THE ECONOMIC VALUATION, PRICING AND PROMOTION OF RECYCLED WATER

BY

ANGELIKI MENEGAKI

SUBMITTED IN ACCORDANCE WITH THE REQUIREMENTS FOR THE DEGREE OF DOCTOR OF PHILOSOPHY

THE UNIVERSITY OF STIRLING

DEPARTMENT OF ECONOMICS

DECEMBER 2005

The candidate confirms that the work submitted is her own and that appropriate credit has been given where reference has been made to the work of others

11/05

ACKNOWLEDGEMENTS

Data collection in this work was financed by the Greek Ministry of the Environment, Physical Planning and Public Works (ΕΤΕΡΠΣ). The author would like to thank Dr. Konstantinos Tsagarakis (University of Crete) and Prof. Nikos Sakkas (Technological Institute of Crete) who were the above programme administrators, Dr Margarita Genius (University of Crete) for providing the DB-DC Eviews code in Chapter 4 as well as econometric guidance, Mr Brett Day (University of East Anglia) for providing the GAUSS code for the TSCA in Chapter 4, Dr Nikos Paranychianakis (National Agricultural Research Foundation) for providing agricultural information in Chapters 1 and 2, Prof. Vangelis Tzouvelekas (University of Crete) for his comments on production function data, Dr Yiannis Christodoulides (University of Stirling) for mathematical help, Prof. Bengt Kriström for providing guidance in DB-DC data analysis. Thanks are also due to Mr K. Panagiotakis, Mr E. Pantagakis, Mrs E.Skoula, Mr D. Tampakakis and Mr E. Fanourakis for their help at data collection.

The author would also and foremost like to thank her main supervisor Prof. Nick Hanley (University of Stirling) for supporting and guiding her research and Prof. Bob Hart (University of Stirling) who was her second supervisor. Last but not least, Prof. Jim Malley (University of Stirling) who was the author's second supervisor while at University of Glasgow where she started her PhD studies.

DEDICATION

This work is dedicated to Kostas,

who was the instigator in my PhD venture

ABSTRACT

This thesis topic is the evaluation of recycled water in Crete, Greece. Recycled water is a derivative of fresh water and as such it can be regarded as a good of a similar nature to fresh water (at least for some of its uses such as irrigation). The departure point for this research was given by specific articles and principles of the 60/2000 Water Framework Directive. According to them, recycled water evaluation can be viewed as a corollary of this directive. Since Crete is a European region with intense water shortage problems, this was a good opportunity to apply the suggestions of the directive: solve the problem of water shortage internally (i.e. in Crete, with the island's own means and plans, since Crete can be regarded as a single river basin district), make the most of marginal waters while at the same time enhancing the environment.

The evaluation of recycled water has been implemented through the involvement of two distinctive groups of people: farmers and consumers. Therefore, on the one hand, the research asks farmers whether they would be willing to use recycled water of certain qualities for the irrigation of olive trees and tomatoes and on the other hand, the research asks consumers whether they would be willing to use and pay for food products irrigated with recycled water. Results show there is social acquiescence on recycled water usage. This is confirmed by the correspondence of willingness to use recycled water between farmers and consumers. Conclusions from the willingness to use and willingness to pay models provide useful pricing and marketing signals for recycled water.

Besides the evaluation of recycled water, another part of the research dealt with the role water plays in the production of olive oil and the confirmation of irrigation water shortages.

CONTENTS

CHAPTER 1. INTRODUCTION 1
1. The physical and pricing situation for fresh water 2
1.1. Fresh water as a depletable but renewable resource 2
1.2. Irrigation water demand and supply in Greece 3
1.3. Principles of irrigation water pricing 6
1.3.1. Marginal cost pricing 7
1.3.2. Tiered or two part pricing 8
1.3.3. Water markets 8
1.3.4. Area based pricing 9
1.3.5. Crop-based pricing 9
1.3.6. Average cost versus marginal cost pricing 9
1.4. Irrigation water is under priced 12
1.5. Economics of irrigation water use 14
1.6. The need for recycled water 16
1.7. Fresh water prices in Greece 18
1.7.1. Athens 19
1.7.2. Salonica 21
1.7.3.Crete 22
1.7.4. Heraklion Crete 23
1.8. Description of irrigation water market in Crete 24
1.8.1.Water origin and property rights 24
1.8.2. Examples of irrigation water prices in Crete 30
1.8.3. Water demand and supply in Crete 31
1.9. Full cost recovery is needed for the water market to balance 32
2. Wastewater treatment and recycling; a technical primer 36
2.1. Introduction 36
2.2. Definitions 37
2.3. Wastewater treatment 39
2.3.1. Centralized wastewater treatment 39
2.3.2.On site treatment 41
2.3.3. Wastewater treatment in Greece 42
2.4. Wastewater re-use 42
2.4.1. Risks from recycled water usage 43
2.4.2. Irrigation of agricultural land 44
2.4.3. Irrigation forested land and fire protection 46
2.4.4. Irrigation of public spaces 48
2.5. Irrigation water qualities 50
2.5.1. Water quality stars: 0 51
2.5.2. Water quality stars: * 51
2.5.3. Water quality stars: ** 52
2.5.4. Water quality stars: *** 52
2.5.5. Water quality stars: **** 53
3. Wastewater treatment facts and potential in Crete 54
3.1. Wastewater treatment in Crete 54
3.2. Reuse Case Studies in Crete 55
3.3. Potential for Water Recycling and Reuse 56
4. The 60/2000 water framework directive and Greek Legislation 57
4.1. The 60/2000 water framework directive 57

4.2. Greek national legislation on Water Resources 59
5. Thesis structure 63
6. References 64
CHAPTER 2. THE ROLE OF WATER IN THE PRODUCTION OF OLIVE OIL IN CRETE 74
1. INTRODUCTION 74
1.1. Chapter stracture 74
1.2. Crete 75
1.2.1. Island geography 75
1.2.2. A brief survey of the Cretan economy 76
1.2.3. Cretan Agriculture 77
1.3. Olive-tree cultivation in Crete 78
1.4. Olive-tree irrigation essentials 79
1.5. The value of water in different economic sectors in Crete 82
2. THE SURVEY DESIGN 83
2.1. Sample size 84
2.2. The sampling design 85
2.3. Survey description 86
3. REPRESENTATION OF IRRIGATION WATER DEMAND IN OLIVE-OIL PRODUCTION FUNCTION 86
3.1. Irrigation water prices in farmers' sample 86
3.2. Irrigation water demand 88
3.2.1. Irrigation water supply 88
3.2.2. Irrigation demand function representation 89
3.2.3. Comparison of various demand function specifications 92
3.2.4. Measurement error in water demand 94
4. REPRESENTATION OF OLIVE OIL PRODUCTION WITH A TRANSLOG FUNCTION 96
4.1. Why the translog production function 98
4.2.The sample size and input variables 100
4.3. Model 1 107
4.4. Robustness of Model 1 109
4.5. Model 2 111
4.6. Stability of Model 1 114
4.7. Sensitivity analysis of Model 1 115
4.7.1.The first order sensitivity index 116
4.7.2. The total effect sensitivity index 117
5. FRESH WATER AVERAGE AND MARGINAL PRODUCTS IN OLIVE OIL PRODUCTION 120
5.1. Fresh water total product 122
5.2. Fresh water average product 123
5.3. Fresh water marginal product 124
6. CONCLUSION 127
References 130
7. APPENDICES 136
7.1. Farmers' questionnaire 136
7. 2. Questionnaire structure 140
7.2.1. Questionnaire introduction 140
7.2.2. Part A 141
7.2.3. Part B 143

7.2.4. Part C 147
7.2. Eviews Demand function appendix 148
7.2.1. Tables appendix 148
7.2.2. Figures appendix 151
7.3. EViews production function appendix 153
7.3.1. Tables appendix 153
7.3.2. Figures appendix 175
7.4. Simlab output 180
CHAPTER 3. WILL CRETAN FARMERS USE RECYCLED WATER FOR THE IRRIGATION OF THEIR OLIVE TREES? 182
1. INTRODUCTION 182
2. THE CONTINGENT VALUATION; A BRIEF DESCRIPTION OF THE METHOD 183
2.1.The total value of recycled water for farmers 183
2.2.The total value of recycled water for consumers 184
2.3. The Contingent Valuation Method; Definition and theory 185
2.4. Question formats in Contingent Valuation Method and empirical evidence 192
2.5. Information and Experience in CVM 197
2.6. Hypothetical bias 199
2.7. Embedding or scope effects 200
2.8. Protest-responses 201
2.9. Validity and Reliability 202
2.10.The design of our questionnaires 204
3. DESCRIPTIVE STATISTICS OF WILLINGNESS TO USE AND WILLINGNESS TO PAY 205
3.1 Willingness to Use 205
3.2. "Don't know" responses 207
3.3. Willingness to Pay 207
4. CORRELATION AMONG REGRESSORS 213
4.1. Correlation among "awareness variables" 213
4.2. Correlation among all regressors 214
5. WHAT DETERMINES FARMERS WILLINGNESS TO USE RECYCLED WATER FOR IRRIGATION 214
5.1. Willingness to Use Product 1 (Model 1) 214
5.1.1. Robustness of Model 1 215
5.1.2. Model 1 expectations and verification 215
5.1.3. Model 1 Results 217
5.1.4. Model 1 marginal probabilities 217
5.2. Willingness to Use Product 2 (Model 2) 218
5.2.1. Robustness of Model 2 218
5.2.2. Model 2 expectations and verification 219
5.2.3. Model 2 results 219
6. WHAT DETERMINES FARMERS WILLINGNESS TO PAY FOR RECYCLED WATER FOR IRRIGATION 220
6.1. Willingness to Pay for Product 1 (Model 3) 220
6.1.1. Model 3 expectations and verification 221
6.1.2. Model 3 results 221
6.1.3. Significance of Model 3 222
6.1.4. Model 3 specification and coefficient stability 224
6.2. Willingness to Pay for Product 2 (Model 4) 224

6.2.1. Model 4 expectations and verification 225
6.2.2. Model 4 results 225
6.2.3. Significance of Model 4 226
6.2.4. Model 4 specification and coefficient stability 227
7. CONCLUSIONS 228
7.1. Farmers' Willingness to Use and Willingness to Pay for Recycled Water 228
7.2. Factors that determine farmers' Willingness to Use and Willingness to Pay for Recycled Water 229
References 231
CHAPTER 4. CONSUMERS' ATTITUDE TOWARDS RECYCLED WATER 249
1. INTRODUCTION 249
1.1. The variables 250
1.2.The research sample 251
2. DESCRIPTIVE STATISTICS OF WILLINGNESS TO USE AND WILLINGNESS TO PAY 252
2.1. Willingness to use 252
2.2. "Don't know" responses 256
2.3. Willingness to pay 258
2.3.1. Open-question data 259
2.3.2. DB-DC data 261
2.3.3. Comparison of the mean WTP from the open and DB-DC data 264
3. CORRELATION AMONG REGRESSOR VARIABLES 267
3.1. Correlation among "awareness variables" 267
3.2. Correlation among all regressor variables 268
4. WHAT DETERMINES CONSUMERS' WTU AND WTP FOR PRODUCTS IRRIGATED WITH RECYCLED WATER 269
4.1. Willingness to Use Product 3 269
4.1.1.The methodology 270
4.1.2.The assumption of parallel slopes 272
4.1.3. Model 1 273
4.1.4. The cutoff points in Model 1 275
4.2. Willingness to Consume Product 4 277
4.2.1. Model 2 277
4.2.1.1. Robustness of Model 2 278
4.2.1.2. Model 2 estimates 278
4.2.2.The cutoff points in Model 2 279
4.2.3. Ordered vs Multinomial Model 280
4.3. Willingness to Use Product 5 280
4.3.1. Model 3 280
4.3.2.The cutoff points in Model 3 281
4.4. Willingness to Pay for Product 3 284
4.4.1.The log normal distribution assumption 284
4.4.2. Model 4 (open-question data) 286
4.4.3. Model 5 (DB-DC data) 287
5. CONCLUSIONS 295
5.1. Willingness to Consume/Use 295
5.2. Willingness to Pay 297
5.3. Policy conclusions derived from WTU 298
5.4. Policy conclusions derived from WTP 299

References 300
6. APPENDICES 304
6.1. Consumers' questionnaire 304
6.2. Consumers' questionnaire structure 307
6.3. The Turnbull Self- Consistency Algorithm (TSCA) 310
6.3.1. Calculations for the "imitated TSCA" 310
6.3.2. Gauss output from true TSCA 310
6.3.2.1. Non-parametric Mean WTP 310
6.3.2.2. Non parametric 95% confidence intervals for mean WTP 312
6.4. EViews code for double-bounded dichotomous choice data 313
6.5. Limdep outputs 314
6.6. EViews outputs 326
CHAPTER 5. CONCLUSIONS 328
1. Summary results 329
1.1. Irrigation water shortage in Crete 329
1.2. Social acceptability and evaluation of recycled water in Crete 330
1.3. Factors affecting society's Willingness to Use and Willingness to Pay for recycled water 332
2. Policy conclusions 336
2.1. Recycled water pricing clues 336
2.2.The dissemination of information 341
3. Research problems; an account 342
4. Directions for further research 344
4.1. Further research for chapter 3 344
4.2. Further research for chapter 4 346
References 346

LIST OF FIGURES

Figure 1.1. Average versus marginal cost pricing. 10
Figure 1.2. Average cost versus marginal cost pricing in the natural monopolist. 12
Figure 1.3. Variation of the water table of a Cretan aquifer, as reported from a representative well 36
Figure 1.4. Typical extended aeration flow chart. 40
Figure 1.5. Schematic representation of a free water surface constructed wetland..... 41
Figure 1.6. Septic tank definition cut 42
Figure 1.7. Irrigation of green stripes for forest protection in the event of fire. 48
Figure 1.8. Irrigation of public places with surface application; restricted and unrestricted to public access areas. 49
Figure 1.9. Cross sections of a typical shallow unfilled leak field 50
Figure 1.10. Suitable use for 1* water quality 52
Figure 1.11. Suitable use for 2* water quality 52
Figure 1.12. Suitable use for 3* water quality 53
Figure 2.1. Frequency distribution of irrigation water prices, as stated by farmers 87
Figure 2.2. Hypothetical irrigation water supply 89
Figure 2.3. Irrigation water demand curve with respect to quantity. 91
Figure 2.4. Irrigation water inverse demand curve. 91
Figure 2.5. Typical water demand function in agriculture 94
Figure 2.6. Normality test of Model 1 regression residuals 110
Figure 2.7. Normality test of residuals from Model 2. 114
Figure 2.8. Total, average and marginal product in the "three stages of production" 120
Figure 2.9. Total product of fresh water. 123
Figure 2.10. Average product of fresh water 124
Figure 2.11. Marginal product of fresh water 126
Figure 2.12. Logarithmic demand function normalized with respect to quantity. ... 151
Figure 2.13. Logarithmic demand function normalized with respect to price. 151
Figure 2.14. Exponential demand function with respect to quantity. 152
Figure 2.15. Exponential demand function with respect to price. 152
Figure 2.16. Residuals graph for Model 1 175
Figure 2.17. Residuals graph for Model 1a. 175
Figure 2.18. Residuals graph for Model 1a with low quantity of water. 176
Figure 2.19. Residuals graph for Model 1a with high quantity of water. 176
Figure 2.20. Normality test of residuals for Model 2. 177
Figure 2.21. Residuals graph for Model 2 177
Figure 2.22. Recursive residuals for Model 1a 178
Figure 2.23. Pairwise correlation among all pairs of inputs and output. 179
Figure 2.24. Simlab output for sensitivity analysis (part 1). 180
Figure 2.25. Simlab output for sensitivity analysis (part 2). 180
Figure 2.26. Simlab output; Cobweb plot of production function sample generated with Monte Carlo simulation. 181
Figure 3.1. Total economic value of recycled water for farmers. 184
Figure 3.2. Total economic value of recycled water for consumers 185
Figure 3.3. WTP for product 1 (pecuniary amount). 208
Figure 3.4. WTP for product 2 (pecuniary amount). 210
Figure 3.5. Jarque-Bera residual normality test of Model 3 223
Figure 3.6. Jarque-Bera residual normality test of Model 4 226

Figure 3.7. Jarque-Bera residual normality test of Model 3 245
Figure 3.8. Jarque-Bera residual normality test of Model 4 246
Figure 4.1. All products percentage WTU answers 257
Figure 4.2. Cutoff points in model 1 277
Figure 4.3. Cutoff points schematic comparison of models 3, 4 and 5 282
Figure 4.4. Choice probabilities schematic comparison of models 3, 4, and 5 284
Figure 4.5. Calculations for the "imitated TSCA" 310
Figure 5.1. Factors determining the price of a product 337

LIST OF PHOTOS

Photo 1.1. Untreated wastewater as was discharged into a Greek sea..... 37
Photo 1.2. Extended aeration system at Embonas, Rhodes island, Greece..... 40
Photo 1.3. View of a free water surface constructed wetland at the experimental field of the National Agricultural Research Foundation of Heraklion... 41
Photo 1.4. Vineyard irrigated with treated wastewater in Israel (Arad region). 45
Photo 1.5. Almond trees irrigated with treated wastewater in Israel..... 45
Photo 1.6. Experimental Gerbera flowers in the green house of NAGREF at Thessaloniki, irrigated with the treated wastewater from the wastewater treatment plant at Sindos. 46
Photo 1.7. Experimental tomato plants in the green house of NAGREF at Thessaloniki, irrigated with the treated wastewater from the wastewater treatment plant at Sindos. 46
Photo 1.8. The islet where the wastewater treatment plant of Chalkis is located; this view was seen before using the treated effluent for irrigation. 47
Photo 1.9. The islet of the previous photo after using the treated effluent for the irrigation of forested land. 47
Photo 1.10. Eucalyptus trees irrigated with treated effluent form the wastewater treatment plant of Hersonissos..... 47
Photo 1.11. Fire hydrant connected to the recycled water tank of the Hersonissos municipality. 48
Photo 1.12. Landscape irrigation with treated effluent in a wastewater treatment in Israel. 49
Photo 1.13. Free access area at a Cretan hotel irrigated with recycled water from the wastewater treatment plant of the hotel (left). Sign showing this is not potable water (right)..... 50
Photo 1.14. Primary treated effluent at the wastewater treatment plant of Volos, Greece..... 51
Photo 1.15. Location of wastewater treatment plants in Crete..... 55

LIST OF TABLES

Table 1.1. Brief presentation of most common irrigation water pricing schemes 7
Table 1.2. Municipal enterprises (DEYA) investigated in 2003 19
Table 1.3. Fresh water prices in Athens 20
Table 1.4. Billing scale on a four-month basis for households in Salonica 21
Table 1.5. Billing scale for industries in 2005 22
Table 1.6. Quarterly Tariffs for households at the municipality of Heraklion 23
Table 1.7. Number of wells in the four Cretan prefectures. 25
Table 1.8. Irrigation sources in our farmer sample. 29
Table 1.9. Water pricing in Avdou and Gouves villages for year 2002. 31
Table 1.10. Water demand and supply scenarios in Crete. 32
Table 1.11. Development of MWTP in Crete according to their number p.e. and s.p. 54
Table 1.12. Principles and Articles from 60/2000 Water Framework Directive 58
Table 1.13. Greek Laws in the water sector 61
Table 2.1. Number of people working in each sector in Crete from 1971-1991 77
Table 2.2. Nominal yield and net value of agricultural production of main cultivation types in Crete 78
Table 2.3. Olive tree water needs in lt/tree per day 80
Table 2.4. Descriptive statistics of irrigation fresh water price (€/m³) 88
Table 2.5. Summary of irrigation water demand models. 93
Table 2.6. Olive oil production and price in the years 1993-2002. 102
Table 2.7. Olive oil price (from 4 April-16 May) in the largest six co-operatives in Crete 102
Table 2.8. List of variables. 105
Table 2.9. Descriptive statistics of the inputs and output of the translog production function. 105
Table 2.10. Number of agricultural holdings, their utilized agricultural area and average area per holding, by Region 106
Table 2.11. Yearly remuneration indices for factors of production in agriculture, base year 2000 107
Table 2.12. Model 1; Translog production function with physical inputs (land in 0.1ha) and output. Capital and fertilizers expressed in€. 108
Table 2.13. White heteroskedasticity test for Model 1. 110
Table 2.14. Wald test on separability condition in Model 1. 111
Table 2.15. Translog production function with monetary inputs and output. 112
Table 2.16. White heteroskedasticity test for Model 2. 112
Table 2.17. Chow Forecast test as stability test for Model 1, n1=180. 115
Table 2.18. Chow Forecast test as stability test for Model 1, n1=200. 115
Table 2.19. Chow Forecast test as stability test for Model 1, n1=250 115
Table 2.20. First and total order indexes for input variables of model 1 118
Table 2.21. EVIEWS full output of demand function normalized with respect to quantity. 148
Table 2.22. EVIEWS full output of demand function normalized with respect to price. 148
Table 2.23. EVIEWS full output of demand function normalized with respect to price with a dummy on water origin. 149
Table 2.24. EVIEWS full output of demand function normalized with respect to quantity with a dummy on water origin. 149

