities to be served by the middle-route water transfer project[80], substantially more funds could possibly be raised from residents in all the benefited cities along the water transfer route. Therefore, a water protection PES scheme co-funded by water users and the central and local governments could be highly feasible without imposing heavy financial burden to water users. In fact, even if a PES scheme solely funded by water users is financially feasible, it may not be as politically feasible as a multi-source funding scheme because the findings revealed in Chapter 4 indicate that respondents had high expectation on the

[79] The "water supply area" includes 40 counties (the villages surveyed in this study belong to one of these counties) of three provinces that are designated by the water source protection plan.

[80] The exact number of cities and the total population that will be supplied with the transferred water are currently unavailable for a more comprehensive estimate of residents' total WTP.

governments, especially the central government to play the leading role in funding the water protection.

6.2 Improving Sloping Land Conversion Program in the Water Supply Areas

6.2.1 Marginal Values of Program Attributes in Similar Studies

The Choice Experiments study discussed in Chapter 5 has revealed farmers' preference for major attributes of the SLCP such as the marginal values of the program attributes of contract length and the maximum percentage of commercial trees [81] to be planted in the sloping land. As reviewed in Chapter 2, only two choice modelling studies on the SLCP have been found in the literature, and they both conducted surveys in different provinces of China and adopted different choice modelling designs from this study (Grosjean and Kontoleon 2009; Chen *et al.* 2009a). However, findings from those studies were rather consistent with the results of this study.

Chen *et al.* (2009b) included the annual payment and contract length in the modelling attributes but neglected the maximum percentage of trees. Their results showed that farmers significantly preferred a 6-year contract than a 3-year one, but did not show preference for a 10-year contract over a 6-year one. Chen *et al.* (2009b) did not calculate the marginal value of an extra contract year, but according to the coefficients in their model [82], the marginal value of an extra contract year (in the range of 3-6 years) would be 9.97 yuan/year, which is quite close to the result of this study (8.27 yuan/year [83]). Grosjean and Kontoleon (2009) included the maximum percentage of commercial trees in their choice modelling, but they neglected the attribute

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[81] "Commercial trees" (such as fruit trees), compared with "ecological trees", refer to trees that can generate relatively high economic profits but less ecological benefits. The specific tree species belonging to the two categories are designated by the Chinese National Bureau of Forestry.

[82] Marginal values are simply the ratios of the coefficients of non-monetary attributes (e.g. contract length) to the coefficient of the monetary attribute (annual payment).

[83] This is the estimate for the pooled sample of both participant and non-participant farmers by the Conditional Logit Model (CLM). The results of the separate samples were 11.37 and 6.97 yuan/year, respectively. As the results of the CLM and the Random Parameter Logit Model are not substantially different, only the results of the CLM are discussed in this chapter.

of contract length. Nevertheless, they found that marginal value of 10% more commercial trees were 11.68 yuan, while the corresponding result of this study is 12.54 yuan.

6.2.2 Using Information of Farmers' Trade-offs between Program Attributes to Improve SLCP

Marginal values represent farmers' choices to trade-offs between the program attribute of annual payment and the non-monetary attributes of contract length and maximum percentage of trees. In a broad sense, the choice modelling study discussed in Chapter 5 has constructed a utility function to represent farmers' satisfaction to different policy scenarios (i.e. different combinations of attributes at different levels) of SLCP [84], i.e.

Utility = 0.042*Payment + 0.035*Contract-length + 0.053*P-econ-trees

where *Payment* is in the unit of 10 yuan/year/mu, *Contract-length* in year and the maximum percentage of commercial trees in the unit of 10% (for the convenience of presenting the results). The larger utility farmers derive from a policy scenario, the larger possibility they would prefer this scenario over others. And at the same utility level, trade-offs can be made between all the three attributes.

In addition to the marginal values, trade-offs between the two non-monetary attributes also provide valuable information for policy makers. For example, the utility function indicates that the utility change of each 10% more commercial trees is equal to 0.053/0.035=1.5 extra contract year for farmers. Interestingly, policy makers of the SLCP have also made trade-off between contract year and the maximum percentage of commercial trees since there are two types of SLCP contracts at the same payment level, i.e. the 5-year contract for planting commercial trees and the 8-year one for ecological trees. This implies that policy makers are willing to trade 0.3 extra contract year with 10% less commercial trees while farmers would require 1.5 extra contract years. In other word, policy makers have underestimated farmers' preference for commercial trees and the current design of SLCP contracts is actually discouraging farmers to plant ecological trees which can generate more ecological benefits.

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[84] Explanation of the Utility Theory underlying this choice modelling study can be found in Section 3.5. As mentioned before, this utility function is based on the CLM results.

Another way to examine this problem is to compare the utility of the two SLCP contracts calculated by the above function. The utility farmers derive from the 8-year/ecological-trees contract is 1.25 [85] while the utility of the 5-year/economic-trees contract is 1.67. Obviously, farmers would prefer the contract of planting commercial trees, which confirms the argument stated above that the current SLCP design is not favourable for the planting of ecological trees. Moreover, based on the utility function, it can be inferred that policy makers should either prolong the contract to 20 years at the current payment level or continue to offer an 8-year contract but increase the annual payment to 331 yuan/year/mu to attract farmers to plant ecological trees [86]. With regard to the aggregate payment in the contract term, the 20-year contract is 230*20=4600 yuan and the 8-year contract is 331*8=2548 yuan. The 20-year contract at the current payment level seems more efficient since it can achieve more than double duration of ecological benefits with less than double aggregate payments.

Generally, longer contract is desirable for policy makers since it could bring longer period of ecological benefits. Yet, concerns may arise for the possibility of long-term funding. A PES scheme that levies higher water fees in northern cities is promising to provide this long-term funding as residents' water consumption in the northern cities is naturally long-term. As mentioned in the last section, the potential funds from water users in the four surveyed northern cities alone could account for 76% of the budget of the governmental water protection plan and 113% of the SLCP funds needed in all the water supply area during 2011-2020. Actually, most water protection measures in the governmental plan are engineering projects (e.g. riparian zone construction, terrace land construction, new wastewater treatment plants) and thus need much less funds to maintain once they are constructed. So, even if the central government stops funding the SLCP after 2020, the PES scheme proposed in this study can provide sufficient funds for farmers to maintain trees in the sloping land.

Interestingly, recent news reported that the central government has been planning the third round of SLCP and it is very likely that the new SLCP will

[85] Utility is an ordinal variable to present the degree of satisfaction and with no specific unit.