Table 2.25. EVIEWS full output of demand function normalized with respect to quantity (price expressed in pence)..... 150
Table 2.26. Model 1; Translog production function with land (in 0.1.ha), labor, water in physical form, capital and fertilizers expressed in euros..... 153
Table 2.27. White Heteroskedasticity test in Model 1..... 154
Table 2.28. Separability test in Model 1..... 155
Table 2.29. Chow forecast test for Model 1..... 156
Table 2.30. MODEL 1a; Translog production function with output, land (%), water, labor expressed in physical terms and fertilizer and capital costs expressed in euros..... 157
Table 2.31. White heteroskedasticity test for Model 1a..... 158
Table 2.32. Separability test for Model 1a..... 159
Table 2.33. Chow Breakpoint test for Model 1a..... 159
Table 2.34. Model 1a; Translog production function with output, land (%), water, labor expressed in physical terms and fertilizer and capital costs expressed in euros (small farmers i.e. low output)..... 160
Table 2.35. Model 1a; White heteroskedasticity test for Model 1a (small farmers i.e. low output)..... 161
Table 2.36. Model 1a; Translog production function with output, land (%), water, labor expressed in physical terms and fertilizer and capital costs expressed in euros (big farmers i.e. high output)..... 162
Table 2.37. Model 1a; White heteroskedasticity test for Model 1a (big farmers i.e. high output)..... 163
Table 2.38. Model 1a; Translog production function with low quantity of water.. 164
Table 2.39. Model 1a; White heteroskedasticity test (in low quantity of water).... 165
Table 2.40. Model 1a; Translog production function with high quantity of water. 166
Table 2.41. Model 1a; White heteroskedasticity test (in high quantity of water)... 167
Table 2.42. Model 2; Translog production function with all inputs and output expressed in money terms..... 168
Table 2.43. White heteroskedasticity test in Model 2..... 169
Table 2.44. Model 2; Translog production function with small farmers (low output)..... 170
Table 2.45. Model 2; Translog production function with big farmers (high output)..... 171
Table 2.46. Model 2; Translog production function with irrigated land expressed as percentage of total land..... 172
Table 2.47. Wald test for the significance of Model 1..... 173
Table 2.48. Production inputs correlation matrix..... 174
Table 2.49. Variable terminology in Table 2.48..... 174
Table 3.1. WTU product 1..... 205
Table 3.2. WTU product 1a..... 206
Table 3.3. WTU product 2..... 206
Table 3.4. WTP1 as intention..... 208
Table 3.5. Descriptive statistics of WTP for product 1 (non-irrigators excluded)... 209
Table 3.6. WTP2 (as intention)..... 210
Table 3.7. Descriptive statistics of WTP for product 2 (non-irrigators excluded)... 210
Table 3.8. List of variables..... 211
Table 3.9. Correlation matrix of regressors..... 213
Table 3.10. Model 3 OLS estimation results..... 222
Table 3.11. Coefficient Stability for Model 3..... 224

Table 3.12. Model 4 OLS estimation results 225
Table 3.13. Coefficient Stability for Model 4 227
Table 3.14. Limdep output for Model 1 240
Table 3.15. Limdep full output for Model 2 242
Table 3.16. EVIEWS full output for Model 3 244
Table 3.17. EVIEWS full output for Model 4 245
Table 3.18. Ramsey RESET test for Model 3 247
Table 3.19. Ramsey RESET test for Model 4 248
Table 4.1. List of variables 251
Table 4.2. WTU olive oil irrigated with recycled water of quality 2. 252
Table 4.3. WTU olive oil irrigated with recycled water of quality 3. 254
Table 4.4. WTU tomatoes irrigated with recycled water of quality 3. 254
Table 4.5. WTU a park irrigated with recycled water of quality 4. 255
Table 4.6. WTP (as intention) for product 3. 259
Table 4.7. Descriptive statistics of WTP (open-ended data) for product 3 260
Table 4.8. Bid design for DB-DC data. 261
Table 4.9. Bid interval frequency with DB-DC data (overlapping intervals). 262
Table 4.10. Bid interval frequency with DB-DC data (mutually-exclusive intervals). 263
Table 4.11. Comparison of mean WTP from the open and DB-DC data. 265
Table 4.12. Consumers' averting behavior to bid increase. 266
Table 4.13. Correlation matrix of chapter 4 models regressors. 267
Table 4.14. Model 4 (WTP open-ended data) 287
Table 4.15. Four bid options 290
Table 4.16. Model 5 (WTP DB-DC data) 292
Table 4.17. Model 6 (WTP DB-DC data) 293
Table 4.18. Limdep full output for Model 1 (ordered logit) 314
Table 4.19. Limdep output for multinomial version of Model 1 316
Table 4.20. Limdep full output for Model 2 (ordered logit) 318
Table 4.21. Limdep output for multinomial version of Model 2 320
Table 4.22. Limdep full output for Model 3 (ordered logit) 322
Table 4.23. Limdep output for multinomial version of Model 3 324
Table 4.24. EVIEWS full output of Model 4. 326
Table 4.25. EVIEWS output for Model 5 (DB-DC data). 326
Table 4.26. EVIEWS output for Model 6 for (DB-DC data) 327
Table 5.1. Research product directory. 331
Table 5.2. Willingness to Use comparison between farmers and consumers. 332
Table 5.3. Willingness to Use and Willingness to Pay models for farmers and consumers 334
Table 5.4. Calculation of a price for recycled water 339

CHAPTER 1.

INTRODUCTION

This chapter provides an introduction to the research done (and presented in the following chapters) on people's attitude towards recycled water and its evaluation. Five parts compose it. The first part describes fresh water physical and pricing situation, which lead us to the use of recycled water. The second part is a technical primer on recycled water. It is a primer in the sense that it tries to put across technical material in the simplest possible way. Technical information is about how recycled water is produced (through the wastewater treatment plant), what a wastewater treatment plant consists of, what the characteristics and possible applications of recycled water are, potential risks etc. It also contains various photographs and figures, which help towards information consolidation. Furthermore, this part includes the information given out to respondents of the two questionnaires (used for data collection in chapters 2-4) in the form of an information booklet[1]. The third part discusses wastewater treatment status and further potential in Crete. The fourth part is a short discussion on the 60/2000 Water Framework Directive (EU, 2000) whose corollary for wastewater actually induces the implementation of the present research. Last, a brief discussion on Greek environmental legislation is provided. Part five is a brief layout of the thesis structure.

[1] The booklet is the technical primer in part 2 of this chapter.

1. The physical and pricing situation for fresh water

Since the need to use recycled water comes from fresh water shortage problems, we see fit to spend some effort describing what the fresh water physical and pricing situation is, worldwide and in Greece. Fresh water pricing is viewed as the major reason for water shortage, because it does not signal its scarcity and thus leads to its squandering.

1.1. Fresh water as a depletable but renewable resource

Historically, water has been regarded as a gift of nature. El Serafy and Lutz (1989) regard this as a bias, which has provided false signals for policymakers. They state that this approach *confuses the depletion of valuable resources with the generation of income.* But this is not true income, because it is not sustainable. Sustainable income is achieved only when the maximum amount a recipient can consume in a given period does not reduce possible consumption in a future period. However this was not the case in the past. Dominant was the idea that rapid rates of economic growth could be obtained by exploiting a diminishing resource base. This is exactly the case with irrigation water in Greece and other countries, mostly Mediterranean. Irrigated agriculture is more productive than non-irrigated agriculture (see sub-section 1.4 in chapter 2). As a result of this, farmers keep pumping water with the visible danger of desertification. Pearce and Markandya (1998) remark that *resource depletion may well yield temporary gains in real income in the same way that anyone can borrow from a capital fund, but continued depletion is likely to result in medium-to long-run income losses, depending on the dynamics of the development process.*

Fresh water is renewable through the so-called water cycle. It can be rendered non-renewable or better scarce and inadequate through human actions. Hence it is

both renewable and non-renewable. Myers (1989) summarizes the peculiar situation of water in the following: *Water is rarely available in the right amount at the right place at the right time, largely because of precipitation patterns.* As a consequence of this, water consumption is also rival because the consumption of one person can reduce the consumption of the other. Although exclusion from water usage is feasible, it is not wished that any people were excluded from using water, because without water, human beings will die.

In conclusion, fresh water has a dual nature, which affects its qualification as a public good. On the one side, it is a public good in the sense that it is nobody's property, but at the same time it is scarce and its abuse affects all of us. Kindler (1999) suggests that *we must learn to think of water as a factor input with value similar to electricity, natural gas or food.* On the other side, water is an economic good but not like the others. Arrojo (1999) suggests *that the concept of water should be one of eco-social asset*, pointing to the fact that in contrast to pure economic goods such as cars, it has, besides its function as a productive input, also environmental and social functions. The eco part is justified because water does have environmental functions, which are essential for life.

1.2. Irrigation water demand and supply in Greece

Irrigation water usually comes from the same sources that household water comes. In Greece, irrigation water is potable water or generally water of good quality that could be rendered potable with little treatment. In few countries of the world does irrigation water come from wastewater treatment plants. Among these countries are Israel, Jordan, Cyprus the state of California (Angelakis *et al.*, 2002; Doppler *et al.*, 2002), but in most cases irrigation water is fresh water.

Greek agriculture represents 12% of the total GDP and over 20% of the active population is employed in agricultural activities. Agriculture currently uses four-fifths of the country's water supplies. Surface water accounts for approximately six-sevenths of total quantity of water. Twenty eight per cent of total cultivated area is irrigated, of which 40% is irrigated by collective irrigation works and 60% by individual ones (OECD, 1998). It has been reported that 85% of the total water use is spent on agriculture in Greece, while for the island of Crete it is 83% (Tsagarakis *et al.*, 2001b). The above numbers are absolutely eloquent of the size of irrigation water consumption in Greek agriculture.

Greece belongs to the countries in which irrigated agriculture is much more productive than dry-land agriculture ((according to OECD (1998), globally the productivity of irrigated land is double than that of rain-fed land)). Garrido (1999) pinpoints some of the characteristics of these countries, which are: *Strong intersectoral competition for water resources, wide differences in net agricultural returns depending on whether or not irrigation exists, long and deep involvement of public agencies water works and irrigation projects, increasing difficulties in preserving the environmental quality of waterways, without reducing the quantity available to users and the increasing costs of generating new sources of water supply.*

Total annual precipitation in Greece and total water potential (surface and groundwater quantity) are estimated to be $115{,}375 \times 10^6$ m³/yr and $69{,}000 \times 10^6$ m³/yr respectively, including water transported (through natural underground networks) from countries in the north of Greece such as Bulgaria and FYROM. At the beginning of 1990s total water consumption was estimated at $5{,}500 \times 10^6$ m³/yr, but by the end of the decade it had increased by about 30%. It is estimated that water

consumption in Greece increases by more than 3% per year. The major water use is irrigation, which varies among water regions (there are thirteen water regions in Greece with distinctive water characteristics) from 17% to 95% while domestic use ranges from 3% to 66% and industrial use from 0.2% to 16% of the total consumption (Tsagarakis *et al.*, 2001a). Worldwide the agricultural share of water is the greatest with 69%, the industrial with 23% and domestic only 8% (Ringskog, 2000). In OECD countries though, is the industrial share of water the greatest, 65% of total water, with agricultural share reaching a 35% and the domestic being a modest 5%.

The increased water demand, for both urban and agricultural use, cannot always be met despite adequate precipitation. Water imbalance is often experienced, especially in coastal and southeastern regions, due to temporal and spatial variations in the precipitation, the water demand increase during summer months, and the difficulty of transporting water due to the mountainous terrain. Moreover, major water losses occur (seepage, evaporation, leakage, etc.) during the delivery of water to agricultural sites for irrigation and to municipal sites for domestic use (Chartzoulakis *et al.*, 2001). However, on average, there is a high per capita water availability, i.e. around 5,800 m^3/inh.·yr (per inhabitant per year). Per capita consumption is only 62 m^3/inh.·yr (Tsagarakis, 2005).

Only one third of Greek agricultural land is irrigated (in Crete this is 36%). Mean annual water demand increase is estimated to be 1-1.5%. This translates into that not only is there a lot of unirrigated land (a further 60%) due to water shortage, but there is also an increased water demand even for the already irrigated land (see chapter 2). Thus the potential for water reuse and recycling, particularly in southeastern parts of Greece such as Crete, is very high.

1.3. Principles of irrigation water pricing

Because different forms of pricing apply among industry, agriculture and households, and given the fact that our research interest lies mostly in agriculture, we will concentrate on the principles of irrigation water pricing.

Pricing is a policy tool, which can be used based on what policymakers want to achieve. Johansson *et al*. (2002) state *that pricing of one sort or another is used to induce efficiency in water allocation, however the notion of an optimal water-pricing policy does not command consensus among economists, let alone policymakers.* Water prices generally should be set in such a way that i) they ensure efficient water use and lead to its conservation, ii) ensure an adequate return to fully cover operation and maintenance costs (dams, canals, water pipes, drainage facilities etc) and in some countries capital cost (depreciation cost), iii) will be within the capacity of farmer to pay, iv) reduce the burden on the general taxpayer (polluter pays principle), iv) will be simple to administer, v) will be consistent with the socio-economic development policy of the country, vi) they are agreeable to all stakeholders (Abu-Zeid, 2001).

Furthermore, OECD (1999) states that the price of agricultural water should depend on how productive water is to irrigators. This productivity depends on water quality, the level of uncertainty in fulfilling contracted allotments, frequency and certainty of water availability for field applications, technological conditions of any metering devices, discrepancies between charged volumes and accessible volumes at farm gates and last water pressure. Below, Table 1.1 provides a concise presentation of the most common irrigation water pricing schemes adopted in practice.

Table 1.1. Brief presentation of most common irrigation water pricing schemes (adapted in part from Johansson *et al.* (2002))

Pricing scheme	Equity	Implementation costs[2]	Characteristics
Single-rate volumetric	Undermines fairness principle	Complicated	Requires water use monitoring
Tiered	Can be used to target income groups for subsidy or tax	Relatively complicated	As above
Two-part	As above	Relatively complicated	As above
Output/input	As above	Less complicated	Requires input/output monitoring
Per area	As above	Easy	Requires cropping patterns by season
Water markets	Depends on type of market	Difficult	Requires developed water institutions and infrastructure

Next, we analyze in more detail some of the pricing schemes presented in Table 1.1. Some of the titles below do not directly appear in Table 1.1 under the same name, because they constitute one of the most common forms the corresponding category in the table usually takes.

1.3.1. Marginal cost pricing

It is a form of volumetric pricing. It equates the price of a unit of water with the marginal cost of supplying it. It is difficult in its application because, it presupposes an extensive calculation of all benefits and costs (environmental externalities, future supply scarcity etc). It is also accompanied by the high cost of metering. When scarcity cost is high, marginal cost pricing can drive low-income farms out of business. Metering is a prerequisite for this form of pricing to take place. More is said on this form of pricing, juxtaposed to the average cost pricing in sub-section 1.3.6 of this chapter. Dinar and Subramanian, (1998) state that among industrial countries, France sets urban water prices on the basis of the long-term incremental

[2] This is the physical, institutional and political environment in which prices are formed.

costs of supplying water to account for future resource development costs.

1.3.2. Tiered or two part pricing

This is another form of volumetric pricing, sometimes called block-rate pricing; Different prices are charged for the different volumes of water. A special case of this form of pricing is the declining block pricing where consumers pay a relatively high price for some initial quantity of water, up to some maximum, and then pay lower prices for quantities in excess of this level. The justification given for this form of pricing is that the cost per m^3 of water delivered to large consumers is lower than the cost of getting water to small consumers. This is a very unfortunate price structure because it produces incentives for water over consumption in order for the consumer to enjoy lower prices. Increasing block tariff is exactly the other way round which leads to a more conservative use of water.

1.3.3. Water markets

They are a form of non-volumetric pricing. They rely on market pressures to determine the price for irrigation water according to its opportunity cost. Water markets are also responsible to allocate or transfer water between sectors of economy depending on where water get its larger value, e.g. municipal versus agricultural use.

For formal water markets to work, we need well-defined tradable water rights and the appropriate infrastructure and institutions for distributing water. OECD (1999) refers to this as passive trading; *the district offers a price-presumably the one, which equates aggregate water supply and demand and farmers make use of whatever amount of water they want. Farmers' consolidated rights to water are then charged to the average price, but those whose consumption is higher would have to*

pay the offered price, and those consuming below their rights, receive a payment for their thrift. This type of pricing works in an analogous fashion to tradable pollution permits.

1.3.4. Area based pricing

Pricing takes place according to the locations of areas served with minimum control of the amount of water supplied (This is also the case with the villages of the farmers' sample of our research). Abu-Zeid (2001) states *that control in the irrigation scheme that uses this pricing form is usually achieved through arrangements among farmers to alternate in skipping a turn or to cut back on the time allowed to receive water.*

1.3.5. Crop-based pricing

This is also a form of area- based pricing. It sets prices for each crop on the basis of the crop water requirements. Abu-Zeid (2001) states this method has some of the effects of volumetric pricing in that an element of efficiency can be introduced by inducing shifts in cropping patterns towards more water-efficient crops.

1.3.6. Average cost versus marginal cost pricing

Today most water prices consist of i) a connection charge, ii) a fixed charge and iii) a volumetric charge based on consumption. Fixed rates vary greatly between countries, while per unit rates are in a reasonable range (Dinar and Subramanian, 1998). The fixed charge gives the service provider a reliable stream of revenue to cover overhead expenses and the variable charge provides consumers with incentives to use water efficiently.

For both urban and agricultural water, all developing countries and some developed ones, set charges on the basis of average rather than marginal cost of supply (Dinar and Subramanian, 1998). Average cost pricing means that costs of delivering water are divided by the total quantity of water delivered and prices are set accordingly. This form of pricing does not aim at profit. Figure 1.1 provides a simplified example of the effect of average cost versus marginal cost.

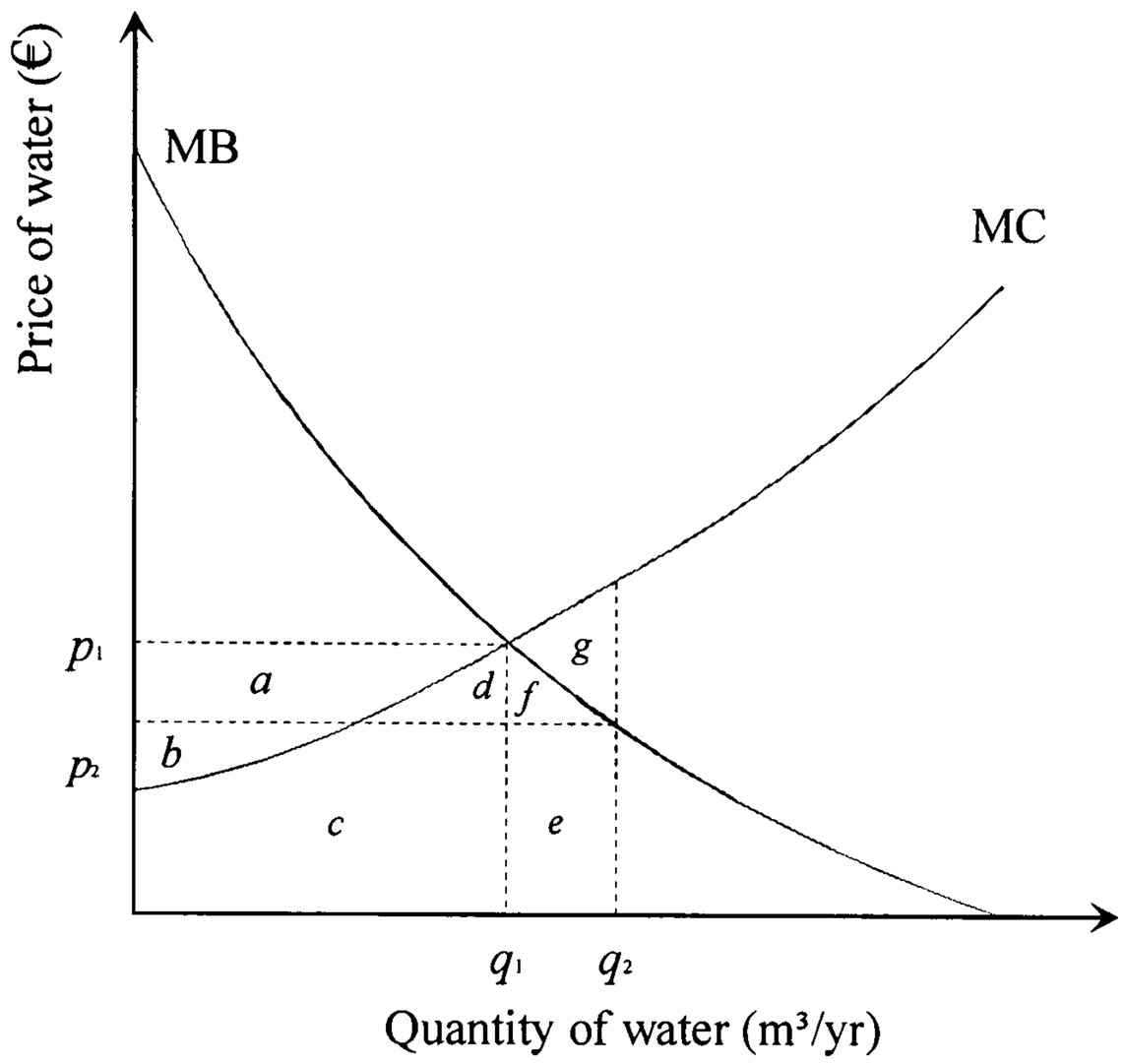


Figure 1.1. Average versus marginal cost pricing.

The marginal benefits function of consumers derived from consuming water is shown by curve MB, while MC is the long-run marginal cost function based on the costs of delivering water. The efficient quantity of water is q_1 m³ per year and the market-clearing price is p_1. Suppose that the water seller charges this price. Total costs of water supply are the amount given by the areas c+d. Total revenue is equal to price multiplied by the quantity, namely the rectangle given by the areas a+b+c+d, which exceeds the amount given by areas c+d. Therefore the water seller accrues a profit. Because the purpose of a water utility is not the profit (since it also has a social role to play, i.e. to provide everybody with enough water to go by at an

affordable price), water utilities charge at a price lower than the marginal cost, for example something like p_2. By setting the price this way, total cost equals total revenue (areas c+d+e+f+g equals areas b+c+e). However this price is not efficient because the marginal valuation of consumers is lower than the marginal cost of production.

Next, we will display all the above in the typical natural monopolist diagram (Figure 1.2), which would be more illustrative in a water utility case. Natural monopolies are a special case of monopoly because of the economies of scale they enjoy. In this case AC declines over the entire demand implying that one firm can produce the entire output more cheaply than many firms. The monopolist, if left alone will not produce the socially optimal level of output. He will produce at Q_m , namely at the point where MR=MC. This corresponds to a price P_m, which is above AC. Therefore social welfare is not maximized at this point. If the regulator sets price at P_c as determined by the intersection of MC and the demand curve, the quantity bought by consumers is Q_c. Price equals to MC and the welfare of society is maximized but the monopolist needs to be subsidized to stay at this point, because price is below the average cost. Because MC pricing is infeasible to be subsidized, regulators would set prices according to AC. This is price Q_{ac} determined by the intersection of demand with AC, where AR=AC and thus a zero or normal profit is accrued.

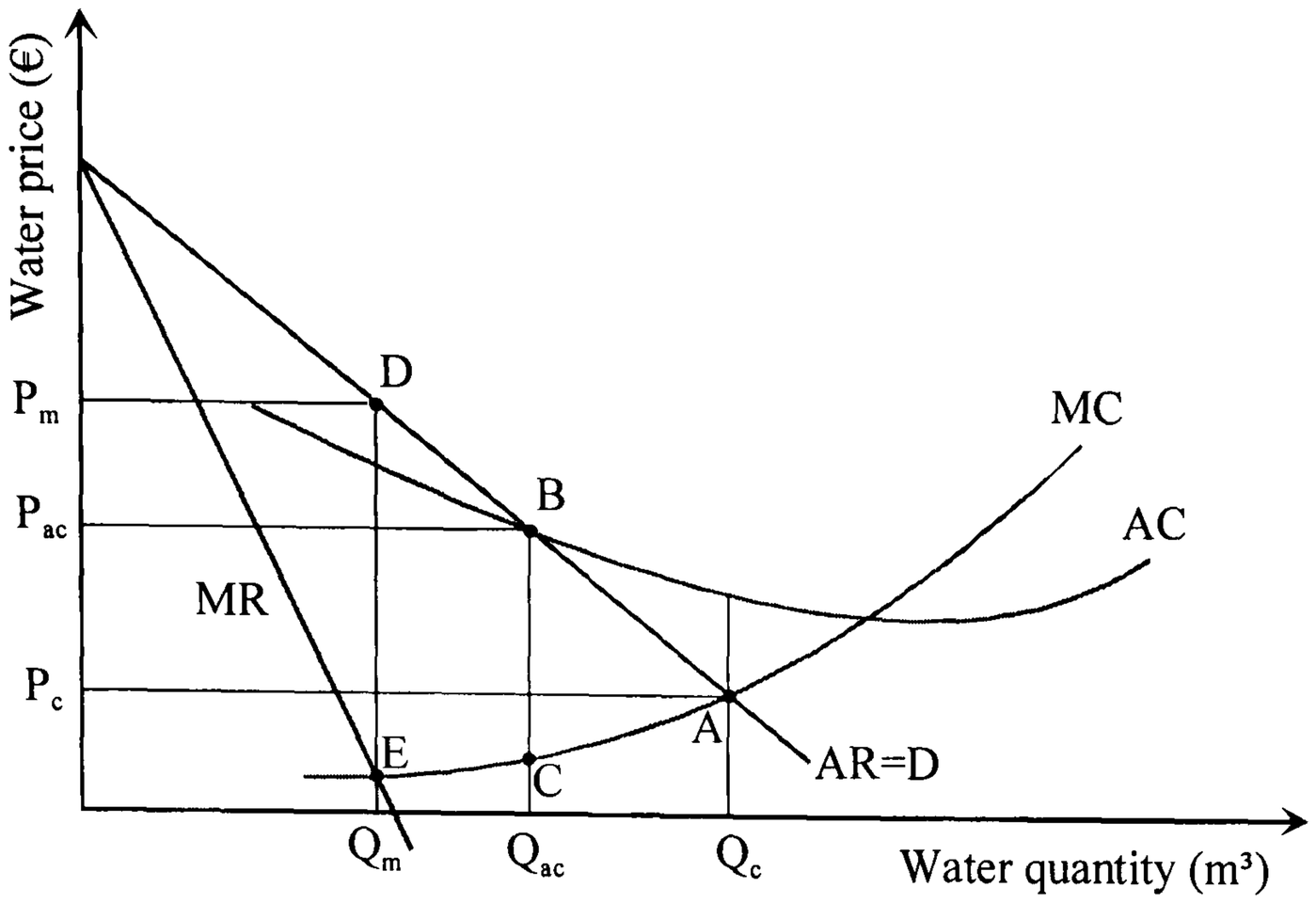


Figure 1.2. Average cost versus marginal cost pricing in the natural monopolist.

Both AC and MC are designed to expand output higher than the one offered by the monopolist. AC is easier to implement however, but they both reduce the cost of monopoly to society.

1.4. Irrigation water is under priced

In Greece, water price levels are different across regions and even across different cities (see sections 1.6 and 1.7 in this chapter for an example from Crete). An important explanation for water price disparities is *the different levels of cost recovery, partly due to the difficulties in assessing accurately the real full costs* (European Commission, 1999). Prices are not based on the laws of demand and supply. Roth (2002) comments *that tariff structures in European Union are mostly created to prevent the risk of revenue variation in times of low demand.*

The pricing situation of fresh water is characterized, almost universally, by under pricing. The level of water prices in European Union countries is generally lower than the cost recovery level (Doering, 1998) and certainly lower than the marginal social cost. In southern European countries, water prices cannot cover even

operating expenditure or depreciation and a return on capital. *Under pricing may be useful in certain occasions and be used with the purpose of reducing farmer's yield variability risk, helping achieve food self sufficiency, keeping people in farming, adding value to rural communities and providing environmental services or landscape amenities. These are of special concern for countries such as France, Japan and Greece* (Doering, 1998). Under pricing however generates minuses, which outweigh the above positive intentions. It leads to revenue shortfalls resulting in poor maintenance, substantial water losses and delays in new projects. Furthermore, it does not signal the opportunity cost of water, thus leading towards its over-consumption. Last, it destroys incentives for better risk management and hedging (Koundouri *et al.*, 2006).

Determinants of water consumption are metering, price level, price structure (flat fee, increasing or decreasing blocks), consumer income, and other factors such as climate and intermittency. In Greece, as with most OECD countries, water metering is an unusual procedure in most agricultural districts (OECD, 1999), while it is increasingly common in the domestic sector and almost universal for industrial users. In agriculture, water use is often charged per surface of irrigated area and according to crops type. In the north of Europe it often charged per volume (OECD, 1999). For Greece, Vakalis (1996) found that: *the most important factors, which affect the demand for irrigation water, are the use of water-saving technology, the way irrigation water is used by farmers and the expected return of the various cultivations. The factors, which have been found to affect irrigation water demand the least are: the price of irrigation water and weather conditions*. The fact that water price is not so important to determine irrigation water demand (demand is inelastic up to a point) is verified by the farmers' survey results in chapter 2 of this thesis.

1.5. Economics of irrigation water use

Irrigation water comes from both surface (lakes, rivers) and groundwater (wells). Fresh water stock cannot be increased (in the same way the fish or any other biological population would), therefore we assume it is constant. Irrigation is a practice that cannot be deferred because crops will be destroyed or yield will be reduced.

Generally fresh ground water is renewable, but it can be rendered non-renewable under circumstances, namely when the pumping or extraction rate is higher than the recharge rate. When water-pumping or extraction rate is higher than recharge rate, groundwater reservoirs are emptied and filled with saline water. This causes an irreversible environmental problem called desertification, because the land that is above the saline intruded reservoirs is transformed into a permanent desert. Therefore, to achieve efficiency the first thing necessary is the hydrological balance between the pumping or extraction and recharge rates as shown in Relationship 1.1.

Pumping or Extraction rate = Recharge rate (1.1)

Besides the hydrological balance that is the first prerequisite for the efficient use of irrigation water, another condition is that farmers, who use water, do not do that at the expense of the consumption of some other more profitable farmer. Given the fact that there is individualistic competition among farmers, there is another relationship, which is pursued together with the relationship described in Relationship 1.1 and will lead to an equilibrium situation. Farmers accrue a benefit from water-pumping/extraction, which is the profit they enjoy from their increased irrigated crops yield. They are also subject to a cost which depends on the pumping/extraction

effort because the deeper they dig to find water, the more expensive this becomes and the more environmental problems it causes to their land (desertification). Therefore, the net benefit each farmer gets is the difference of the benefit minus cost. Farmers want the net benefit to be maximum (Relationship 1.2)

$$\text{Net benefit} = \text{Benefit from water pumping} - \text{Cost from water pumping} > 0 \qquad (1.2)$$

Assuming that water extraction/pumping is open-access (which is not officially, but practically it is due to lose control from authorities), then if farmers jointly act in such a way that they abide by the above two relationships (1.1) and (1.2), then they extract water at a sustainable level and no farmer is harmed by the over extraction actions of the other. Up till now the discussion has taken place in the partial equilibrium framework. Now we need to introduce economy, as a whole, in the stage.

Suppose that economy consists of two sectors, farmers and non-farmers. These two sectors are competitive about fresh water. The more water farmers use in agriculture, the less is left for other sectors, industry, domestic use etc. Also, the unsustainable use of fresh water by farmers affects the non-farmers in that they are left with a destroyed environment to bequeath to the next generation. Therefore, the net benefit (Relationship 1.2) of society is different from the net benefit of farmers. To achieve social efficiency from water consumption, we need to add one more relationship, which would be the economy wide counterpart of relationship (1.2).

Farmers' net benefit coincides with social net benefit only if, to quote from Perman *et al*. (2003), i) fresh water price reflects all social benefits (with the assumption of exogenously determined water prices), ii) no extraction/pumping

externalities are present in the cost and benefit function of farmers as described in the previous paragraph, and iii) the private and social water consumption rates are identical.

To induce efficiency, *policy may be directed towards removing externalities, improving information*[3], *developing property rights, removing monopolist industrial structures and using direct controls or fiscal incentives to alter rates of extraction/pumping whenever there is reason to believe that extraction programmes are inefficient* (Perman *et al.*, 2003). The same writers continue with an idea of creation of forward markets for natural resources, which is very brilliant but maybe too sophisticated.

In Crete there are laws governing the water quantity that should be pumped, or the number of wells to be dug etc, but control is very loose (see sub-section 4.1). Authorities do not spend time supervising well-owners on this, and rules are easily violated. Illegal well drilling cannot be easily detected either. This combined with the non-volumetric irrigation water pricing, does not give much way to efficiency. The introduction of recycled water in irrigation is going to reduce the pumping rate and thus reservoir recharge will take place within a shorter period of time, thus alleviating the water stress situations experienced in some cases by the economy.

1.6. The need for recycled water

Recycled water is a valuable irrigation water resource, which used to be processed, cleaned and, up to some years ago, thrown into the sea. Today, after having experienced the consequences of prolonged droughts and serious rain imbalances,

[3] Part of the research programme from which funds were raised to carry out the two surveys whose results are the spine of this thesis, was the dissemination of information about the consequences of unsustainable use of fresh water.

people have started to realize how important it is to make the most of every other possible source of water even marginal waters, before coming to use the scarce fresh water. Arrojo (1999) claims that: *It is often cheaper and more equitable to increase efficiency of existing water uses than increase supplies*, while Gleick *et al.* (2002) successfully pinpoint that *"the needle to be threaded" in water management is how to get the most value from water that is available, while not depriving people of sufficient clean water to meet their basic needs.*

A key point in the use of recycled water is not only its own price, but the price of fresh water too. Farmers will not buy recycled water for irrigation, unless fresh water becomes more expensive and scarce. The latter has become already a situation, in various parts of the world, the former though is not a case. Water of whatever use (irrigation, household, industrial etc.) is cheap. Unavoidably, we reach the conclusion that pricing is a valuable tool to be used in order to promote not only the use of recycled water, but generally the efficient allocation of water among its competing demanders.

Before making suggestions about the pricing policy to be followed for recycled water, we could derive some valuable insight from the pricing policies followed for fresh water. Recycled water is a fresh water derivative and as such, it is expected that the pricing of the two types of water should have things in common. However, what comes as a surprise is that wastewater pricing naturally emerges as too sophisticated a matter, because simple fresh water pricing is performed without using any economic tools. Fresh water pricing in practice appears to be a rather random procedure, which does not have much to give as an exemplary pricing model or strategy for recycled water pricing.

Proper pricing of water is not a panacea though. It is a prerequisite for its

sustainable use, but, alone, it will not solve much. Greig (1998) argues that: *it is a limited solution to a fiscal or allocative problem. But when it is combined with the implementation of an undistorted trading environment, institutional reform involving real devolution to farming groups (with or without transfer) and a tough regulatory framework, as well as an appreciation of the fact that farmers and "the environment" can achieve a "win-win" outcome by a genuine understanding of synergies, the result will be a dynamic and vibrant agricultural sector which is adaptive to change and capable of achieving much better financial and environmental outcomes.* Rogers *et al.* (2002) add to the above argument by saying that *there are many different ways to promote equity, efficiency and sustainability in the water sector and that water pricing is probably the simplest conceptually, but maybe the most difficult to implement politically.*

1.7. Fresh water prices in Greece

Law 1069/80 provided the legal framework for the establishment of municipal non-for-profit organizations (their Greek name is DEYA), which would be the official drinking water and sewerage service providers. These organizations are set up in cities with a population higher than 10,000 inhabitants. Today there are 180 DEYAs in the whole Greece. The water pricing policy they follow is based on the recovery of operational cost, sometimes not even this, as stated by Safarikas *et al.* (2005). From a survey done for seventy-four DEYAs (Table 1.2), average water (drinking) price was 1.19 €/m³ which has been estimated to be only 41.67% of its true economic cost. In other words, the price has to increase from 1.19 €/m³ to 2.04 €/m³ in order for the latter to be recovered.

Table 1.2. Municipal enterprises (DEYA) investigated in 2003 (Safarikas *et al.*, 2005)

Administrative region	Number of DEYAs	Population served	Water consumption (m^3/inh)	Water price (€ /m^3)
East Macedonia	8	31,1380	25,747,620	1.32
Central Macedonia	15	303,475	33,046,417	1.06
Western Macedonia	5	130,967	8,588,413	1.30
Thessalia	11	390,692	31,527,376	0.91
Epirus	3	113,502	8,932,000	1.59
Ionian Islands	2	43,070	3,674,533	1.55
Central Greece	5	114,957	9,945,380	1.10
Western Greece	4	118,284	9,093,679	0.91
Peloponnissos	5	127,475	10,142,102	1.16
North Aegean Islands	2	59,975	3,504,519	2.01
South Aegean Islands	7	113,298	10,924,188	1.42
Crete	7	277,894	19,926,816	1.23
Total	74	2,104,969	175,053,043	1.19

As already mentioned, irrigation water is cheap in Greece. So is fresh drinking water, which absorbs only 0.4% of the personal disposable income, while in the UK for example it absorbs 1.2%, in Germany 1% and Denmark 0.8% (Ringskong, 2000). Water prices are set independently by each municipality and vary between municipalities. Three pricing examples are presented in the sub-sections that follow: They are Athens, Salonica and Crete.

1.7.1. Athens

The municipal enterprise of Athens is called EYDAP S.A. Table 1.3 shows the pricing scheme followed for each sector.

Table 1.3. Fresh water prices in Athens (EYDAP, 2005).