[86] This means that farmers can derive the same utility from these two contracts as they derive from the contract of 5 years for planting commercial trees.

give farmers the full flexibility of planting commercial trees in the enrolled sloping land (Gu 2014). This is quite a radical change compared with the current requirement of no more than 20% commercial trees. Apparently, policy makers have realized farmers' strong preference for commercial trees, and they are willing to forgo the additional ecological benefits generated by the ecological trees in exchange for farmers' re-enrolment in the new SLCP. As revealed by this study, removing the restriction on commercial trees is indeed an economical way to raise the SLCP's attractiveness to farmers since the other two measures, i.e. increasing the annual payment level and contract length, will both raise the cost of the program. However, the rationale of removing the restriction on commercial trees is also dependent on how much more ecological benefits the ecological trees can generate than the commercial trees. If the difference is too large, higher re-enrolment rate of the new SLCP does not guarantee greater ecological benefits. Unfortunately, this important question has not been examined by researchers and policy makers and it is beyond the scope of this PhD study. Great attention should be paid to this question by the policy makers and interdisciplinary efforts from both ecologists and economists should be involved in the future.

Disregarding the possible loss of ecological benefits by removing the restriction on commercial trees, the information of farmers' trade-off between the annual payment and contract year can be used to improve the economic efficiency of the new SLCP with no restriction on commercial trees. Results in Chapter 5 indicate that farmers would forgo 8.27 yuan/mu/year for each extra contract year on the basis of the current contract for commercial trees (230 yuan/mu/year for 5 years). So, if policy makers would like to achieve long-term ecological benefits, they can offer longer contracts with slightly lower annual payment (shown in Table 6.2). For example, a 10-year contract with 189 yuan/mu/year could generate the same utility as the current 5-year contract with 230 yuan/mu/year. Compared with a 10-year contract with the current annual payment, the suggested contract design could save 310 yuan/mu in 10 years. For the 30.98 thousand hectares of sloping land enrolled in the SLCP in all the water supply areas, a total of 144 million yuan (about £ 14.4 million) could possibly be saved in 10 years.

Table 6.2 Policy Options for New SLCP (100% commercial trees)

The original cost is the production of the contract year and the current payment (230 yuan/mu/year).

Payment (yuan/mu/year)	Contract Length (year)	Total Cost (yuan/mu)	Original Cost (yuan)
230	5	1150	1150
222	6	1332	1380
213	7	1491	1610
205	8	1640	1840
197	9	1773	2070
189	10	1890	2300
180	11	1980	2530
172	12	2064	2760
164	13	2132	2990
156	14	2184	3220
147	15	2205	3450

6.2.3 Hypothetical Program for Reducing Fertilizers

The choice modelling study shown in Chapter 5 has also revealed farmers' preference for major program attributes of a hypothetical water protection program for reducing the use of Nitrogen and Phosphate fertilizers in farmland that cannot be covered by SLCP. A utility function can also be constructed with the modelling results for this hypothetical program.

Utility = 0.046*Payment + 0.120*Contract-length - 0.075*P-fert-reduce

where *Payment* is increments of 10 yuan/year/mu, *Contract-length* in year and the percentage of fertilizers reduction in the unit of 10%. The negative sign of the coefficient of *P-fer-reduce* means that the higher the fertilizer reduction rate, the less likely farmers would be to accept the program.

This function can help to assess the attractiveness of different policy scenarios. For example, a contract of 6 years with 480 yuan/year/mu and fertilizer reduction rate of 25% is more attractive than a contract of 8 years with 500yuan/year/mu and the fertilizer reduction rate of 75%. Results shown in Chapter 5 indicate that farmers would be willing to forgo 25.40 yuan/mu/year for each extra contract year but it would require 16.39 yuan/mu/year for each 10% fertilizer reduction. Farmers' trade-off between the two monetary attributes indicates that under the same payment level, each 10% more fertilizer reduction rate requires 1.6 extra contract years to compensate farmers' loss in utility. Using this information of farmers' trade-off between the three program attributes, policy options that generate the same utility as a particular reference scenario can be provided like those listed in Table 6.2. However, since there is no such fertilizer reduction program under implementation or results in similar studies to provide a benchmark, no further policy suggestions can be provided for this hypothetical program here. Nevertheless, this study has provided a basis for further research in this uncharted area.

6.3 Summary

Based on the research results in Chapters 4 and 5, this chapter examines the financial feasibility of establishing a water protection PES scheme for the middle-route South-to-North Water Transfer Project and improvement that could be made to the contract design of Sloping land Conversion Program in the water supply area (as an important part of the governmental water protection plan).

Using the estimates of residents' mean WTP for water protection in Chapter 4, aggregate calculation shows that the annual WTP per capita of Beijing, Tianjin, Shijiazhuang and Zhengzhou are 44.73, 11.75, 17.72 and 14.27 yuan which account for 0.14%, 0.04%, 0.09% and 0.07% of the annual disposal income per capita in the four cities, respectively. These estimates are much more conservative than the results in similar studies, which could be attributed to the use of an increase in water price instead of a lump-sum of money to elicit respondents' WTP.

In total, 945.09 million yuan/year could be raised from all water users of the four cities, which accounts for 76% of the annual budget of the government's *Plan of Water Pollution Control and Soil Conservation in Danjiangkou Reservoir and Upstream Areas* or 113% of the annual SLCP funds for all the water supply area during 2011-2020. With the estimates given in this chapter and the findings from Chapter 4, it is evident that a water protection PES scheme co-funded by water users and governmental budgets is both financially and political feasible without imposing heavy financial burden to water users.

Choice modelling results shown in Chapter 5 help to construct a utility function to assess the attractiveness of different contract designs of the SLCP. The analysis shows that policy makers have underestimated farmers' preference for planting commercial trees in the sloping land and the current SLCP contract of planting ecological trees is actually discouraging farmers to choose ecological trees which can generate more ecological benefits but less economic profits. To rectify this design flaw, policy makers should either prolong the contract of planting ecological trees to 20 years at the current payment level or keep the current 8-year contract but increase the annual payment to 331 yuan/year/mu. If the 20-year contract is adopted, funding raised from water users in northern cities can sufficiently support the extra 10 years of program after 2020 (beyond the duration of the governmental water protection plan).

If policy makers plan to remove the restriction on commercial trees (as reported by the recent news) to increase the attractiveness of the new round of SLCP to farmers, greater attention should be paid to the difference of the ecological benefits generated by the ecological and commercial trees; otherwise, a higher enrolment rate does not necessarily mean higher ecological benefits of the new SLCP. Moreover, based on the information of farmers' trade-offs between program attributes, a series of policy options for contracts with no restriction on commercial trees are offered to policy makers. With longer contracts and appropriately less annual payment, these policy options can generate the same utility for farmers as the current SLCP contract of planting commercial trees but achieve long-term ecological benefits with less total cost.