Tariff categories	Monthly consumption (in m^3)	From 1/1/2002 to 3/31/2002* € /m^3	From 4/1/2002 to 3/31/2003 € /m^3	From 4/1/2003 to today € /m^3
I. Households	0-5	0.3580	0.3755	0.38
Obligatory Consumption of 2 m^3/month	5-20	0.5458	0.5725	0.59
	20-27	1.5788	1.6562	1.70
	27-35	2.2127	2.3211	2.38
	More than 35	2.7644	2.8999	2.97
II. Industrial-professional	Up to 1,000	0.7072	0.7419	0.77
Obligatory Consumption of 100 m^3/month	More than 1,000	0.8305	0.8712	0.90
III. Public-municipalities	Independent of consumption	0.8422	0.8835	0.91
IV. Communal faucets-Piraeus harbor organization	Independent of consumption	0.5898	0.6187	0.64
V. Social charity	Independent of consumption	0.2377	0.2493	0.26
VI. Municipalities network support	Independent of consumption	0.2582	0.3096	0.45
VII. Ships supply	Independent of consumption	2.0660	2.1672	2.24
VIII. Fire prevention	Independent of building volume or category	9.3088	9.7649	10.10
IX. Raw water	Independent of consumption	0.1584	0.1662	0.17

Apparently, the crucial pricing step for the increasing-block tariff in Athens occurs at about 20 m^3 of water per month per household (667 L/d). At this point, access to cheap water stops (i.e. price where households pay less than the price charged to industry) and water becomes significantly more expensive (i.e. prices increase to twice the levels paid by industry). Average per capita consumption by domestic users in Athens is estimated by OECD (1999) to be 140 L/inh·d (litre per habitant per day) so, allowing for scale economics in water use, a household of five should therefore

be able to stay in the cheap water tranche- at least during climatically average periods of the year. Furthermore, we observe that water charge for uses described in categories III-VIII, is independent of consumption but in cases significantly more expensive that household consumption, e.g. water for fire prevention, which by the way could very well be replaced by recycled water, is the most expensive of all.

1.7.2. Salonica

Salonica is the second biggest city in Greece after Athens. Water resources are managed by EYATH S.A. Its billing scheme for households is presented in Table 1.4. Its basic pricing aim is to recover its operational cost, motivate water saving after providing everybody with a basic water quantity enough to live. Thus we see that there is a yearly increase in water prices of all consumption levels and a substantial increasing charge for high consumption levels. Price is almost double between 0-10 m^3 and 31-60 m^3 of water consumption. Moreover, if we compare Tables 1.4 and 1.3, namely the billing pattern between Salonica and Athens, we see that the least water quantity (the one necessary to get by at subsistence level), is cheaper in Salonica than in Athens in 2003. Each city follows its own pricing logic and calculations. Hence no direct trustworthy comparisons can be made.

Table 1.4. Billing scale on a four-month basis for households in Salonica (EYATH, 2005).

Billing scale in € on a four month basis	2002	2003	2004	2005	2006
0-10 m^3	0.24	0.26	0.30	0.33	0.37
11-30 m^3	0.37	0.40	0.43	0.47	0.50
31-60 m^3	0.46	0.48	0.52	0.55	0.59
61-120 m^3	0.90	0.92	0.96	0.99	1.03
121-180 m^3	1.86	1.94	2.01	2.12	2.27
181-over m^3	3.52	3.70	3.77	3.88	4.03

As far as the industrial sector is concerned, EYATH (2005) states that it will not put

an increase in the water billings of this sector for the next five years with the aim to prevent an increase of the product prices they offer. Therefore, we see (Table 1.5) that there is a more tolerant pricing scheme in this sector. The highest price imposed here is between the price charged for 31-60 m^3 and 61-120 m^3 of consumption for households. We cannot directly compare the industry water rates in Salonica and Athens, because they concern different dates.

Table 1.5. Billing scale for industries in 2005 (EYATH, 2005).

Monthly billing scale for industries	Price in €
1-500 m^3	0.44
500- over m^3	0.73

1.7.3.Crete

Papagrigoriou *et al.* (2003) write that the average price of irrigation water varies significantly between the Western and Eastern part of the island. Prices reflect the increased availability of water in the western part of Crete but on the rest we could say they are not formed within a strict economic framework. At the same time, in the eastern part of Crete (where water shortage is more obvious), only in a few municipalities a different water charging system is applied when water consumption goes beyond a certain level for some types of cultivation. Namely, there is a flat rate. This should not be the case for a scarce resource, because it does not show its scarcity and does not lead to its conservation.

As far as drinking water prices are concerned, they vary even more. The average price is doubled in towns by the sea. In big towns of Crete the cost of water ranges from 0.41 €/m^3 (in Agios Nikolaos) to 1.38 €/m^3 in Ierapetra and 1.17 €/m^3 in Chania. The differences in prices reflect (but not adequately) the level of demand, the availability of water (e.g. whether water sources are underground or surface, rainfall

etc), cleanness of water and the depreciation cost of water infrastructure.

1.7.4. Heraklion Crete

Heraklion city is the largest city in Crete with a population of 120,000 people. Table 1.6 presents the quarterly fresh water tariffs that apply for the city. Prices are cheaper in Heraklion as compared to Athens, because demand is larger in Athens, the depreciation of infrastructure is also larger and the competing users are numerous.

Table 1.6. Quarterly Tariffs for households at the municipality of Heraklion (DEYAH, 2004).

Tariff component	Households	Household with discount
Water Charge € /m³		
Consumption 1-21 m³	0.22	0.13
Consumption 22-27 m³	0.22	0.13
Consumption 28-50 m³	0.41	0.25
Consumption 51-100 m³	0.61	0.37
Consumption 101-150 m³	0.97	0.58
Consumption >150 m³	1.14	0.69
Fixed costs (€)		
Minimum charge for <21 m³	-	-
Zero consumption water supply	7.17	4.30
Zero consumption sewerage	5.12	3.07
Maintenance cost per hydrometer	3.60	3.60
Other costs (€)		
Investment surcharge*	80% over the water charge cost	
Sewerage surcharge	100% over the water charge cost	
VAT for water supply	8%	
VAT for sewerage	18%	

*This is charged according to Law 1069/80 (foundation law for DEYA in Greece), applies to the total charge for the water consumed and is common for all water companies in Greece

Prices are charged with i) an additional 80% for construction works or debt service (Law 1069/80), ii) a 100% sewerage tax. This applies to households connected to sewerage, iii) a 3.60 euros meter maintenance tax for each trimester, iv) an 8% value added tax on water value and an 18% value added tax for the sewerage. For 88% of the meters in houses and blocks of flats, prices are low because the municipality

pursues a social policy. For the rest 12% of the meters, which are for other water uses, prices are higher in order to prevent consumption and also fill the gap from the cheap household prices. Also, this pricing scheme protects specific population groups such as people with special needs and people with many children.

1.8. Description of irrigation water market in Crete

This part gives a brief description of irrigation water market in Crete. In particular it deals with water origin and property rights in sub-section 1.7.1, examples of irrigation water prices in Crete in sub-section 1.7.2 and water demand and supply in Crete in sub-section 1.7.3. This part has connections with results derived in chapter 2 of the thesis but is presented in this chapter, because it is introductory material.

1.8.1.Water origin and property rights

Usually, property rights can be classified under the following broad categories: riparian rights link ownership to adjacent land ownership, public allocation based on priorities of use determined by government or prior allocation determined by actual historical use (Johansson *et al.*, 2002). In Crete water rights are all the above.

Water sellers in Crete can be classified under the following broad categories as either i) the municipality which is supposed to work as a typical public utility, or ii) local water unions (they are the Greek TOEBs), or iii) private owners of wells, or iv) a combination of all the three previous categories. Below, we give a short description of the context each case works in.

- CASE 1. The municipality draws water from natural springs or has drilled its own wells and has the advantage of a broad water distribution network. It also sells water at lower prices than private owners of wells. Municipalities behave as

natural monopolies (for the characteristics of natural monopolies, refer to sub-section 1.3.6).

- CASE 2. These farmer unions work in a similar fashion as the one described in case 1. Here, water is rationed. There are 37 such self-administrated unions in Crete.

- CASE 3. The owners of wells usually are able to serve only a small territory, because of property dispersion in Crete, i.e. each farmer owns land, which is dispersed in various places. Therefore, a farmer cannot get water from only one private seller. For each different field he owns, he buys water from a different well, that is located at a convenient distance from his field. It is estimated that 60% of irrigated land in Crete is irrigated by private wells (Region of Crete, 2003b). This was not confirmed in our sample (presented in chapter 2) where the majority appeared as irrigating from public wells. There are 2413 wells in the four municipalities of Crete (Table 1.7). Approximately 50% are located in Heraklion thus indicating the larger demand for water in this prefecture.

Table 1.7. Number of wells in the four Cretan prefectures (Region of Crete, 2003a).

Prefecture	Number of wells
Chania	359
Rethimno	362
Heraklion	1298
Lasithi	394

In villages where only private sellers of irrigation water exist, they seem to constitute an oligopolistic market. The characteristics of an oligopoly are: the existence of a rather small number of sellers who are dependent on each other for their decisions, limited entry, perfect information or perfect knowledge and the fact that products can be homogeneous or differentiated. The product here, irrigation water, is

homogeneous. Service, which encompasses, for example seller's reliability, can be differentiated. One point must be underlined though. In Crete, usually farmers with large properties have a well drilled mainly to cover the irrigation needs of their own fields. If farmers decide[4] that water is too much for them, they have the opportunity to sell it. Thus, water selling is not their principal reason for having a well dug.

From all the literature known oligopoly cases, the Edgeworth case appears to resemble this market more. The most important reason to believe so, is the basic assumption that Edgeworth made on the development of his model, namely the fact that each oligopolist cannot satisfy the needs of all the market. For this reason the productive capability of each firm is limited. Consequently, if each of the two oligopolists (we have assumed the existence of a simple duopoly) tries to lower his price with the aim to obtain more customers, he will soon find out that he cannot cover the needs of all of them. The latter can be met by the second oligopolist at a higher price. So, the first oligopolist will increase price up to the level it was before the decrease, and thus the price will always be fluctuating within a certain range (i.e. no equilibrium is ever reached). These price fluctuations are indeed possible in the type of market we are examining because buyers are incapable of any reaction (at least in the short-run) since irrigation water is a necessity.

In oligopoly, price is set higher than both unit and marginal cost. In whatever equilibrium is reached, the marginal valuation of buyers is greater than the marginal cost of output. If the commodity were priced at either marginal or average cost, buyers would like to purchase more than producers would be willing to sell (Gould and Lazear, 1989).

---

[4] According to the corresponding legislation (articles 9 and 2 of Law Nu: 1739/87) which pertains the issuing of well drilling permits in the prefecture of Heraklion, after farmer's irrigation needs have been met, excessive quantities of water in wells can be asked to be returned to the local government.

- CASE 4. Some farmers may use a combination of municipality, union and private water. The reason for this is that they may think that the municipality or union water they get, may not be enough for the needs of their cultivations. Since union water is rationed, some farmers find access to private water as a complement.

Studying the four characteristics of well-defined property rights as discussed by Hanley *et al*. (2001), the water property rights as presented above are not well defined at all. This is explained as follows:

i) Comprehensiveness. For property rights to be comprehensive, *all resources must either be privately or collectively owned, and all entitlements are defined, well known and enforced.* This does not apply for fresh irrigation water. Some water is collectively owned and some privately. The first is when water belongs to the municipality or a club and the second when it is owned by independent farmers who were the first ones to drill a well in a specific area and get the water. In the second case, nothing can prevent a farmer from drilling a well in his field if he complies with the rule of a certain distance that must be kept from the well nearest to his field. The drilling of new wells and exploitation of water clearly comes on a "first come first serve" basis.

ii) Exclusiveness. For property rights to be exclusive, *all benefits and costs from use of a resource should accrue to the owner, and only to the owner, either directly or by sale to others. This applies to both private and common property resources.* Exclusiveness therefore, applies when the owner is a municipality or club, but it does not apply when the owner is

an independent farmer. In this case, costs from use of water accrue to the whole society since the whole water cycle is perturbated from possible desertification.

iii) Transferability. Property rights should be transferable *from one owner to another through a voluntary exchange. The owner has incentive to conserve the resource beyond the time he or she expects to make use of it.* This characteristic applies for the municipality/club, but less for the independent well owner. However, the second does not have much incentive to save water for the generations to come.

iv) Security. *Property rights to resources should be secure from involuntary seizure or encroachment by other people, firms and the government. Security provides the owner with an incentive to improve and preserve a resource while it is in his or her control rather than exploit the assets.* This again does not apply for well owners. A well owner has to worry about the possibility that a second farmer drills a new well and reduces the level of water. The municipality/club is more protected from that, because it has means of more direct repression of illegal behavior.

Because irrigation water property rights are ill defined, market fails and we do not reach a socially desirable outcome. Hanley *et al*. (2001) claim that *understanding how and why market fails is the first step to correct the problem* and they explain the four types of market failure for environmental resources.

i) Externality. *An externality exists when a person does not bear all the costs or receive all the benefits of his or her action*. This is more apparent with independent well owners, who face a free riding problem. Over-

extraction of water is not traceable and thus everybody has the motive to over extract. Costs of desertification are borne by society as a whole and not by the independent farmer himself (ecosystem externalities).

ii) Public good. *A public good exists when a person cannot be excluded from its provision and when one person's consumption of the good does not reduce its availability to anyone else.* This is exactly what happens with irrigation water with the private well-owner. Municipalities/clubs apply some form of rationing.

iii) Common property. *If one farmers' use reduces the total available to all, everyone has the incentive to capture benefits as quickly as possible before someone else gets them.* This resembles more independent well owners behavior.

iv) Hidden information. *Market failure can occur when people cannot observe what other people are doing.* This sometimes happens again with independent well owners. Illegal extraction is not always observed and repressed.

Irrigation fresh water origin is described in Table 1.8 based on the findings we had from our sample in chapter 2. It is obvious that water is traded under different market schemes in the various Cretan villages.

Table 1.8. Irrigation sources in our farmer sample.

Irrigation source	Percentage %
Public well (case 1 and 2)	84.00
Private well-other farmer (case3)	11.80
Privately own well (by the farmer himself)	14.10
Potable water	0.60
Other (e.g. river etc)	7.78

Note: Percentages do not sum to 100% because some farmers irrigate from two sources, and thus they appear in two categories.

According to chapter 2 sample findings, the majority of farmers (84%) irrigate from public wells (they are under case 1 and 2). These two cases have been summed because not all respondents in the questionnaire had distinguished between them. We should also note that some of the farmers, who irrigate from this source, could also irrigate from other sources. 13.5% of farmers were reported to be irrigating from at least two sources.

1.8.2. Examples of irrigation water prices in Crete

East Crete has higher water prices than West Crete. This difference amounts to 2.9 cents/m^3 (Region of Crete, 2003a). The increasing block tariff is applied only in some East Crete water unions. In West Crete it is not and consequently over consumption takes place. Noteworthy is the fact that *water prices reflect only the operational cost of water companies. The cost of infrastructure depreciation is not included in prices and thus it is shifted to all tax-payers* (Region of Crete, 2003b). It is naturally deduced that if the cost of infrastructure depreciation is not included in water prices, then there is no chance for the environmental cost of water use to be currently included.

Table 9 displays the pricing structures of two villages, Avdou and Gouves, in the prefecture of Heraklion, situated only a few km away from Heraklion city, in the same river basin. It can be used for comparison with our corresponding findings in chapter 2. These tables were not found published anywhere. The thesis writer got them in person from a couple of village authorities this was possible.

Table 1.9. Water pricing in Avdou and Gouves villages for year 2002.

	Consumption m³		Price €/m³
Avdou village			
Households	1	15	0.18
	16	40	0.35
	41	-	1.75
Commercial			0.34
Livestock	1	3	0.18
	4	-	1.75
Connection charge			7.20
Re-connection charge			70.53
Gouves village			
Households	1	100	0.23
	101	150	0.35
	151	250	0.58
	250	-	0.88
Commercial	1	300	0.44
	301	1500	0.58
	1500	-	0.88
Irrigation	1	1500	0.17
	1501	2000	0.29
	2001	-	0.58

As we see, water is cheaper in Gouves than Avdou. This is due to Gouves being closer to sea, in a flatter area, with a larger population. Water infrastructure cost is cheaper and shared among a larger number of people. As far as irrigation water is concerned, it is cheaper than domestic use water. Gouves is the only village from which we have managed to get official charging rates for irrigation water. In Avdou village only the domestic pricing system was available. We need to note that the mean irrigation water price we found from our survey in chapter 2, is close to the one charged by Gouves village, so this gives some evidence of reliability for the water price data we collected.

1.8.3. Water demand and supply in Crete

In 2003, the Region of Crete (2003b) conducted a research project on the potential of Cretan water supply and its maximum outcome in agricultural production value

terms. The project was implemented on RIBASIM[5] software, which simulates river basin behavior under various hydrological conditions. Total water demand and supply were estimated under three different scenarios. Current water demand is 535.7 million m³ with a deficit of 163.7 million m³. This shows that currently we are short of water by 30%.

Table 1.10. Water demand and supply scenarios in Crete (Region of Crete, 2003b).

	Scenario 1	Scenario 2	Scenario 3
Demand	Normal	Normal	Future (increased)
Hydrological conditions	Normal	Normal	Normal
Technical infrastructure	Existing	Future (increased)	Future (increased)
Total demand	535.7 m³	535.7 m³	775.8 m³
Irrigation demand	458.4 m³	458.4 m³	670.8 m³
Domestic and other demand	77.3 m³	77.3 m³	105 m³
Total supply	371.75 m³	421.4 m³	498.74 m³
Irrigation supply	302 m³	344.1 m³	398.3 m³
Domestic supply	69.75 m³	77.3 m³	100.44 m³
Total water deficit	163.95 m³	144.3 m³	277.06 m³
Economic appraisal / Value of agricultural production from irrigated areas	148,891.3m €	166,318.4 m €	185,038.9 m €

Comparing scenarios 1 and 2, which are the most possible to occur, we see that ceteris paribus if infrastructure increases, total water deficit will be decreased by almost 12%. This places emphasis on the immediate beneficial effect the infrastructure increase will bring about. The gap could possibly be seen to close by a further 5% with the introduction of recycled water in irrigation (section 3.3 in chapter 1).

1.9. Full cost recovery is needed for the water market to balance

It is understood that the concepts of cost, value and price are three different things.

[5] RIBASIM stands for River Basin Simulation Model.

Cost includes i) operation and maintenance costs, ii) opportunity costs as well as iii) costs of economic and environmental externalities. Value is about i) benefits to users, ii) indirect benefits and intrinsic values. Price is the amount set by the market, the political and social system to ensure cost recovery, equity and sustainability. Price is the vehicle through which cost, value or both can be reflected. Of course what seems a priority is the coverage of cost. Cost is usually undisputable and objective (externalities excluded) while value could be more subjective.

From what we have discussed in the previous paragraphs, it is easily understood that current water prices cover neither water cost nor its value. Therefore they are far from leading to full cost recovery, which World Water Commission (2000) has characterized as the single most immediate and important measure that should be adopted for Water services. Water full cost recovery happens when pricing fulfills the following three objectives (Ringskog, 2000): efficiency (signal future costs), cost recovery (revenue should pay for operations and maintenance and debt service) and equitability (make tariff affordable). This is the situation when the price incorporates both the aforementioned cost and value items or more specifically when price encompasses operation and maintenance costs, capital costs, opportunity costs, resource costs, social costs, environmental damage costs and long run marginal costs. As far as the latter is concerned, Pearce and Markandya (1999) claim *that the water price should relate to the long run marginal cost of supply*[6] *but the allocation of water between users should also take account of their varying willingness to pay (WTP).* A particular institutional arrangement involving tradable water rights should be established. The concept of tradable water rights relates to the WTP principle. The

[6] Supply is represented as a long run marginal cost curve and demand is shown as a marginal benefit curve. When water price is below long-run marginal costs, the present consumers are receiving a subsidy from the consumers of future generations. When consumers pay less than the cost of service, they are subsidized. When consumers pay more than their own cost of service through the structure, they provide cross-subsidies that are seldom transparent (Ringskog, 2000).

EU framework directive promotes the use of full cost water pricing in order to enhance the sustainability of water resources. There is a move in the approach of water pricing from general subsidies to full cost recovery (EU, 2000).

Porta (1999) eloquently describes what happens if the water cycle is not charged at its real cost: *If this situation goes unchecked and such works are not carried out, then the tariff will have to be raised, at times by a significant amount, which will be difficult to justify and will lie well above the rate of inflation. As the clients are not used to this kind of price increases, they show their disapproval and finally the service continues to be invoiced at a price lower than its true cost.* Porta places emphasis on the timing of this change. The later it takes place, the more difficult to be applauded by people.

Bonnis and Steenblick (1998) discuss some reasons as to why full-cost pricing is uncommon with respect to irrigation water: One of them relates to *the difficulty of attributing costs of multiple-purpose infrastructure to different uses, especially when one of the purposes is the generation of hydroelectricity. In some countries water is treated as a public good and therefore so is the infrastructure built to collect and distribute it.*

Socratus (2000) estimates that full costing of water to agriculture will not be easy to apply at least in this decade. This obviously has to do with the lack of political will to impose suddenly an absolutely different model of thought in water pricing. It will have to break a long-lived establishment. Also, according to OECD estimates (1999), the application of efficiency based pricing policies in the agricultural sector are only practical if the country in question has progressed beyond the stage of expansion of irrigation.

The latter does not apply for Greece, not only because it is not a pioneer

country from a technological point of view, but also because its agriculture, due to the country's geographical position and climatological conditions, cannot exist without ample irrigation water. In Greece and Crete, irrigation water pricing is mainly performed through average cost pricing which means than prices are so set as revenues to cover costs. In Crete, this happens when the water seller is the municipality. When it is not (see chapter 2, section 3.3), water pricing is performed in an arbitrary process which of course varies from seller to seller and has not been officially recorded anywhere.

2. Wastewater treatment and recycling; a technical primer

This part aims at introducing the thesis reader to the basics of water treatment and recycling. It can be regarded as information on the production process of the product under study.

2.1. Introduction

The rapid technological developments offer opportunities for major improvements in life quality. At the same time, the overexploitation of human resources and the increased pollution threaten the environment and put natural resources at risk. Figure 1.3 shows an example of water overexploitation; as a result of this, the depth at which water is drilled becomes higher as years go by. Life and its quality depend on our ability to assimilate the huge progress and face the future with a new perspective: the combination of useful economic activity with the respect and protection for the environment.

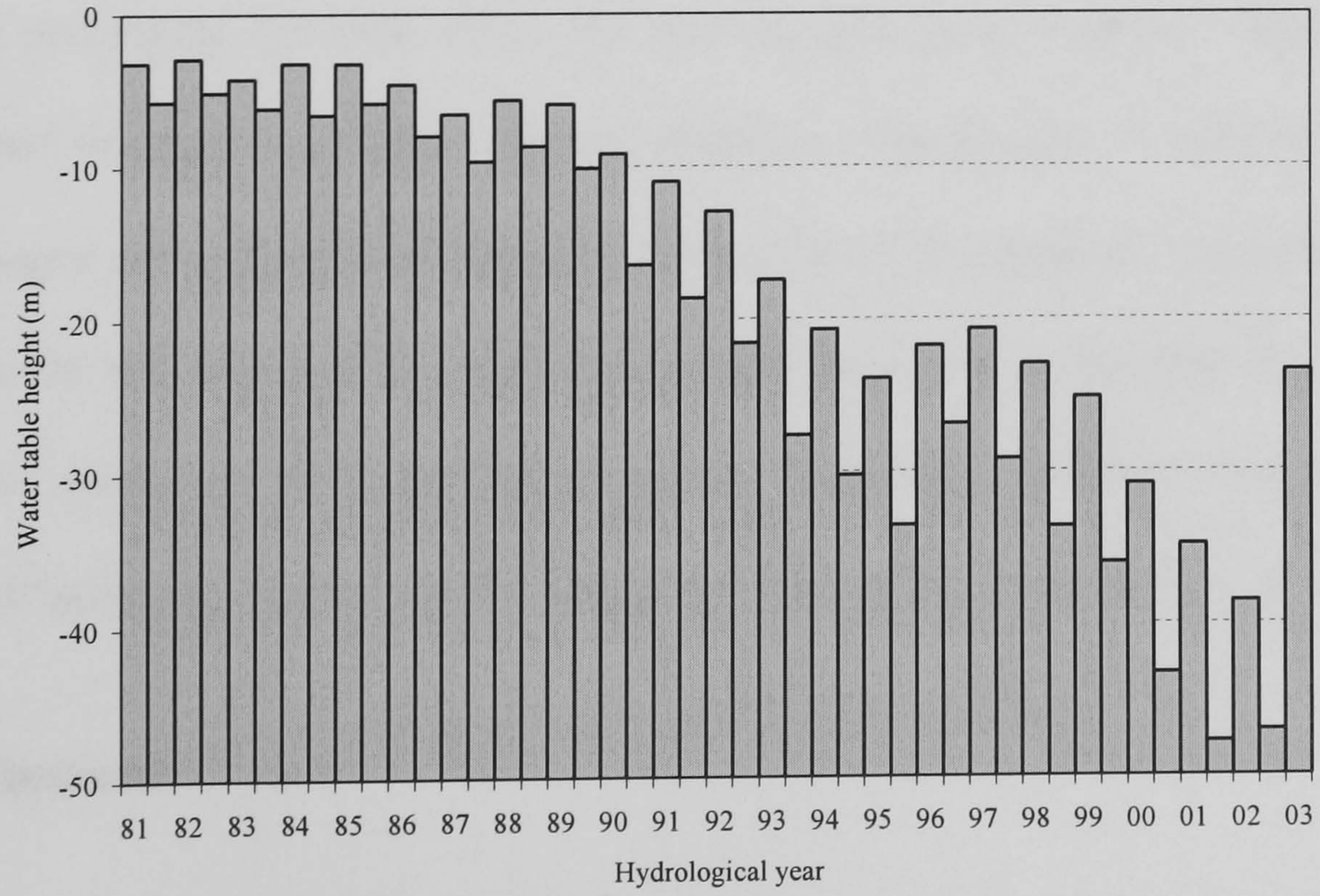


Figure 1.3. Variation of the water table of a Cretan aquifer, as reported from a representative well (Region of Crete, 2003a)

Water resources management is a very important part of environmental problems solutions, since water constitutes a prerequisite for the development of every activity type and is one of the most important factors necessary for the survival of the human being and all living organisms. New activities development, the need for the present ones to increase their productivity, and the improvement of life quality in our country, demand an increase in fresh water availability and the safeguarding of its qualitative characteristics.

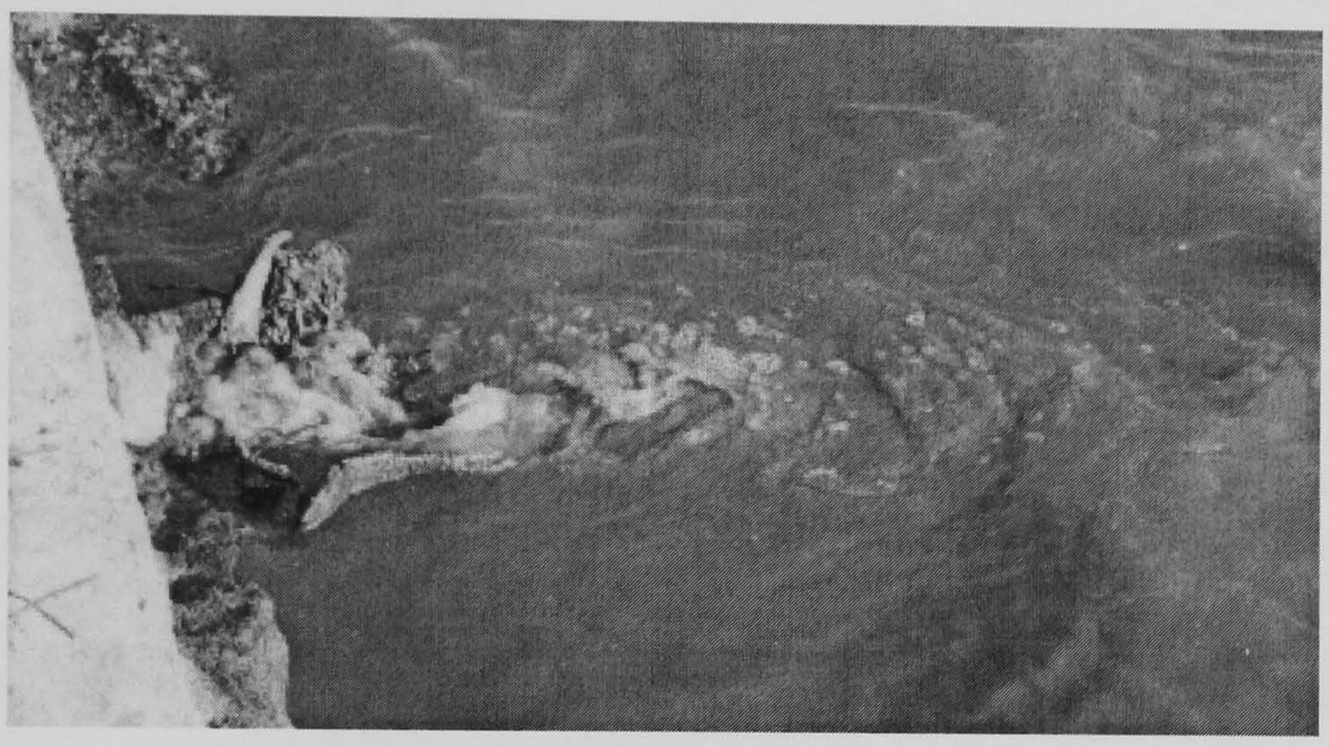


Photo 1.1. Untreated wastewater as was discharged into a Greek sea

The pollutants existent in wastewater whose removal we are after through the different processing systems, affect the environment (seas, beaches, rivers, lakes, ground and underground water). Special attention must be paid to toxic substances and pathogen microorganisms (bacteria, viruses etc). The treatment requirements are related to the sensitivity of the recipient. Typical municipal wastewater is composed of 99.9% water and 0.1% pollutants, mainly suspended, colloidal and dissolved solids, and microorganisms, some of which are pathogenic (Angelakis *et al.*, 2001).

2.2. Definitions

- **Biochemical Oxygen Demand (BOD_5).** Is defined as the mass of dissolved oxygen required by a specific volume of liquid for the process of biochemical

oxidation under prescribed conditions over 5 days at 20°C, in the dark. The result is expressed as milligrams of oxygen per litre of sample (mg/L) (Methods for the Examination of Waters and Associated Materials, 1989).

- **Population Equivalent (p.e).** Is a unit of measurement of biodegradable organic pollution representing the average load of such pollution produced per person per day. It is specified in the 271/91/EC Directive as 60g BOD_5 per day (EU, 1991).

- **Water recycling.** It is every form of water reuse. It addresses mainly to water of low quality, after it receives the appropriate treatment.

- **Receiver.** It is the place where treated wastewater is disposed. This can be the sea, a lake, a river, a stream or the soil.

- **Septic wastewater.** It comes from the evacuation of septic tanks. Septic wastewater needs special treatment due to their increased pollution load compared to the sewerage municipal wastewater. Their existence is sometimes unavoidable because it is not possible to connect very remote houses to the municipal sewerage network.

- **Effluent.** It is the treated wastewater after exiting the wastewater treatment unit or plant.

- **Sludge.** It is the residual solid, which looks like sludge and is removed after sedimentation.

- **Wastewater treatment plant**. It is the facility where wastewater is cleaned from various pollutants to such a degree that there are no harmful effects from its disposal into the environment.

- **Wastewater.** It is produced by everyday domestic, agricultural, industrial and other activities, which require water as an input.

2.3. Wastewater treatment

This section provides a simple technical description of wastewater treatment.

2.3.1. Centralized wastewater treatment

For the wastewater treatment of urban areas, we need to collect wastewater through the wastewater sewerage network and then lead this to a treatment plant. Various system types can be used for this purpose. Usually when we refer to a wastewater treatment plant, we mean a system with a series of tanks and electromechanical equipment. These systems are the most widespread in Greece and abroad and are called "activated sludge systems". One of its versions is widely used in Greece and it is called "extended aeration system" (Tsagarakis *et al.*, 2001b). There are also systems, recently established, which use natural processes such as the free water surface constructed wetlands. Both of these systems are explained below.

Extended aeration systems. A typical flowchart of the process is shown in Figure 1.4. During screening, large particles (>2 cm diameter) that are carried with wastewater are removed. At grit removal, mainly non-organic particles (>0.02 cm diameter) and the floating ones (fat and oils) are removed. At aeration tanks the biological degradation of organic matter takes place. Retention time into the aeration tanks for this system is 12-24 h (Tsagarakis, 2001).

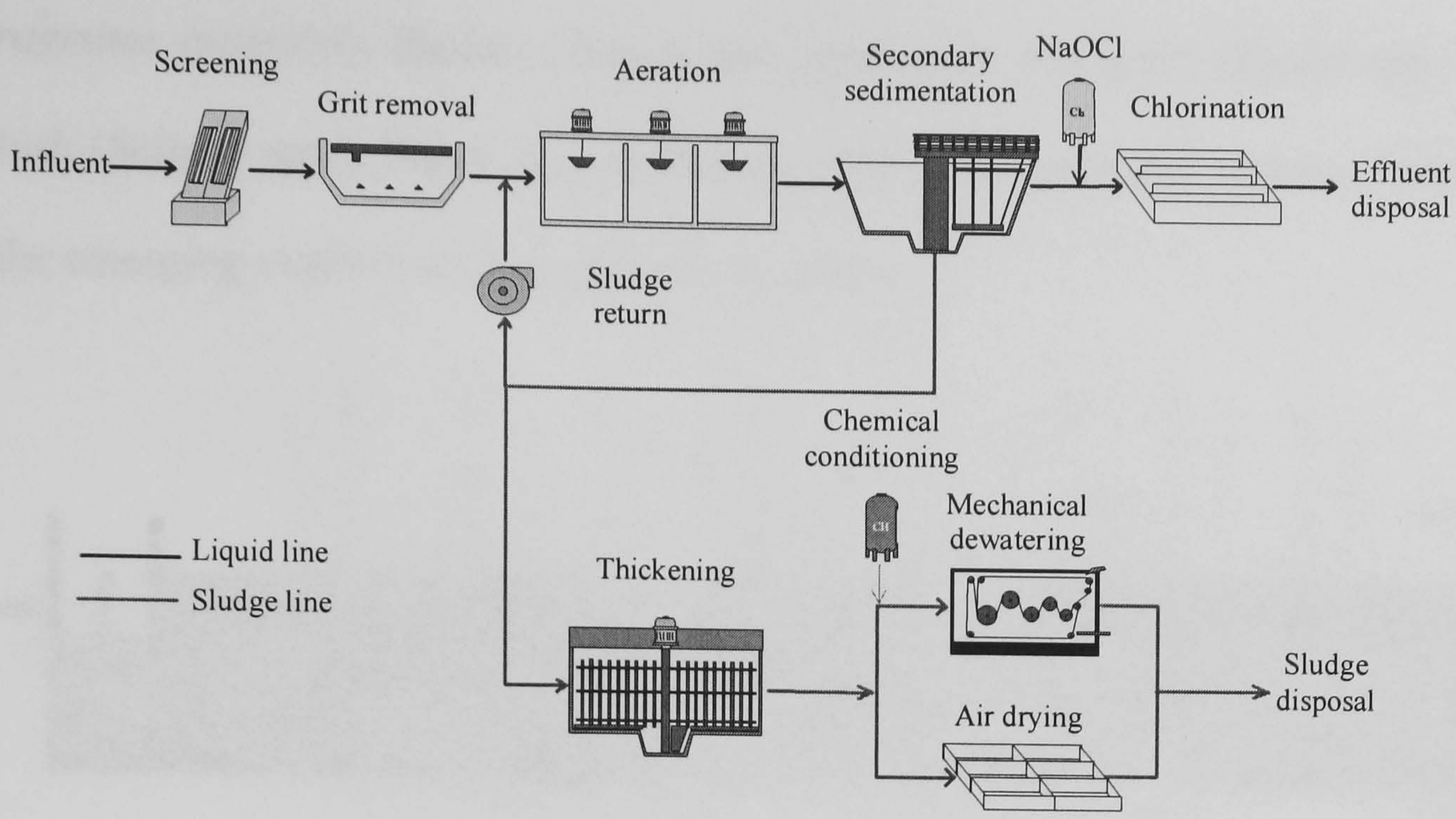


Figure 1.4. Typical extended aeration flow chart (Angelakis *et al.*, 2000).

At secondary sedimentation, water is separated from sludge while during chlorination, effluent is removed from pathogenic organisms before disposal at the receiver. Sludge is thickened and dried in a mechanical way or by air-drying. A small-extended aeration plant is seen in Photo 1.2.

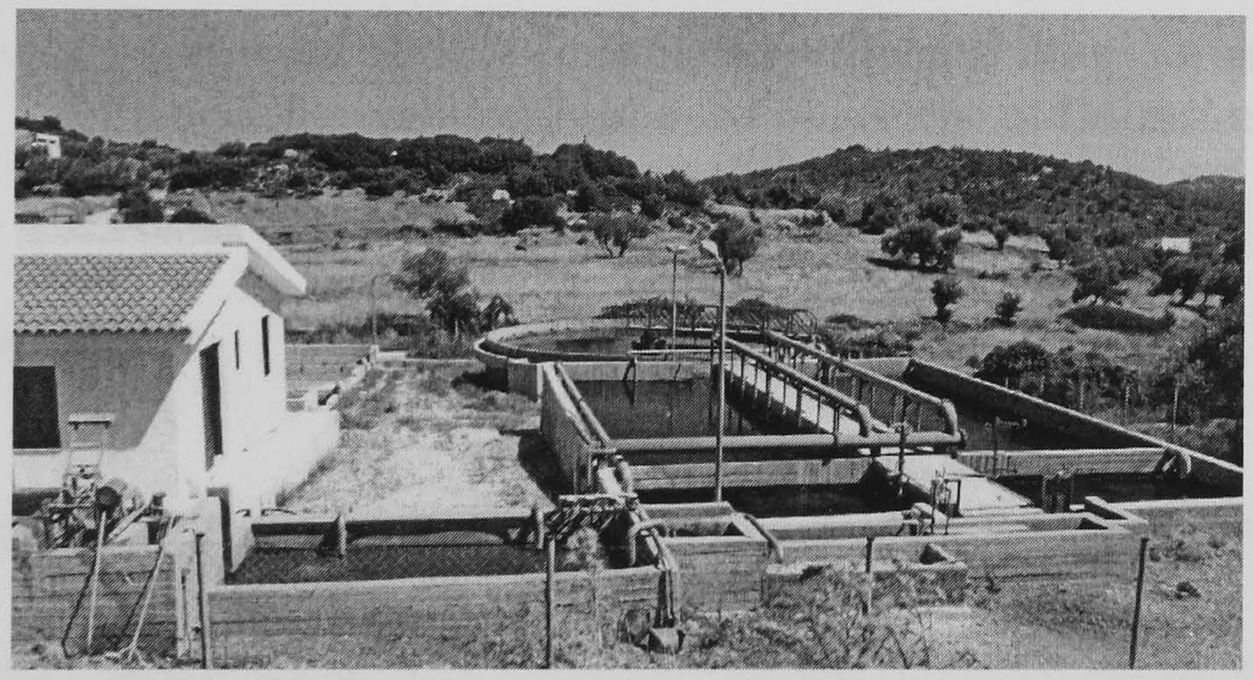


Photo 1.2. Extended aeration system at Embonas, Rhodes island, Greece.

Free water surface constructed wetlands. They consist of basins with lined bottoms, planted with reeds and a small water depth (0.1-0.5 m). Such systems are fed with pretreated wastewater and further treatment takes place while the water is flowing with a small speed through the roots of the existing vegetation (see Figure 1.5 and Photo 1.3). In the beds are planted and developed plants such as: Reeds

(*Phragmites australis*), Rushes (*Juncus* spp.) and types of Cattail (*Typha* spp.) and Bulrush (*Scirpus* spp.). Ponds may contain sand or other terrestrial means of support for the emerging vegetation (Angelakis *et al.*, 2004).