Chapter 7
Conclusions and Perspectives

After presenting the research findings of two surveys in Chapters 4 and 5 and discussing their implications in Chapter 6, this chapter gives the current perspective and conclusions of this study. Section 7.1 provides an overview of the major research findings of this study, Section 7.2 summarizes the significant implications and offers suggestions to policy makers, Section 7.3 highlights the major contributions of this study, Section 7.4 depicts challenges and future research directions and Section 7.5 provides concluding remarks.

7.1 Overview of Research Findings

This research study applied non-market economic valuation to provide policy suggestions for establishing a Payment for Ecosystem Services scheme for protecting the water supply area of the middle route of the South-to-North Water Transfer Project in China. From the water demand perspective, a Contingent Valuation survey was conducted in 4 cities (Beijing, Tianjin, Shijiazhuang and Zhengzhou) along the water transfer route with a total of 755 survey questionnaires in order to investigate urban residents' WTP for water protection. From the water supply perspective, a Choice Experiment survey with 246 survey questionnaires was conducted in 7 villages in the water supply area in order to reveal farmer households' choices of different potential designs of water protection programs. Below is a summary of the questions that have been answered by this study.

(1) Which are the factors influencing urban residents' attitudes toward a PES scheme for water protection?

Generally, the probability of residents' accepting such a PES scheme is significantly decreasing with the proposed increase in water price and significantly increasing with residents' income, knowledge of the water transfer project and supportiveness to the general idea of PES [87]. In contrast, demographic variables (except income) did not show universal

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[87] In the Chinese questionnaires presented to famers, PES was termed as Ecological Compensation, the policy instrument with a similar idea to PES in China which is introduced and discussed in Section 2.2.

influence on residents in the four cities. Particularly, the education level of residents, which was usually reported as a significant variable in similar WTP studies (Spash *et al.* 2009; Ramajo-Hernandez and del Saz-Salazar 2012; Zhao *et al.* 2013; Wang *et al.* 2013b), did not exhibit significant influence on residents' attitudes toward the PES scheme in any of the four cities in this study [88].

On the other hand, the extent of influence and significance level of the influential factors varied considerably among residents in different cities. For example, an increase of 1 yuan/m^3 in water price in Zhengzhou could lessen the odds of residents' acceptance toward the PES scheme by 94% at the 0.001 significance level, but the same increment in Beijing could only lessen the odds by 60% at the 0.1 significance level. Some factors only showed significant influence on residents in one city. For instance, residents with larger family size in Beijing were significantly less willing to pay a higher water price at the 0.01 significance level[89]. More discussion on the influential factors of residents' acceptance to an increase in water price for raising water protection funds can be referred to in Section 4.4 and Table 4.8.

(2) How much are residents (in the northern cities) willing to pay for water protection?

On average, residents in Beijing, Tianjin, Shijiazhuang and Zhengzhou were willing to pay an increase of 0.71, 0.25, 0.39 and 0.36 yuan/m^3 in water price respectively[90] for funding the water protection of the middle-route water transfer project. Income disparity showed a significant effect on residents' WTP. For example, in Beijing, the mean WTP of residents was 0.36 yuan/m^3 with income below 2500 yuan/month and 0.86 yuan/m^3 with income above

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[88] And no strong correlation was found between residents' education level and their knowledge of the water transfer project or supportiveness to the general idea of PES.

[89] This may be explained by the fact that residents in Beijing have substantially larger water consumption per capita than residents in other cities (see Table 6.1), thus larger family size means substantially larger water consumption and the resultant water fees in total.

[90] The WTP estimates of Beijing, Tianjin and Shijiazhuang reported here were the results of the Double Bound Parametric Model, while the estimate of Zhengzhou was the result of the Single Bound Parametric Model. The choice of model estimates was based on the robustness of the model estimation as discussed in Section 4.4.

2500 yuan/month. In Tianjin, residents earning less than 2500 yuan/month were only willing to pay an increase of 0.04 yuan/m^3 in water price. The lower bound of the 95% confidence interval of this small WTP was -0.32 yuan/m^3, which implied that some low-income residents in Tianjin actually looked forward to a decrease in water price[91]. In contrast, residents earning 2500-4000 yuan/month and more than 4000 yuan/month in Tianjin were willing to pay 0.45 and 0.86 yuan//m^3 respectively. More results and discussion of residents' WTP for water protection can be referred to in Section 4.5 and Table 4.10.

(3) Is it feasible to establish a PES scheme for water protection by levying higher prices in northern cities?

From a financial perspective, by levying a hypothetical fee equal to 0.14%, 0.04%, 0.09% and 0.07% of the annual disposal income per capita in Beijing, Tianjin, Shijiazhuang and Zhengzhou respectively, this study shows that a conservative estimate of a total of 945.09 million yuan/year (approximately £ 94.5 million/year) could be raised from water users in the four cities, which accounts for 76% of the annual budget of the central government's Plan of Water Pollution Control and Soil Conservation in Danjiangkou Reservoir and Upstream Areas during 2011-2020 [92] or 113% of the annual funds of Sloping Land Conversion Program, an existing agri-environmental program in the water source areas at the same period [93]. In practice, a water protection PES scheme could raise even more funds than the estimate given in this study as there are far more than four cities that will be served by the middle-route water transfer project. From a political perspective, the surveys in the four cities found that residents were in favour of a multiple-source funding mechanism for water protection involving both governments (central and local) and water users, but they expected the central government to play the leading role in such a PES scheme.

Synthesizing these results, the answer of the above question is that it would be highly feasible to establish a water protection PES scheme that is co-

[91] This could be explained by the fact that residents in Tianjin were currently paying the highest water price in the four cities (see Table 6.1).

[92] The whole duration of the water protection plan is 2004-2020, and it was divided by policy makers as the short-term plan (2004-2010) and long-term plan (2011-2020).

[93] This means 45% of the total cost of the water protection plan and SLCP.

funded by governmental budgets and water users in the northern cities without imposing heavy financial burden to water users.

(4) What is farmers' preference for major design attributes of water protection programs?

Two water protection programs were examined in this study, namely the existing Sloping Land Conversion Program (SLCP) and a hypothetical program for reducing the use of fertilizers in flat farmland that cannot be enrolled in the SLCP. For the existing SLCP, farmers showed significant preferences for higher annual payment, longer contracts and less restriction on the planting of commercial trees in the enrolled sloping land[94]. The preference for longer contracts indicates that farmers put more weight on the positive side of longer contracts in generating stable income than the negative side of reducing the flexibility of land use. This finding is different from findings in similar choice experiments studies on agri-environment programs (Ruto and Garrod 2009; Espinosa-Goded, Barreiro-Hurle and Ruto 2010; Christensen *et al.* 2011; Beharry-Borg *et al.* 2013), and it is particularly useful for policy makers as longer contracts are beneficial to achieving long-term environmental benefits. Similarly for the hypothetical fertilizer reduction program, farmers exhibited significant preference for higher annual payment, longer contract and lower fertilizer reduction rate.