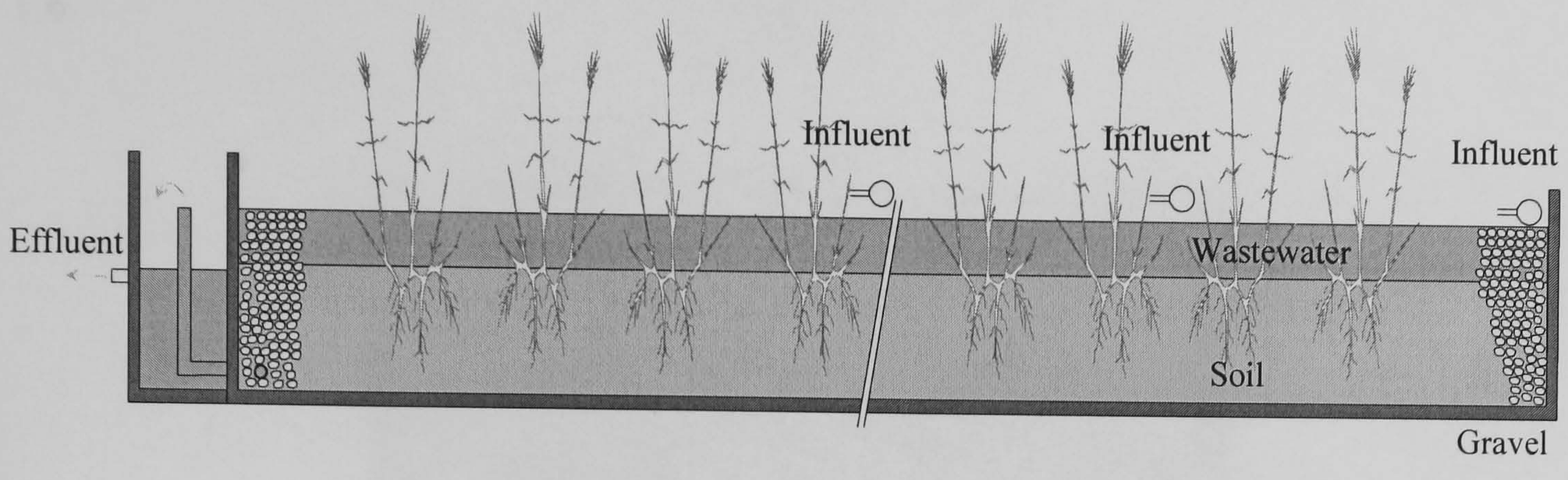


Figure 1.5. Schematic representation of a free water surface constructed wetland (Kapellakis *et al.*, 2004).

Photo 1.3. View of a free water surface constructed wetland at the experimental field of the National Agricultural Research Foundation of Heraklion.

2.3.2.On site treatment

Decentralized treatment is defined as the one where no wastewater network is necessary, but only onsite units such as septic tanks. Filtered septic tank effluent can be used directly to controlled applications on forested land or landscape irrigation, as long as septic tanks have been designed correctly and work properly (Tzanakakis *et al.*, 2003) or as a pretreatment unit for constructed wetlands (Dialynas *et al.*, 2002) or other units (Leverenz *et al.*, 2002). Additional cleaning is achieved through the installation of sand and other filters which aim at effluent recycling. Septic tanks are used mainly for houses or office blocks in the first or final treatment phase. They

typically consist of two compartments for the reduction of solids suspending. The volume of the first is two to three times larger than the second US EPA (1980). Sludge and scum are collected mainly on the first compartment, as is seen in Figure 1.6.

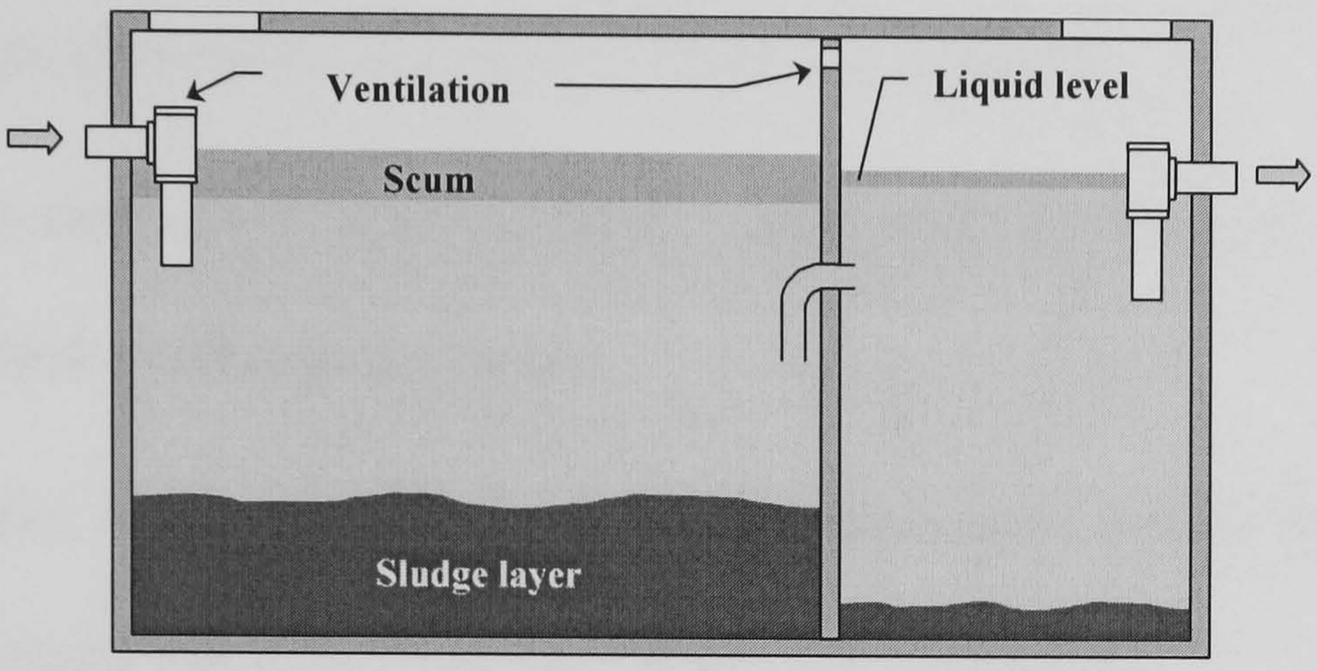


Figure 1.6. Septic tank definition cut (adopted from US EPA, 1980)

2.3.3. Wastewater treatment in Greece

In 1993, there were 170 municipal wastewater treatment plants, in the end of 1997 there were 241, while today there are 350 plants, capable of servicing 67% of the permanent country population. It is also expected that 1500 plants will be constructed for small villages in the near future (Tsagarakis, 2005).

2.4. Wastewater re-use

Wastewater reuse for irrigation has been well established and practiced for years in many countries of the world. Wastewater processing and reuse is offered as a means of water production, appropriate for various useful purposes such as (WHO, 1989; QG, 2003; US EPA, 2004):

- Irrigation of agricultural cultivations and public places or recreation places e.g. parks, schoolyards etc.

- Industrial use e.g. freezing.
- Enriching underground water sources.
- Other uses such as lake creation and fire extinguishing.

Through correct treatment and reuse of wastewater, we achieve:

- Reduction or elimination of polluters from waste effluent.
- Saving on alternative water sources, which can be used in useful places especially in dry or hemi-dry places.
- Cost benefits reaped from saving on fertilizer expenditure since processed effluent contains nutrients for plant and trees development.

The importance of wastewater treatment and reuse, as part of water resources management, has been recognized. This is why it has various applications that increases all over the world. The existing techniques have reached a very advanced level and can give us an effluent quality appropriate for every cultivation type.

However, irrigation with wastewater dates back in the distant past. The first irrigation practice with untreated wastewater took place in Greece, in the Minoan civilization (FAO, 1991; Angelakis and Spyridakis, 1996). This practice is also met in China for centuries, in Germany in the 19th century and farms in England (FAO, 1991; Metcalf and Eddy, 1991). In USA this practice was abandoned at the beginning of the 20th century. From 1930, some rudimentary treatment was necessary before any irrigation took place (Ali, 1987). Wastewater treatment in the sense we know it today, started from 1960s (Asano and Levine, 1995).

2.4.1. Risks from recycled water usage

The treatment level that a properly working secondary wastewater treatment plant

offers is 95% concerning the organic load. If however, the plant has not been designed for the full removal of pathogens, it is possible that it contains significant concentrations of organisms, which are harmful when somebody comes in touch with the water or drinks it. In that case, this water is not appropriate for vegetables irrigation when the edible parts can come in touch with it and consumed raw by human beings. It is appropriate however, for cultivations (such as olive trees and vineyards) and places of greenery. Conclusively, we must be very careful with the usage of recycled water. Panoras and Ilias (1991) state that although people feel uncomfortable with the idea of irrigation with wastewater, it is widely known that water from rivers and other water sources, which is normally used for irrigation, contain significant quantities of wastewater. They also state that Rhine and Thames contain wastewater quantities that amount up to 14-40%.

2.4.2. Irrigation of agricultural land

Treated wastewater is rich in nutrients (nitrogen, phosphorous and potassium) and consequently it contributes to the reduction of fertilizers, if crops are irrigated with treated wastewater. In Jordan, 95% of the total volume of treated wastewater is utilized for irrigation and constituted in 1999 already more than 20% of irrigation water resources (Doppler, *et al.*, 2002). In many countries such as Israel, Australia, Cyprus, USA and South Africa, technology and legislation have allowed the full exploitation of treated wastewater. In California, U.S.A., plenty of plant types are irrigated with recycled water; citrus trees, cauliflowers, barley, apple-trees, broccoli, celery, asparagus, fresh beans, plum-trees, maize, pumpkin plants, lettuce, pepper, sugar trees, pistachio trees, cotton, trefoil, Christmas trees etc. (Panoras and Ilias,

1999). In Israel, during hydrological years 1999-2000[7], 39.6% of irrigation water was originating from wastewater treatment plant effluents (Shelef and Halperin, 2002). Photos 1.4 and 1.5 show a vineyard and an almond tree plantation irrigated with recycled water.

Photo 1.4. Vineyard irrigated with treated wastewater in Israel (Arad region).

Photo 1.5. Almond trees irrigated with treated wastewater in Israel (Arad region).

Although reuse of treated wastewater was not practiced some years ago, lately there has been an increasing interest for this (Tsagarakis *et al.*, 2001a; Tsagarakis *et al.*, 2004; Borboudaki *et al.*, 2005). Experimental results have shown the suitability of treated effluent for particular uses in Greece. One large project was funded for the reuse of the effluents from the wastewater treatment plant of Thessaloniki (Photos 1.6 and 1.7).

[7] Were reported as draught years.

Photo 1.6. Experimental Gerbera flowers in the green house of NAGREF at Thessaloniki, irrigated with the treated wastewater from the wastewater treatment plant at Sindos.

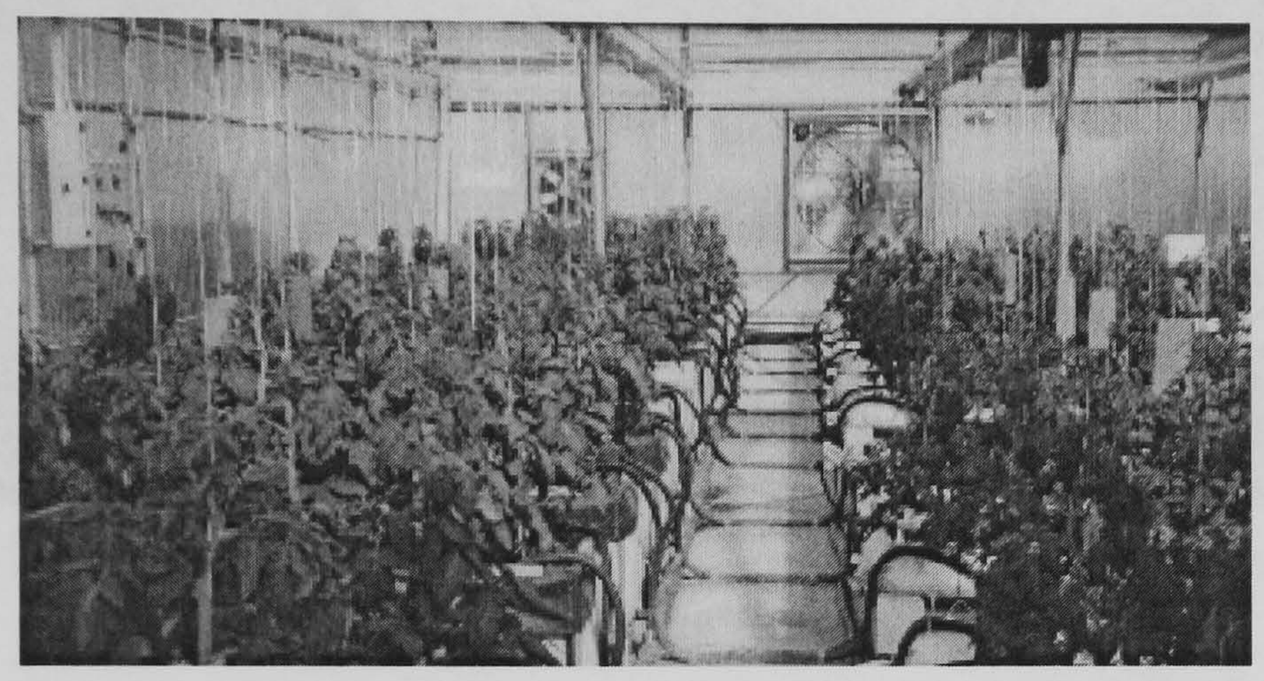


Photo 1.7. Experimental tomato plants in the green house of NAGREF at Thessaloniki, irrigated with the treated wastewater from the wastewater treatment plant at Sindos.

It was estimated that the further treatment of wastewater from secondary treatment units, which have been built in areas with water lack problems, will save a water quantity equivalent to 3.2% of the irrigation water consumed in Greece (Tsagarakis *et al.*, 2001a).

2.4.3. Irrigation forested land and fire protection

Forested land can be irrigated with a low quality of effluent. High effluent concentration in nutrients helps to a quick growing of trees. A forested land irrigation project has been completed in Chalkida. It is about 30 ha with the use of 14.000 m^3/day effluent of the local wastewater treatment plant for irrigation of Eucalyptus and other trees (Photos 1.8 and 1.9).

Photo 1.8. The islet where the wastewater treatment plant of Chalkis is located; this view was seen before using the treated effluent for irrigation.

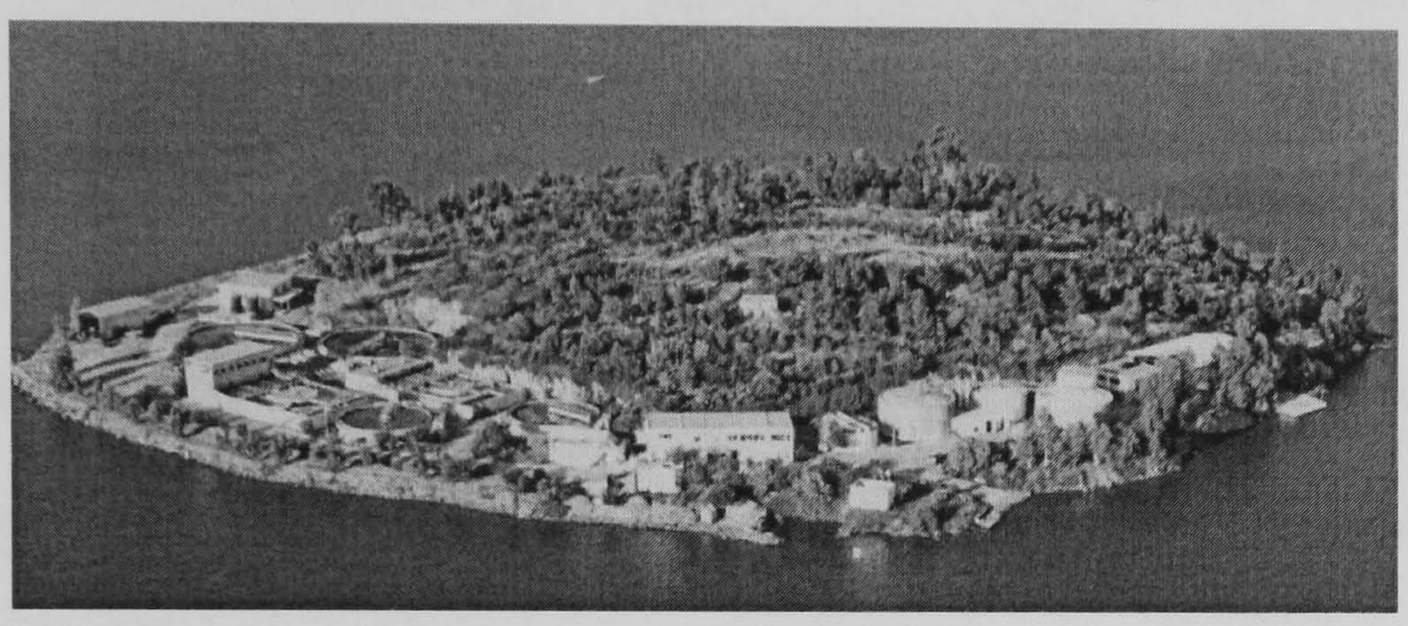


Photo 1.9. The islet of the previous photo after using the treated effluent for the irrigation of forested land.

The effluent of Hersonissos wastewater treatment plant is used, among others, for the irrigation of eucalyptus in the new national roadbeds of Agios Nikolaos (Photo 1.10).

Photo 1.10. Eucalyptus trees irrigated with treated effluent form the wastewater treatment plant of Hersonissos.

Green protection zones can be created with the usage of treated effluent for irrigation. The width of the zones will be determined by the trees height and the speed of the dominant winds. Vegetation that will be irrigated with treated wastewater will constitute a protection shield for the surroundings against fire expansion from wind, as it is depicted in Figure 1.7.

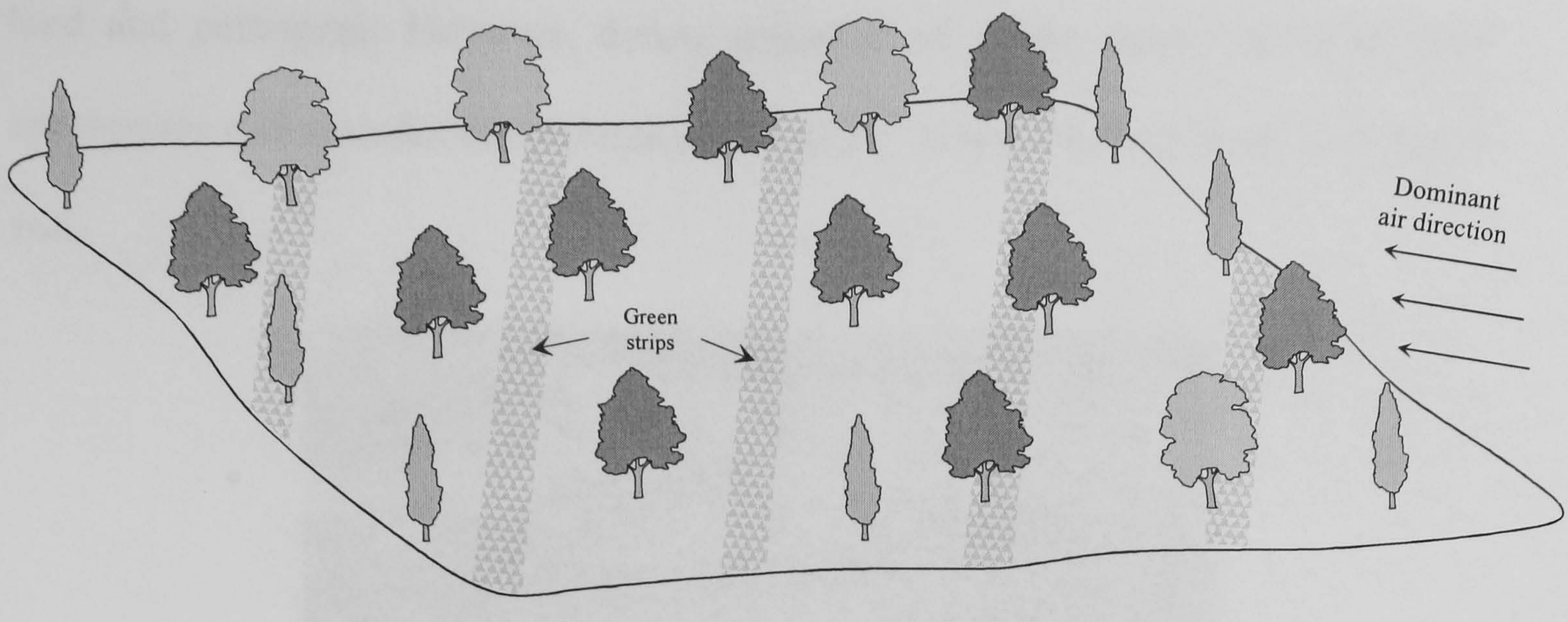


Figure 1.7. Irrigation of green stripes for forest protection in the event of fire (Tsagarakis and Angelakis, 2004).

Integrated management of treated effluent against fire protection presupposes the concentration of significant effluent quantities in a tank or a lined lagoon in an area of higher altitude than the site to be irrigated. Under certain conditions, rainwater can be collected and fill the same lagoon. At Hersonissos municipality part of the treated effluent is saved for fire protection (Borboudaki *et al.*, 2005).

Photo 1.11. Fire hydrant connected to the recycled water tank of the Hersonissos municipality.

2.4.4. Irrigation of public spaces

Treated wastewater may be used for the irrigation of public areas like parks, yards. grass, etc (Photo 1.12). When treated wastewater is applied onto the ground soil, an additional treatment takes place. Therefore we achieve a further reduction of organic

load and pathogens. However, during irrigation of public areas we should take appropriate measures for the protection of visitors' health, because there is the health risk.

Photo 1.12. Landscape irrigation with treated effluent in a wastewater treatment in Israel.

The irrigation of public places must take place at night or it should be in areas of restricted access as is showed in Figure 1.8. This has started becoming a common practice in hotel gardens and yards. These hotels have advanced wastewater treatment facilities (Photo 1.13). Appropriate signs should always be posted.

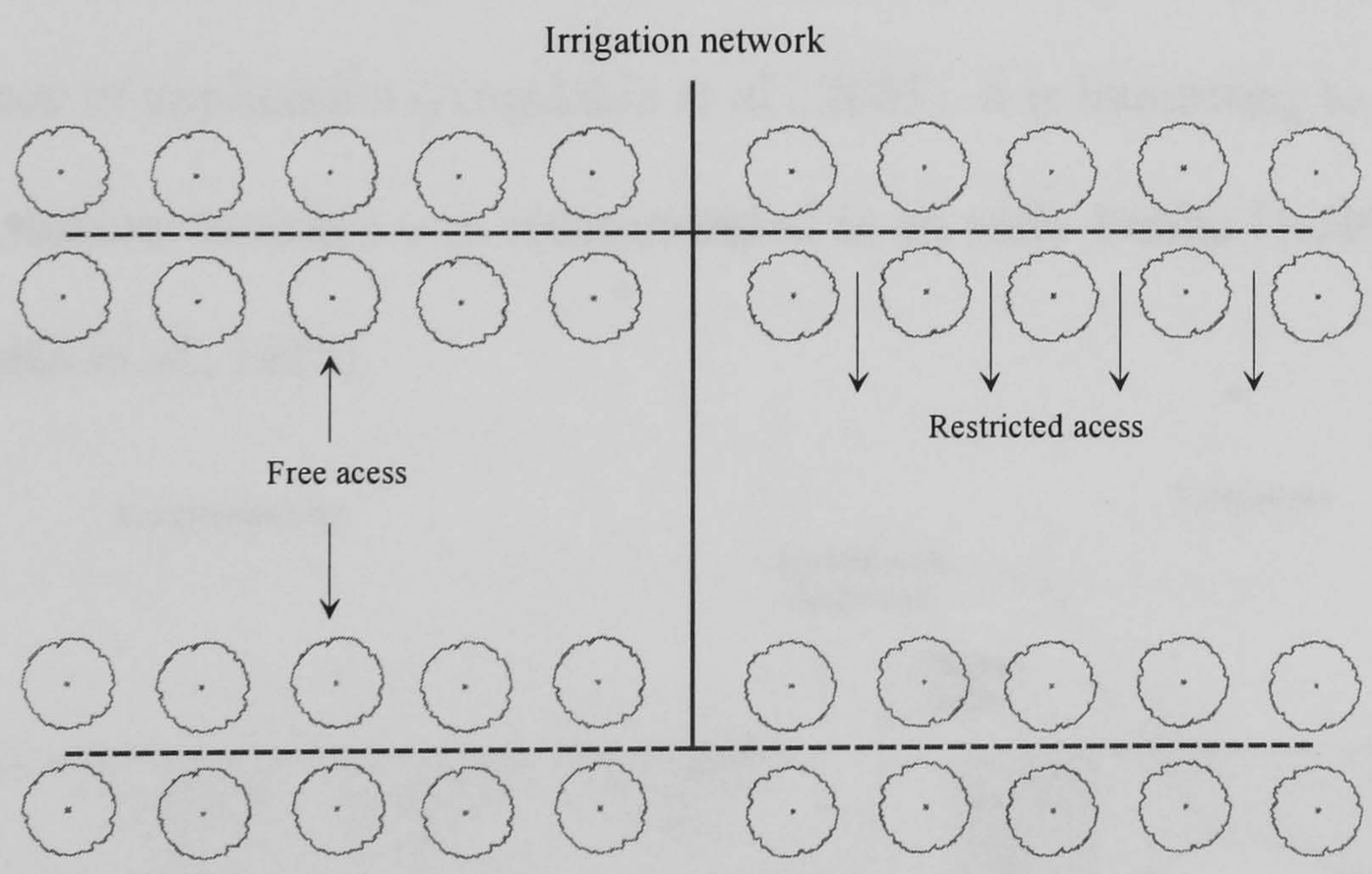


Figure 1.8. Irrigation of public places with surface application; restricted and unrestricted to public access areas (Tsagarakis and Angelakis, 2004).

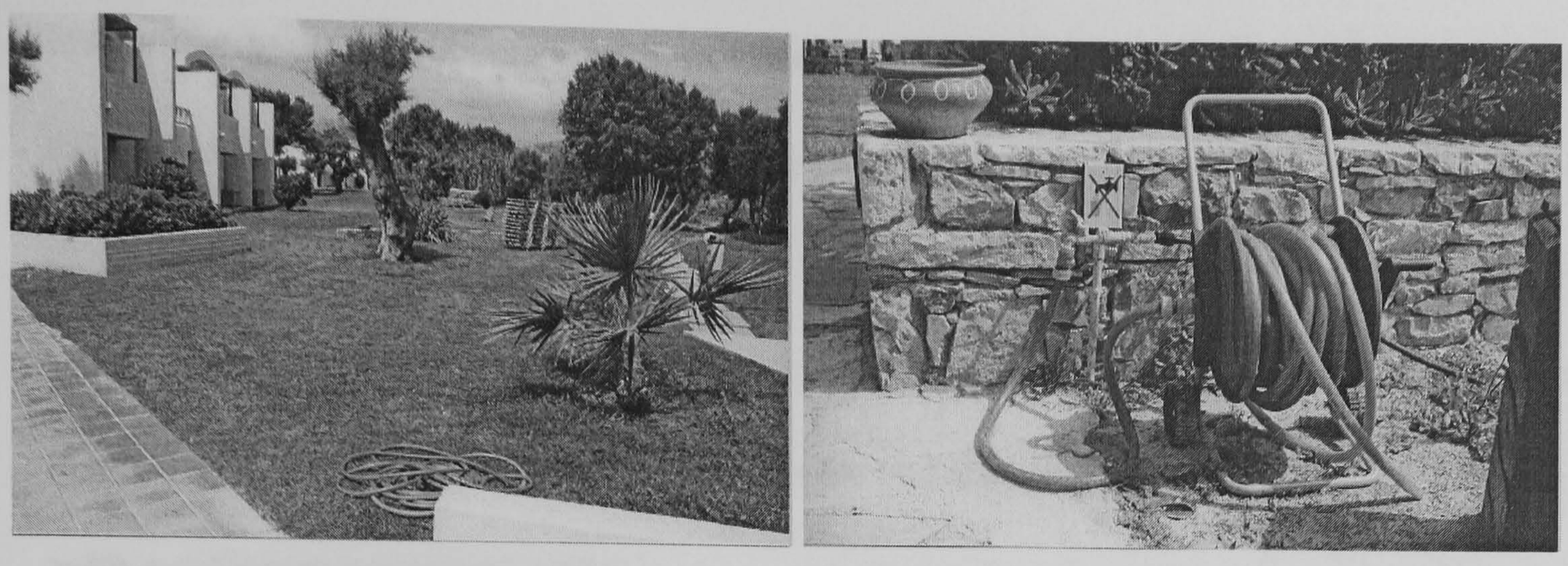


Photo 1.13. Free access area at a Cretan hotel irrigated with recycled water from the wastewater treatment plant of the hotel (left). Sign showing this is not potable water (right).

Effluent application can also be achieved through a system of small depth subsurface application as is depicted in Figure 1.9. Such a system can be created by digging a ditch of 25-30 cm depth. Next is placed a one inch diameter pipe with holes at its ceiling. For odour isolation or reduction, it is covered with a semi-cylinder pipe. Then, the natural soil is put back and vegetation with increased irrigation needs are planted. With this array, there is no risk of disease passing across the visitors who visit the places of application (Angelakis *et al.*, 2001). It is interesting to note that the use of such shallow trenches was recommended in an early Public Health Bulletin in 1915 (Lumsden *et al.*, 1915).

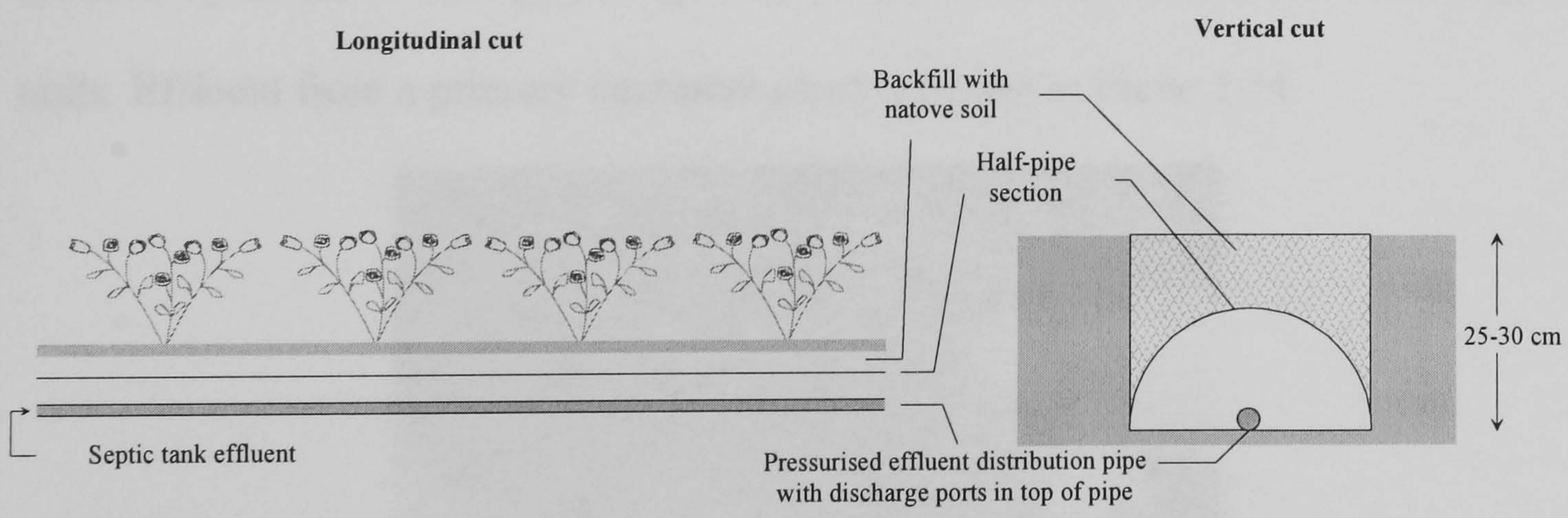


Figure 1.9. Cross sections of a typical shallow unfilled leak field (redesigned from (Lumsden *et al.*, 1915).

2.5. Irrigation water qualities

Depending on recycled water quality and origin, the following five water quality

levels has been proposed. A table of these qualities was presented to all participants (in the surveys described in the following chapters) before completing the two survey questionnaires (see the appendices in chapters 3 and 4). This was shown to respondents in order to make them understand that recycled water has various cleanness levels, each one being appropriate to be applied to a different activity and with a different treatment cost.

2.5.1. Water quality stars: 0

Definition: It is untreated wastewater i.e. wastewater in the form it is found in the wastewater network.

Appropriate uses: None.

2.5.2. Water quality stars: *

Definition: It is wastewater that has received primary treatment, i.e. wastewater that has been subject to a first cleaning stage (technically referred to as primary treatment). The pollution level (organic load and pathogens) has been normally reduced by 30-40%. This percentage may be higher for advanced and well-designed units. Effluent from a primary treatment plant is shown in Photo 1.14.

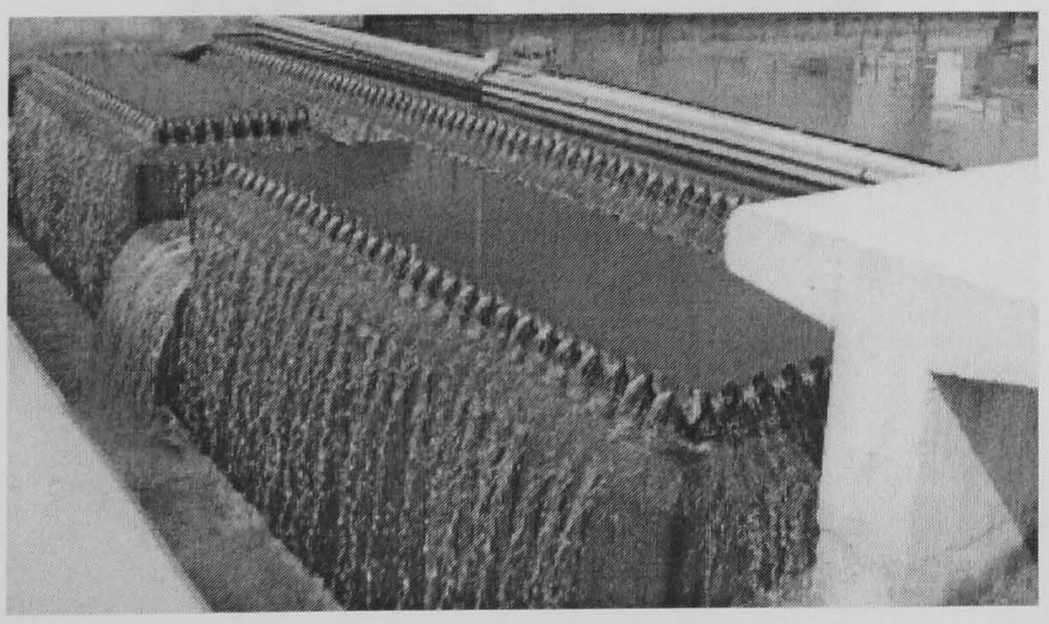


Photo 1.14. Primary treated effluent at the wastewater treatment plant of Volos, Greece

Appropriate uses: Appropriate for the irrigation of forestland in a controlled way (on land with restricted access) by surface or sub-surface application as shown in Figure 1.10.

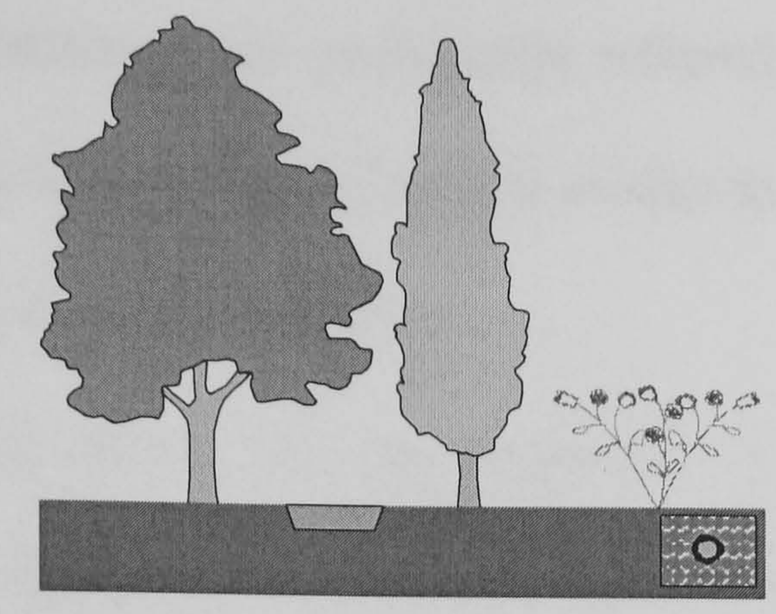


Figure 1.10. Suitable use for 1* water quality.

2.5.3. Water quality stars: **

Definition: It is wastewater that has received secondary treatment, i.e. wastewater that has been subject to a second cleaning stage (technically referred to as secondary treatment). This is the minimum level of treatment a wastewater treatment plant should provide according to 271/91 EC Directive (EU, 1991). The pollution level (organic load) has been reduced by 95%. Usually this type of water has received disinfection.

Appropriate uses: It is appropriate for surface tree irrigation such as olive trees, vineyards, industrial trees and other trees where water does not come in touch with the crops. Figure 1.11 shows a potential application to citrus trees and olive trees

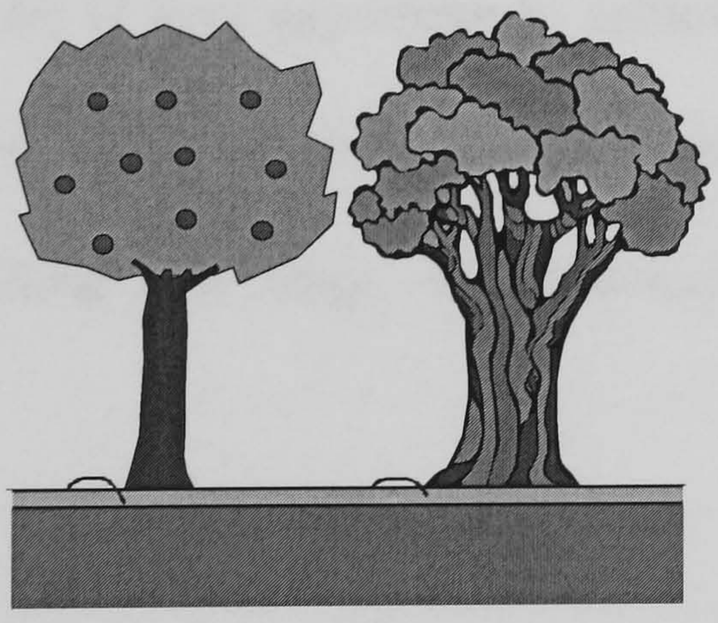


Figure 1.11. Suitable use for 2* water quality.