(5) How do farmers trade-off major design attributes of water protection programs in deciding the preferred program design?

On average, farmers were willing to forgo about 8 yuan/year/mu for every extra SLCP contract year and 13 yuan/year/mu for each 10% more economic trees to plant in the enrolled sloping land[95]. Additionally, every 10% more commercial trees were worth 1.5 extra SLCP contract years for farmers. For practical application, a utility (ordinal variable to present farmers' satisfaction) function (see Section 6.2.2) was established to assess farmers' preference for different program design of SLCP. Assessment using this utility function indicates that policy makers have underestimated farmers' preference for commercial trees and the current SLCP contracts are

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[94] It has been tested and demonstrated in Chapter 5 that farmers did not simply prefer the program design with larger aggregate payment, i.e. the production of annual payment and contract length.

[95] These two marginal values, i.e. the amount of money farmers were willing to trade with a certain change in the non-monetary attributes, were between the estimates of two choice models applied in this study.

discouraging for farmers to choose the contract of planting ecological trees which generate more ecological benefits than the commercial trees.

Interestingly, significant difference was found between the current SLCP participants and non-participants in their trade-offs between annual payment and the other two program attributes. Compared with the current SLCP participants, the non-participant farmers were willing to forgo almost a double amount of decrease in annual payment for the same change of contract length and permission of commercial trees. More results and discussion of the SLCP attributes' marginal values can be referred to in Section 5.4.1 and Table 5.5.

With regard to the hypothetical fertilizer reduction program, farmers were willing to forgo about 27 yuan/year/mu for each extra contract year but required 16 yuan/year/mu for reducing every 10% of the use of fertilizers, and each 10% less fertilizer reduction rate was equal to 1.6 extra contract years in farmers' views. A utility function for assessing different program design was also established for the hypothetical program (see Section 6.2.3). Similarly to the findings on the SLCP, the non-participant farmers were willing to forgo a larger decrease in annual payment and require less for the same change in contract length and fertilizer reduction rate. Detailed discussion can be referred to in Section 5.4.2 and Table 5.8.

(6) An auxiliary but important question: are farmer households better off or worse off after participation in the Sloping Land Conversion Program?

This question was examined from three aspects, i.e. comparison of the income per mu from crops before the SLCP and from trees after the program, comparison of farmers' income from all their sloping land before/after joining in the SLCP, and comparison of the total income (including both on–farm and off-farm income) of participant and non-participant farmers.

In general, trees generated higher income per mu after the SLCP than crops before the program. For example, the average income from orange, poplar and chestnut trees, the most widely planted trees in the enrolled sloping land after the SLCP, was 916, 470 and 661 yuan/mu, respectively. In comparison, the average income from the most widely planted crops in the sloping land before the SLCP, i.e. sesame, wheat and rapeseed, was 381, 394 and 399 yuan/mu respectively. Accordingly, farmers' average income from all their sloping land was 5,365 yuan/year from crops before the SLCP and 7,727 yuan/year from trees after the program. These calculation results correspond with another finding of this farmer household survey that 26% of the participant farmers take “forestland can yield higher income than farmland” as the most important reason for their participation in the SLCP.

Interestingly, although the non-participant farmers received significantly higher on-farm (land) income than SLCP participants[96], they received significantly lower off-farm income (e.g. small businesses, wages of family members working in towns and cities) than SLCP participants. This finding reflects one benefit of participation in the SLCP mentioned by farmers, i.e. trees need less tending time than crops so farmers have more time to earn income from other sources. In fact, shifting farmers from on-farm work to off-farm work is also an objective of the SLCP (Liu *et al.* 2008). In total, non-participant famers received 26,510 yuan/year/household while the SLCP participants received 23,430, but the difference was not statistically significant due to large income disparities within each group of farmers.

Overall, this study found that farmers are not worse off (and possibly even better off) after participating in the SLCP. This could partly explain why farmers favoured longer contracts when choosing the preferred design of SLCP.

7.2 Policy Recommendations

Based on the research findings, major policy suggestions provided by this study are as follows:

(1) Policy makers and practitioners will have a better chance to raise more water protection funds if they can make better efforts to disseminate knowledge about the water transfer project and promote the idea of PES/Ecological Compensation among residents in the northern cities.

(2) A multi-source funding mechanism involving both government funds and additional water fees from water users could be feasible for a PES scheme for water protection in both financial and political perspectives.

(3) It could be better to adopt differentiated increments in water price onto residents at different income levels, given the substantial difference in their willingness to pay for water protection and the potential socio-

[96] This can be partly due to the fact that non-participant farmers in the survey have slightly but significantly (in terms of statistics) more land per household than the SLCP participants

economic effect of raising water price. Specifically, the current starting point of the personal income tax in China (3500 yuan/month) is a useful benchmark which well fits both the practical policy context and the modelling results of this study.

(4) If policy makers want to encourage farmers to plant ecological trees on sloping land to generate more ecological benefits, the current SLCP contract for planting ecological trees is not helping. Policy makers should either extend the contract length or increase the annual payment according to a utility function established by this study to evaluate farmers' satisfaction to different contract design (discussed in Section 6.2.2).

(5) According to the findings of farmers' trade-offs between major design attributes of the SLCP, if policy makers plan to remove the restriction on commercial trees to promote farmers' participation in the next round of SLCP, they can adopt longer contracts with appropriately lower annual payment, such as a 10-year contract with 189 yuan/year/mu, to achieve long-term ecological benefits with lower cost than simply extending the current contract (5 years with 230 yuan/year/mu) at the same payment level.

(6) Since the non-participant farmers were willing to forgo significantly more annual payment for the same extra contract years and permitted percentage of commercial trees than the SLCP participant, it is possible to apply differentiated payment levels onto the two groups of farmers in the new round SLCP, whereby higher payment is given to participant farmers as a reward to "loyal participants" and lower payment is given to new participants (currently non-participant farmers) in order to reduce the program cost and thus improve its economic efficiency.

7.3 Major Contributions to the Literature

This PhD study has contributed to the literature from the following aspects:

(1) This study helped to fill the literature gap of applying non-market economic valuation and integrating public opinions in the design of PES schemes.

(2) This study introduced Stepwise Regression and Best Subset Regression techniques in Contingent Valuation and constructed an integrated procedure with automatic selection algorithm and manual adjustment for model simplification and improvement.

(3) This study strengthened our understanding of applying multiple modelling techniques (non-parametric, single-bound parametric and double-bound parametric models) for WTP estimation.

(4) This study enriched our insights of farmers' preference for different design of agri-environmental programs, their trade-offs between major program attributes and the heterogeneity in farmers' preference.

7.4 Limitations and Directions of Future Research

Despite the research findings, policy suggestions and contributions to the literature as summarized above, this study has limitations that need to be considered and hence, directions of further research are proposed.

(1) Larger sample size and broader study scope

Due to the constraints of funding, time and other resources, the major limitation of this study is the relatively small sample size compared with the large population in the surveyed cities. As for the study scope, this study has focused on four big cities that will be the priority of future supply of the transferred water and seven villages around the Danjiangkou Reservoir where farmers' behaviours can directly influence water quality of the reservoir. However, there are other relatively small cities/towns that will be supplied by the transferred water and other villages in further upstream watershed of the reservoir that are also designated as water supply areas. The limitations in sample size and study scope could to some extent constrain the applicability of the policy suggestions provided by this study. With sufficient funding, time and other resources, surveys with larger sample size can be conducted in more cities/towns and villages to collect more comprehensive information and then test, confirm, improve or rectify the findings and policy suggestions of this study.

(2) More advanced modelling techniques

This study has applied the state-of-art modelling techniques in both Contingent Valuation and Choice Experiments research, and a methodological contribution was made by introducing the stepwise regression and best subset regression techniques in Contingent Valuation for model selection and improvement. Nevertheless, a few more advanced modelling techniques can be researched to further exploit the survey data of this study in the future, especially for the Choice Experiments data. For example, the Latent Class Model is another advanced modelling technique to reveal the heterogeneity of respondents' preference in addition to the

Random Parameters Logit Model used in this study (Beharry-Borg *et al.* 2013; Drake *et al.* 2013). The Agent-based Models for simulating individuals' behaviours and interactions seems to be another interesting extension to choice modelling (Chen *et al.* 2009a).

(3) Linking micro and macro-scale economic research

Contingent Valuation and Choice Experiments investigate individuals' choices in environmental (and other) issues and both belong to the area of micro-economic research. a number of macro-economic studies have been found in literature to apply input-output models (Ma *et al.* 2006; Guan and Hubacek 2007) and game theory-based Models (Wei *et al.* 2010b) on water resources management related to the South-to-North Water Transfer Project. Currently, the micro and macro-economic research spheres are quite disconnected in PES studies. It could be very interesting and challenging to search the possibility of linking those two research spheres to study the regional effects of individual choices in large-scale water transfer projects and PES schemes.

(4) Interdisciplinary research

Raising sufficient funds and allocating funds efficiently with well-designed contracts do not necessarily lead to successful PES schemes since the ultimate success of PES depends on whether the aimed for ecosystem services have really been ensured or improved. In fact, one of the common drawbacks of the existing PES scheme is the lack of clear information between the contracted behaviours like increasing forest cover and ecosystem services like water quality improvement (Muradian *et al.* 2010). As discussed in Chapter 6, understanding the real difference in the ecological benefits generated by ecological and commercial trees is important to determine whether policy makers should remove the restriction on commercial trees in the new round of SLCP. Interdisciplinary research is needed in the future to incorporate economic and ecological studies for achieving the ultimate success of the PES scheme for water protection.

7.5 Conclusions

As the pioneer research to apply non-market economic valuation and PES study for the middle-route South-to-North Water Transfer Project, this study has provided useful findings on urban residents' attitudes toward paying for water protection and farmer households' preferences for different designs of water protection programs. PES is a promising policy instrument to secure the supply of clean water for the middle route project, and Non-market Valuation Methods (including Contingent Valuation and Choice Experiments) are useful tools to reveal public attitudes and preferences in the design of PES schemes.

While this study comes to the end, the middle route of the SNWTP will start transferring water from the Danjiangkou Reservoir to Beijing this October and the legislation of the Ecological Compensation Ordinance is also close to completion to establish the national legal framework for implementing a similar idea of PES in China. The research findings and policy suggestions of this study are of particular policy relevance at this very time and will be valuable for further research in the future.

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List of Abbreviations

AIC	Akaike Information Criterion
BPP	Beneficiary Pays Principle
CE	Choice Experiments
CLM	Conditional Logit Model
CVM	Contingent Valuation Method
EC	Ecological Compensation
ES	Ecosystem Services
FEBCF	Forest Ecological Benefit Compensation Fund
IIA	Independent of Irrelevant Alternatives
MV	Marginal Value
NEPB	National Environmental Protection Bureau
RPL	Random Parameters Logit Model
PES	Payments for Ecosystem Services
PPP	Polluter Pays Principle
SD	Standard Deviation
SLCP	Sloping Land Conversion Program
SNWTP	South-to-North Water Transfer Project
WTP	Willingness to Pay

Appendix 1
Questionnaire of the Contingent Valuation Survey

Questionnaire Number: Date & Time:

Name of city: Street Name:

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1. **What do you think about the supply of domestic water in this city?**

   A. Very abundant B. Abundant C. Moderate D. Scarce

   E. Very scarce F. No opinion G. Don't know

2. **Are you satisfied with the current tap water service?**

   A. Very satisfied B. Satisfied C. Acceptable D. Dissatisfied

   E. Very dissatisfied F. No opinion G. Don't know

   If D "**Dissatisfied*****" or E "*****Very dissatisfied*****", continue with Question 3; otherwise, please proceed to Question 4.***

3. **What has caused your dissatisfaction to the current tap water service? (Please choose as many as applicable)**

   A. Frequent interruption of water supply B. Insufficient water pressure

   C. Turbidity of the water D. Bad odour E. Bad taste

   F. The price is too high G. Others (Please specify):

4. **Approximately, how much does your family pay for the water bill per month?**

   A.______ yuan/month

   B. I don't know.

5. **How many people are usually living in your house including yourself (using water) over the last 12 months?**

   5.1 Number of Adults: ________; 5.2 Number of children: ________

6. Do you know the current water price?

A. Yes _____ yuan/m^3 B. No

7. Have you heard about the South-to-North Water Transfer Project before?

A. Yes B. No

If "Yes", proceed to Question 8; otherwise, the interviewers will give you some background information before you proceed to Question 12.

8. What benefits do you think the South-to-North Water Transfer Project can bring to this city?

A. Provide water for domestic and production use

B. Improve the quality of domestic water

C. Alleviate the decline of underground water table

D. Improve urban ecological-environment

E. Others (Please specify):

F. I don't know

G. No opinion

9. Where did you get the information about the South-to-North Water Transfer Project? (Please choose as many as applicable)

A. TV B. Radio C. Newspapers D. Websites

E. Others (Please specify):

10. Have you heard about the Middle Route of the South-to-North Water Transfer Project before?

A. Yes B. No

If "Yes", continue with Question 11; otherwise, the interviewer will give you some background information, after reading that, please proceed to Question 12.

11. **Do you know where the Middle Route of the South-to-North Water Transfer Project starts?**

    A. Yes, it is:_________ B. No, I don't know.

Now the interviewers will give you some background information to assist you to answer the following questions (on a separate page).

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12. **In your opinion, who should pay for the cost of water quality protection in the water source areas? (Please choose as many as applicable)**

    A. The central government B. Local governments of the water source areas

    C. Local people/entities that implement water quality protection measures

    D. Governments of northern cities which will use the transferred water

    E. Residents/entities that will use the transferred water in northern cities

    F. Others (Please specify):

    G. I don't know

    H. No opinion

13. **Have you ever heard about the Ecological Compensation Policy before?**

    B. Yes B. No

If "Yes", continue with Question 14; otherwise, please proceed to Question 16.

14. Can you briefly describe what Ecological Compensation means?

A.

B. I don't know

15. Where did you get the information about Ecological Compensation?

(Please choose as many as applicable**)**

A. TV B. Radio C. Newspapers D. Websites

E. Others (Please specify):

16. The main idea of Ecological Compensation is to see environment protection as a kind of service. The service providers, i.e. people who carry out environmental protection measures, receive a certain amount of compensation from beneficiaries to assure that the environmental quality is maintained at the required level. What do you think about this idea?

A. Highly agree B. Agree C. I am not sure D. Disagree

E. Highly Disagree F. No opinion

Some more background information we would like to give you before answering the following questions. Thank you for your patience.

Implementation of the *Plan of Water Pollution Control and Soil Conservation in Danjiangkou Reservoir and Upstream Areas* requires more than 19.4 billion yuan by 2020, and it is planned to adopt a co-funding policy between the central government and the local governments in the water source areas. For example, the local governments need to provide about 50% funding for soil reservation projects. Most of the water source areas are mountainous and less economically developed. While the restriction on some industries for pollution control has exerted economic losses to them, they also need to invest more funding to implement the water quality protection plan. This actually has exerted a heavy financial burden to the local governments.

According to the official monitoring data, the water quality of the Danjiangkou Reservoir has fluctuated between Class II and III in 2010, but stayed at Class II in 2011. However, if the problem of insufficient funding is not solved, the water quality may fluctuate in the future, and the economic interests of the water source areas will not be properly safeguarded either.

In order to overcome the funding problem in the long-term, it has been proposed to establish an Ecological Compensation scheme between the water source areas and the cities which will benefit from the water quality protection, such as appropriately increasing the water price in relevant northern cities to supplement the funding for water quality protection. Some people think it is a good idea while others think it is not. Obviously, too much increase in water price will have impact on residents' spending in other aspects, while too little increase offers very limited help to solve the problem. We would like to hear your opinion on this issue.

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17. If the water price increases (   ) yuan/m^3 for funding the implementation of "The Plan of Water Pollution Control and Soil Conservation in Danjiangkou Reservoir and Upstream Areas" to ensure the reservoir's water quality maintaining at Class II, are you willing to pay?

Reminder: (1) the current water price in Beijing is 4 yuan/m^3; (2) according to the National Statistics Bureau’s data in 2009, a resident in Beijing generally consumes approximately 70m^3 of domestic water per year.

A. Yes B. No C. I am not sure D I don’t know

18. Can you briefly explain the reasons for your answer to last question?

19. What about the increase of (X_2) yuan/ m^3 (the interviewer will tell you the value of X_2)? Are you willing to pay?

A. Yes B. No C. I am not sure D I don’t know

20. Can you please briefly explain the reasons for your answer to last question?

Lastly, we would like to get some information about you. All replies will be held securely and confidentially, and they are solely used for this research.

21. Gender

A. Male B. Female

22. Age

A. Below 18 B. 18-21 C. 21-30 D. 31-40 E. 41-50

F. 51-60 G. 61-65 H. Over 65 I. I don't want to answer

23. Education level (Please choose the highest level you've already completed)

A. Primary school or below B. Middle school C. High school

D. Undergraduate Degree E. Masters F. PhD

G. I don't want to answer

24. Individual monthly income (yuan)

A. Below 1500 B. 1500 - 2000 C. 2000 - 2500 D. 2500 - 4000

E. 4000 - 7000 F. 7000 - 15000 G. 15000 - 20000 H. Over 20000

I. I don't want to answer

25. How long have you lived in this city? (year)

A. Below 5 B. 5 - 10 C. 10 - 20 D. Over 20

E. I don't want to answer

26. Have you ever been to the water source areas? (As shown in the map in the "Background Information" given by the interviewer)

A. Yes B. No

27. Do you have any relatives or close friends who are from or living in the water source areas?

A. Yes B. No C. I don't want to answer

28. Occupation:

A. Governmental officer B. State-owned company/institution staff

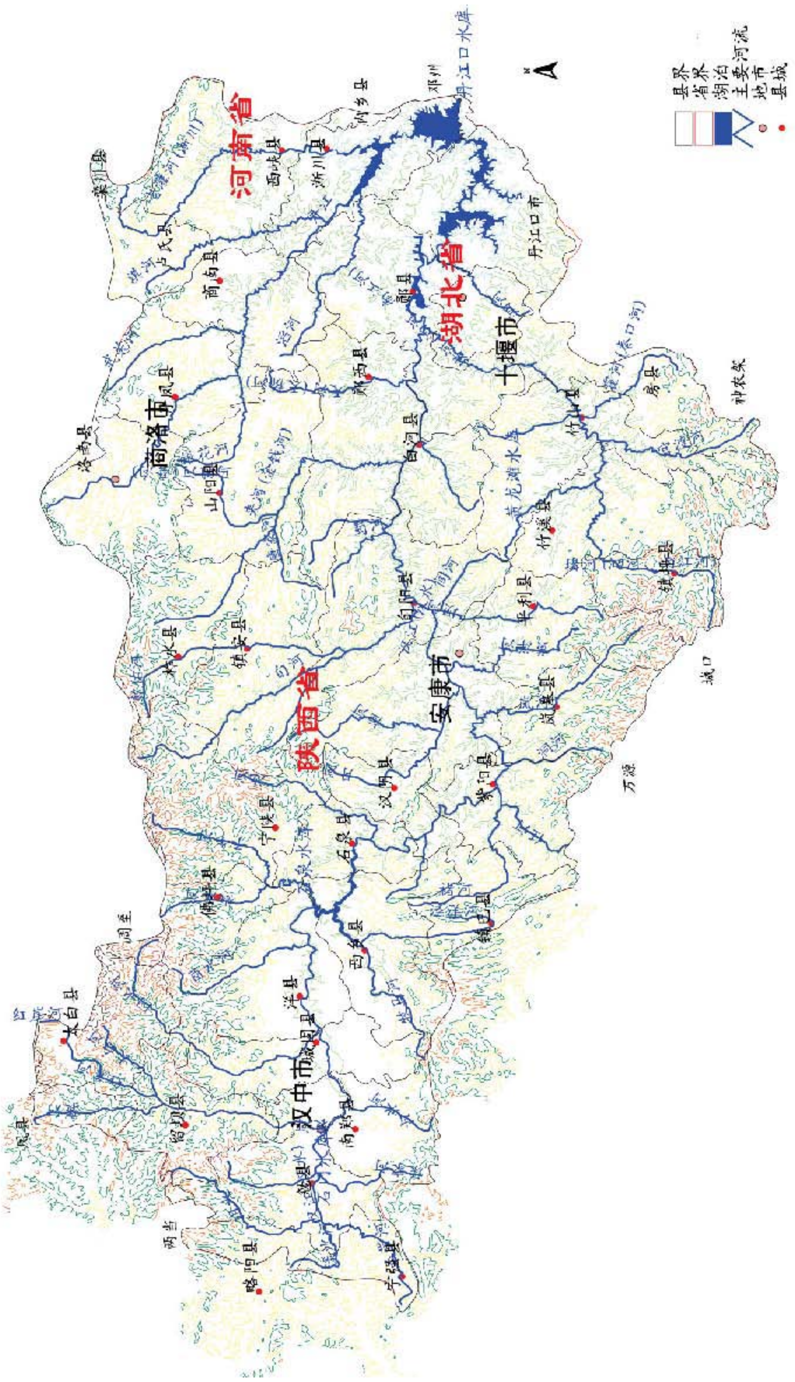
C. Private employer and employee D. Independent businessman
E. Freelancer F. Retired G. Unemployed H. Students
I. Others (please specify): __________ J. I don't want to answer

29. Do you have any comments or suggestions on this survey?

Thanks very much for your time & co-operation!

Illustration of the Middle Route of the South-to-North Water Transfer Project in China (in Chinese)

Illustration of the Water Supply Area of the Middle Route of the South-to-North Water Transfer Project (in Chinese)



Appendix 2
Questionnaire for Household Survey in the Water Supply Area (participants of the Sloping Land Conversion Program)

Interviewer: **Date:** **Time:**

Village: **Questionnaire ID No.:**

Part I. The Sloping Land Conversion Program

1. When did your household start to participate in the Sloping Land Conversion Program?

2. What's the most important reason for you to participate in the Sloping Land Conversion Program? (Please select one option only)

A. The payment from the program is higher than the total income of farming in the enrolled land before.

B. Managing forest (such as fruit trees) can yield higher profit than farming (growing crops).

C. We don't have enough labour to work on the land.

D. The tenure of the enrolled land can be extended.

E. The program is strongly encouraged by the government.

F. Many households in our village have participated in the program.

G. Other reason, please specify:

3. How many mu* of land does your household have in total?

* Mu is the unit of area commonly used in rural China, 15 mu = 1 ha

4. How many mu of your land has been enrolled in the Sloping Land Conversion Program (converted to ecological and economic forest)?

Forest Type	**Area (Mu)**
Ecological Forest	
Economic Forest	

5. What is the payment you receive from the Sloping Land Conversion Program?

6. What trees are planted in the enrolled land now? Apart from the payment of the Sloping Land Conversion Program, do you have extra income from them?

Tree	Area (mu)	Gross Income (yuan/mu/year)

7. Prior to the enrolment, what was the land primarily used for (e.g. grow rice for subsistence or oilseed crops for sale)? And how much had you earned from the specified activity (or activities) at that time?

Land Use	Area (mu)	Gross Income (yuan/mu/year)

8. What is the primary use of the non-enrolled land and how much can you gain from it?

Use of Land	Area (mu)	Gross income

		(yuan/mu/year)

9. Is there any land of household which is eligible for the Sloping Land Conversion Program (with slope larger than 25 degree), but is not enrolled?

A. Yes B. No C. I do not know

If "Yes", how many mu of eligible land is not enrolled, and what is it presently used for?

Use of Land	Area (mu)

And why did you decide not to enrol the land?

10. Has your program contract expired?

A. Yes B. No

If "Yes", please proceed to Question 11; if "No", please jump to Question 12.

11. Have you re-converted the enrolled land to farmland or used it for other purposes?

If "Yes", could you please specify what your plans are, and how much net income you would expect to generate?

Use of Land	Area (mu)	Gross Income (yuan/mu/year)

If "No", could you please give reasons for that?

12. Do you plan to re-convert the enrolled land to farmland or use it for other purposes after the current contract expires?

A. Yes B. No

If "Yes", could you please specify what your plans are, and how much net income you would expect to generate?

Use of Land	Area (mu)	Gross Income (yuan/mu/year)

If "No", could you please give reasons for that?

13. If the current contract will be extended on the same terms and conditions (e.g. payment, duration, etc.), will you continue to participate in the Sloping Land Conversion Program? Please give reasons for your decision.

A. Yes B. No

14. Assuming there are several proposals on revising the contract of the Sloping Land Conversion Program in terms of payment amount, contract duration and the maximum percentage of

economic forests allowed to be planted, within the following proposals presented by the interviewers, which do you prefer?

(The interviewer shows the choice cards to the respondent)

15. Do you have other suggestions and expectations on the adjustment and improvement of the Sloping Land Conversion Program?

Part II Agro-environmental policy

16. Do you think there are some improvements on the local ecological environment after the implementation of the Sloping Land Conversion Program?

A. Yes B. No

If "Yes", could you please specify the improvements that have been made?

17. Apart from the Sloping Land Conversion Program, do you know any other measures implemented by the government to protect the water quality in the Danjingkou Reservoir?

A. Yes B. No

If "Yes", could you please name the measures?

18. Do you know why the government pay so much attention to the water quality in the Danjingkou Reservoir?

A. Yes B. No

If "Yes", could you please give reasons for that?

19. How much Nitrogen and Phosphate-fertilizer do you usually use on your land in a year? What is the cost of the fertilizers last year?

Use of Land	Nitrogen Fertilizer (kg/mu)	Phosphate Fertilizer (kg/mu)
Cost of fertilizer in last year (yuan/kg):		

20. Assume that a new program will be implemented to pay you to reduce the use of Nitrogen and Phosphate fertilizers, in the following proposals presented by the interviewers, which do you prefer?

(The interviewer shows you the choice cards to the respondents)

21. The new program mentioned above is still on a very preliminary design stage, do you have any suggestions for it?

Part III Socio-economic and Demographic Information

In this part, we will ask you some questions about you and your family. Let us re-assure you that all the information provided in this section (and the whole survey) will be treated in strict confidence and will be used solely for this research study.

22. Could you please provide information on the following?

20.1 Gender: A. Male B. Female

22.2 Age: A. Below 30 B. 30 – 40 C. 40 – 50

D. 50 – 60 E. Over 60

23.2 Education (the highest level completed):

A. Below primary school B. Primary school C. Middle school

D. Secondary technical school or High school E. Higher education

23. How many people (including yourself) in your household are living in this village (over 9 months in a year), and how many are working or studying outside the village?

In Village	Studying outside Village	Working outside Village

24. For those household members who are living in this village (over 9 months in a year), what are their age groups and genders?

Age	Below 16	16 – 60	Over 60
Male members			
Female members			

25. How many household members are usually (over 9 months in a year) working on your land?

26. Do you hire someone to work on your land?

A. Yes B. No

If "Yes", how many people do you hire, and what is the annual cost?

Number of People Hired	Total Cost (yuan/year)

27. Apart from working on land (cultivation, forestry, orchard), do you and your household members who live in the village have other sources of income?

Income Source	Gross Income (yuan/year)
Livestock	
Business	
Financial support received from household members who work outside the village	
Other (please specify):	

28. Do you provide financial support for household members studying or working outside the village?

A. Yes B. No

If "Yes", approximately how much does it cost in a year?

Support household members to study (yuan/year)	
Support household members to work (yuan/year)	

29. Have your household members participated in the Cooperative Medical Insurance Scheme administered by the government?

A. Yes B. No

If "Yes", how many household members have participated in the scheme? How much does it cost in total each year?

Number of Participants	Total Cost

30. Have the older family members (over 60) been covered by the Rural Social Endowment Insurance Scheme administered by the government?

A. Yes B. No

If "Yes", how much money do they receive from the scheme (in yuan per person per month)?

31. Has your household taken part in any resettlement scheme to move to this village?

A. Yes B. No

If "Yes", how long have you resided in this village?

Thanks very much for your time & co-operation!

Appendix 3
Questionnaire for Household Survey in the Water Supply Area (non-participants of the Sloping Land Conversion Program)

Interviewer: **Date:** **Time:**

Village: **Questionnaire ID Number:**

Part I. The Sloping Land Conversion Program

1. How many mu of land does your household have in total?

2. What do you use your land for and how much income can your land generate in a year?

Use of Land	Area (mu)	Net income (yuan/mu/year)

3. Are there any households in your village who have participated in the Sloping Land Conversion Program?

A. Yes B. No

4. How many mu of your land is eligible for the Sloping Land Conversion Program? And what it is presently used for?

Land Use	Area (mu)

5. Why did you decide not to participate in the Sloping Land Conversion Program?

7. What changes must be made on the Sloping Land Conversion Program so that you would like to take part in this program?

Part II Agro-environmental policy

8. Do you think there are some improvements on the local ecological environment after the implementation of the Sloping Land Conversion Program?

A. Yes B. No

If "Yes", could you please specify the improvements that have been made?

9. Apart from the Sloping Land Conversion Program, do you know any other measures implemented by the government to protect the water quality in the Danjingkou Reservoir?

A. Yes B. No

If "Yes", could you please name the measures?

10. Do you know why the government pay so much attention to the water quality in the Danjingkou Reservoir?

A. Yes B. No

If "Yes", could you please give reasons for that?

11. How much Nitrogen and Phosphate-fertilizer do you usually use on your land in a year? What is the cost of the fertilizers last year?

Use of Land	Nitrogen Fertilizer (kg/mu)	Phosphate Fertilizer (kg/mu)
Cost of fertilizer in last year (yuan/kg):		

12. Assume that a new program will be implemented to pay you to reduce the use of Nitrogen and Phosphate fertilizers, in the following proposals presented by the interviewers, which do you prefer?

(The interviewer shows you the choice cards to the respondents)

13. The new program mentioned above is still on a very preliminary design stage, do you have any suggestions for it?

Part III Socio-economic and Demographic Information

In this part, we will ask you some questions about you and your family. Let us re-assure you that all the information provided in this section (and the whole survey) will be treated in strict confidence and will be used solely for this research study.

14. Could you please provide information on the following?

14.1 Gender: A. Male B. Female

14.2 Age: A. Below 30 B. 30 – 40 C. 40 – 50

D. 50 – 60 E. Over 60

14.3 Education (the highest level completed):

A. Below primary school B. Primary school C. Middle school

D. Secondary technical school or High school E. Higher education

15. How many people (including yourself) in your household are living in this village (over 9 months in a year), and how many are working or studying outside the village?

In Village	Studying outside Village	Working outside Village

16. For those household members who are living in this village (over 9 months in a year), what are their age groups and genders?

Age	Below 16	16 – 60	Over 60
Male members			
Female members			

17. How many household members are usually (over 9 months in a year) working on your land?

18. Do you hire someone to work on your land?

A. Yes B. No

If "Yes", how many people do you hire, and what is the annual cost?

Number of People Hired	Total Cost (yuan/year)

19. Apart from working on land (cultivation, forestry, orchard), do you and your household members who live in the village have other sources of income?

Income Source	Gross Income (yuan/year)
Livestock	
Business	
Financial support received from household members who work outside the village	
Other (please specify):	

20. Do you provide financial support for household members studying or working outside the village?

A. Yes B. No

If "Yes", approximately how much does it cost in a year?

Support household members to study (yuan/year)	
Support household members to work (yuan/year)	

21. Have your household members participated in the Cooperative Medical Insurance Scheme administered by the government?

A. Yes B. No

If "Yes", how many household members have participated in the scheme? How much does it cost in total each year?

Number of Participants	Total Cost

22. Have the older family members (over 60) been covered by the Rural Social Endowment Insurance Scheme administered by the government?

A. Yes B. No

If "Yes", how much money do they receive from the scheme (in yuan per person per month)?

23. Has your household taken part in any resettlement scheme to move to this village?

A. Yes B. No

If "Yes", how long have you resided in this village?

Thanks very much for your time & co-operation!