2.5.4. Water quality stars: ***

Definition: It is wastewater that has received tertiary treatment, i.e. wastewater has

been subject to a third cleaning stage (technically referred to as tertiary or advanced treatment). The pollution level (organic load) is minimized up to 99%. Disinfection has taken place and there are no pathogens.

Appropriate uses: Appropriate for the irrigation of cultivations, which are consumed by the human being on the condition that the edible parts do not come in touch with this water. Figure 1.12 shows a potential application to tomato plants

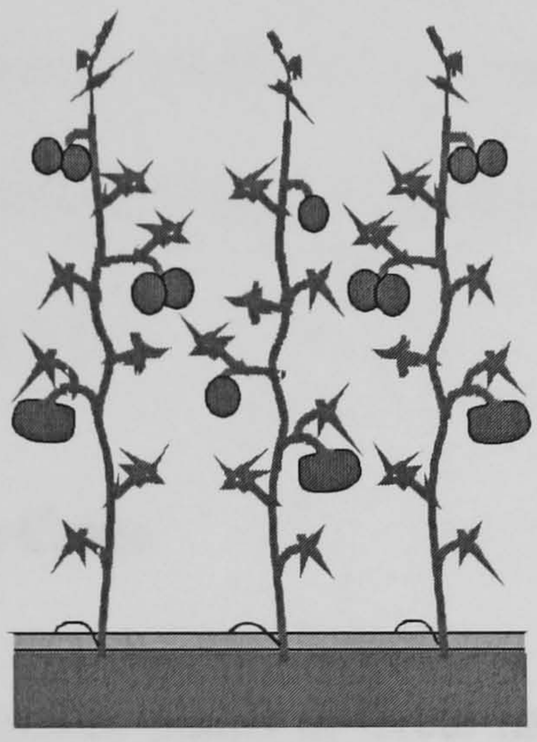


Figure 1.12. Suitable use for 3* water quality.

2.5.5. Water quality stars: **

Definition: It is potable water.

Appropriate uses: It is appropriate for the irrigation of every type of human use and irrigation. This type of water is very expensive to achieve. Even if we were in the position of extreme water shortage circumstances, it would be cheaper to desalinate seawater instead of reaching this stage of cleanness in recycled wastewater (Tsagarakis, 2005).

3. Wastewater treatment facts and potential in Crete

Although groundwater resources in Crete are estimated to be sufficient to cover all water needs, the lack of proper organization and infrastructure has led to serious problems due to increased water demand, particularly during summer, caused by irrigated agriculture and tourism. In the following three sections we give a brief overview of wastewater treatment facilities in Crete (section 3.1), examples of wastewater reuse in Crete (section 3.2) and a comment on wastewater recycling and reuse potential in Crete (section 3.3)

3.1. Wastewater treatment in Crete

The number of wastewater treatment plants in Crete has increased during the past two decades. In 1994 there were nine MWTP in operation but this number had increased to thirteen by 1998 (Tsagarakis, 1999). In 2004 the number of wastewater treatment plants in operation were twenty-five and it is estimated that by 2006 this number will have increased to forty-six (Tsagarakis *et al.*, 2004). The number of wastewater treatment plants, according to their status, their total design population equivalent (p.e.) and served population (s.p.), which reflects the current average flow rate in the hot season, are presented in Table 11. The locations of all existing and planned wastewater treatment plants in Crete together with their status are presented in Photo 1.15.

Table 1.11. Development of MWTP in Crete according to their number p.e. and s.p. (Tsagarakis *et al.*, 2004).

Status	No		p.e.		s.p.
	2002	2006	2002	2006	2002
In operation	25	46	471,550	712,650	313,900
Under construction	7	-	124,100	-	-
Under planning	14	-	117,000	-	-

Note: p.e.= population equivalent, s.p= served population equivalent

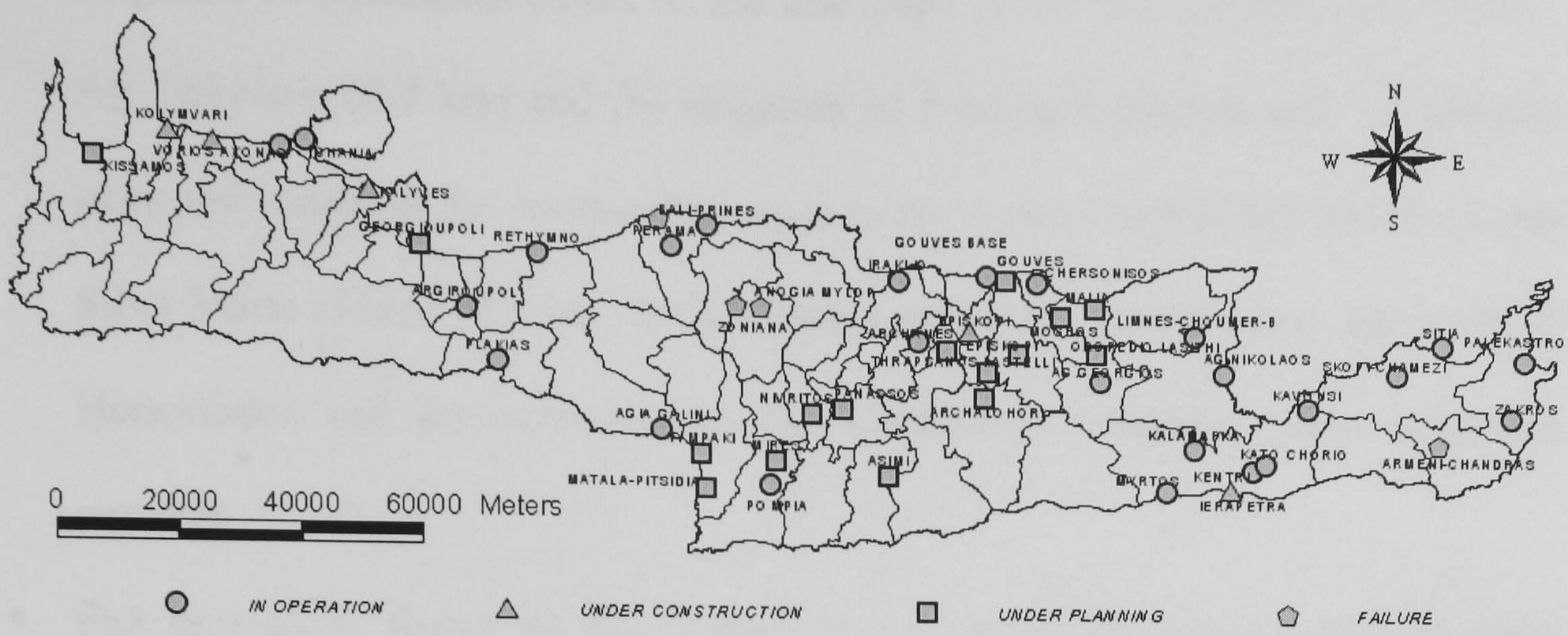


Photo 1.15. Location of wastewater treatment plants in Crete (Tsagarakis *et al.*, 2004).

3.2. Reuse Case Studies in Crete

Wastewater reclamation and reuse in Crete has the potential to provide new and low-cost sources of water particularly for irrigation, to prevent coastal pollution, and to define a public policy emphasizing on resources and nature conservation. At present effluents are recycled by the following wastewater treatment plants (Tsagarakis *et al.*, 2004).

Palekastro. In this plant, 280 m^3/d of treated effluent is used to irrigate olive trees after loading on a 20 m^3 storage reservoir. The irrigation method is close to pipe network (Tsagarakis *et al.*, 2001a).

Zakros. In this plant, 210 m^3/d of treated effluent is used to irrigate olive trees, without any storage (Tsagarakis *et al.*, 2001a).

Herssonisos. Treated effluent is stored in two reservoirs of total volume 1000 m^3. The main uses of recycled water are (Borboudaki *et al.*, 2005):

- Irrigation of agricultural land. The whole system provides water for irrigation of olive trees covering an area of 2,200 ha.
- Landscape irrigation. Two types of landscape irrigation are practised: (a)

irrigation of ornamental plants on the side slope of the new national road Iraklio-Ag. Nikolaos (6-7 km) and (b) irrigation of 5 ha land planted with ornamental trees and scrubs in the surrounding areas to the 5 star Creta Maris and the 4 star Silva Maris Hotels (0.5 ha). Both of these hotels are located near the town of Hersonissos and are connected to the wastewater treatment plants sewerage network.

- Fire protection. Water for fire protection is provided through the storage tanks used for agricultural irrigation. Water, in these tanks should never drop below 200 m^3 as this quantity is regarded as the minimum needed in case of fire at the surrounding area.

Archanes. Plans exist to further treat the secondary effluent by filtration and UV radiation and reuse it for the irrigation of about 14 ha of olive trees and vineyards.

3.3. Potential for Water Recycling and Reuse

An analysis has been carried out to estimate the potential use of recycled water in agriculture in Crete. It is concluded that by reusing the effluent of the existing wastewater treatment plants, particularly for irrigation of agricultural land, irrigation water quantity could be increased by 5.1% or the same quantity of fresh water, which is currently used for irrigation, could be saved for 2002 (Tsagarakis *et al.*, 2004). The aforementioned percentage has been calculated on the basis of existent fresh irrigation water quantity and will originate only from the wastewater treatment plants of villages. Currently, there is no way urban recycled water can be transferred to villages.

4. The 60/2000 water framework directive and Greek Legislation

4.1. The 60/2000 water framework directive

European legislation has touched the subject of marginal waters (water of low quality) early enough. Article 12 of the European Wastewater Directive (91/271/EEC) stated: "*Treated Wastewater shall be reused whenever appropriate*" (EU, 1991). From then on, this matter has been on the foreground of European legislation as well as in the fora of various organizations such as the World Health Organization (WHO), which has published guidelines about recycled water application in agriculture, Food Agricultural Organization (FAO), World Wide Fund for Nature (WWF) and others.

The 60/2000 Water Framework Directive, introduces a modern and complete water resources management. Besides the qualitative criteria that should be sought for all types of water, this directive states that water resources should be managed within river basin limits and not within the actual geographic country borders. The directive also seeks an economic analysis of all water uses, an estimation of their environmental and scarcity cost and a management oriented at the cost-recovery principle.

Tsagarakis (2005) in his paper with title "Recycled water valuation as a corollary of 2000/60/EC (EU, 2000) directive" claims that *any integration, protection and sustainable management of water in today's societies will incorporate marginal waters that can be recycled.* His main argument is that since wastewater is a by-product of fresh water consumption, several principles and articles of the directive can be applied to recycled water. Principles 1, 11, 12, 14 and 46 as well as Articles 5, 9 and 14 of 60/2000 of the Water Framework Directive give rise to the

research done in this thesis i.e. the evaluation of recycled water in Crete. In Table 12, we quote from the aforementioned principles and articles.

Table 1.12. Principles and Articles from 60/2000 Water Framework Directive (adapted in part from Tsagarakis, 2005).

Principle number	Principle wording extract
1st	" …water is not a commercial product like any other but, rather a heritage which must be protected, defended and treated as such…"
11th	"… the Community policy on the environment is to contribute to the pursuit of the objectives of preserving, protecting and improving the quality of the environment, in prudent and rational utilization of natural resources, and to be based on a precautionary principle and on the principles that preventive action should be taken, environmental damage should, as a priority, be rectified at source and that the polluter should pay…"
12th	" … the community is to take account of available scientific and technical data, environment conditions in the various regions of the community, and the economic and social development of the community as a whole and the balanced development of its regions as well as the potential benefits and costs of action or lack of action"
14th	"…the success of this directive relies upon close cooperation and coherent action at Community, Member states and local level as well as on information, consultation and involvement of the public, including users…"
46th	"…to ensure the participation of the general public including users of water in the establishment and updating of river basin management plans, it is necessary to provide proper information of planned measures and to report on progress with their implementation with a view to the involvement of the general public before final decisions on the necessary measures are adopted…"
Article number	Article Wording extract
5th	"…each member state shall ensure that for each river basin district for the portion of an international River basin district falling within its territory, an economic analysis of water use is undertaken…"
9th	"… member states shall take account of the principle of recovery of the costs of water services, including environmental and resource costs, having regard to the economic analysis conducted according to Annex III, and in accordance in particular with the polluter pays principle…"
14th	"… member states shall encourage the active involvement of all interested parties in the implementation of this Directive, in particular in the production, review and updating of the River Basin Management plans. Member States shall ensure that, for each River Basin District, they publish and make available for comments to the public, including users…"

Before we give some insight into what we mean by extension of those principles and articles to cover recycled water practices, we will stop to give a short definition on river basin and its management; River basin is the entire geographical area drained

by a river and its tributaries. As was presented in Table 12, every member shall ensure that for each river basin district, an analysis of its characteristics, a review of the impact of human activity on the status of its surface water and its groundwater as well as an economic analysis of water use should be undertaken. Crete is a region in the European community with various small river basins, but due to its size, can be regarded as a single river basin and a single hydrological department.

Crete is facing water scarcity problems and as such (according to article 5) it should pursue an effective water (fresh or recycled it may be) management plan. Principle 11 invites Crete to act in a precautionary way to solve its water shortage problems. Damage should be rectified in the place where it is generated and only people who are involved must pay (Polluter Pay Principle). Crete must take into account all the technical and scientific data it has in order to do a cost-benefit analysis on whether recycled water can be used (Principle 12, Article 9). The collection of Willingness to Pay and Willingness to Use responses (in chapters 3 and 4 of this thesis) constitutes part of the aforementioned technical and scientific data. Principles 14 and 46 as well as Article 14 speak of involvement of the public in the procedure of water management plans. What we did in the surveys included in this thesis encompassed public involvement and information. The interview was preceded by an information session, which informed and educated Cretans. The session was accompanied by the giving out of a leaflet, resembling much the technical primer in part 2 of this chapter (this is why it has not been annexed separately in the thesis).

4.2. Greek national legislation on Water Resources

Greek general environmental policy became explicit in 90s.The most fundamental

environmental Greek laws were passed in 70s and 80s. Law 1650/1986, which states that *environment protection is i) a prerequisite for the human, as part of the society, to live in high quality environment, in which his health is protected and the development of his personality is favored and ii) fundamental and integral part of cultural and development procedure and policy.*

Furthermore, article 24 of the Greek Constitution must be reported here, according to which *environment protection is responsibility and duty of all people and the State. To safeguard the environment, the State should assume precautionary or corrective sustainability measures.* The Greek ministry of external affairs (2000) admits that *Greek legislation on environmental matters has been characterized by a fragmentary nature, which has prohibited the genesis of a cohesive legal structure for the protection of the environment.*

The water framework directive 2000/60 entered the Greek legislation with the National Law N. 3199/2003. However, WWF (2005a,b,d) spots a lot of vagueness and gaps in this law. The first lies in that, the aims of the directive and the target date 2015, by when the good chemical and ecological condition of all types of water (groundwater, seawater etc) must have been achieved, have not been included in the law. The law speaks generally of preservation, protection and improvement but not of prevention of aggravation of water resources. Second, river basins are not defined. Without the definition of river basin districts, the water framework directive 2000/60 simply cannot be implemented. Third, contrary to the demand of the directive, the law abides by the outdated belief that water should be exploited for the development of the country. Fourth, it does not, sententiously, encourage the involvement of the public in the solution of water problems. Last, Law 3199/2003 demands the establishment of a specific administrative structure (national water council, central

water committee and water service offices across the country), which have not been set up yet.

Table 13 provides a selection of some older Greek legislation in water sector. It is worth going through them, because they are the most relevant in the context of our discussion. Law 1739/1987, which has been the most important water law before the passing of Law 3199/2003, has not come in effect yet, because not all the presidential decrees necessary for its validity have been issued yet.

Table 1.13. Greek Laws in the water sector (Technical Chamber of Greece, 1993, and other sources).

Law	Content of Law
Law 439/1945	About water extraction limits to safeguard uninterrupted water provision to cities, villages and suburbs
Law 52956/1975 (Minister of Public Works)	About simplification of the existent pricing scheme (at that time) and increase of water price
Law 481/1943	Administration and management of water for irrigation
Law 1739/1987	Management of water resources; This law has not come in full effect yet
Law 256/1989	About water extraction permits
Law 16/6631/1989 (Decision of Ministers of Internal Affairs, Tourism, Public Works, Industry and Agriculture)	Determination of lower and upper limits of water extraction to achieve rationalization in irrigation
Law 504/1988	Establishment of decentralized organization for the management of water resources in Epirus and Crete
Law 16/8500/1991 (Decision of Ministers of Internal Affairs, Tourism, Public Works, Industry and Agriculture)	Determination of lowest and upper limits of water extraction to achieve rationalization in household water
Law 1650/1986	Protection of water environment
Law 18166/271/1988	Measures for the protection of water environment; definition of threshold prices for dangerous substances in wastewater
Law 2947/2001	A body of environmental inspectors has been established. This service is supposed to check compliance with environmental legislation and imposition of penalties (WWF, 2005c)
Law Y2/2600/2001 (Ministerial decision)	Qualitative characteristics of water for human consumption in compliance with Directive 98/83EU of European Council of 3rd November 1998 (University of Macedonia, 2005)

It is interesting to see that the laws on extraction limits are relatively recent. The one for irrigation water dates back to 1989, while the one for household water is even more recent, in 1991.This is a reflection of the progressive appearance of the water shortage problem and the gradual environmental awareness increase.

Last, WWF (2005a) in its report entitled " Engagement without effect: Environmental legislation in Greece" reaches the following, not so flattering statements about Greek environmental legislation: "…it is chaotic, vague, complicated, and with an environmental shortage; unsatisfactory compliance of public authorities with legislation and court decisions is observed; there is incomplete adapting with European Community Directives".

Also, although according to Law 2947/2001, the body of environmental inspectors is responsible for watching whether environmental laws are kept, this service cannot carry out its duty in full since there are a lot of gaps in its infrastructure and organizations. Environmental controls can also be carried out by other bodies, which issue environmental rules such as specialists from the Ministry of the Environment or other Ministries, Prefectures, Municipalities etc. However, a lot of these controls remain at a theoretical level because of the large political pressure. WWF (2005c) concludes that much environmental crime in Greece remains unpunished.

5. Thesis structure

The main aim of the thesis is to make us understand the attitudes and values of both farmers and consumers in front of recycled water. Recycled water is a water resource that remains unexploited from society. Its usage can remedy fresh water shortage situations. Following this introduction (chapter 1), this thesis contains four more chapters.

Chapter 2 shows the role fresh water plays in the production of a Cretan agricultural product: olive oil. It is undertaken with the aim of understanding the marginal value of water in agriculture and the benefits from using recycled water in irrigation. After the presentation of olive-tree cultivation essentials and the description of farmers' questionnaire, we continued with deriving a demand function for fresh water. Next, a production function was derived and the corresponding total, average and marginal products of fresh water were commented on. The analysis of this chapter is performed in a more descriptive way due to data deficiencies explained both in chapter 2 and chapter 5.

Chapter 3 deals with farmers' attitude towards recycled water and its evaluation. The former is achieved with the formulation of two Willingness to Use models (simple binary logit analysis) and the latter with two Willingness to Pay models (simple linear regressions). This chapter also contains a short Contingent Valuation Method literature overview with particular focusing on the main caveats of the method. Conclusions are formed both on the size of the Willingness to Pay for recycled water and the factors that determine its formation.

Chapter 4 deals with consumers' attitude towards recycled water and its evaluation. The former is implemented through the formulation of three Willingness

to Use models (ordered logit models) and the latter with two Willingness to Pay models (one simple linear regression and one double bound dichotomous choice maximum likelihood regression). Willingness to Use is studied through three products; olive oil, the tomato and a park while Willingness to Pay is studied only through the olive oil. Conclusions are formed both on the size of the Willingness to Pay for olive oil irrigated recycled water and the factors that determine its formation.

Chapter 5 bridges the conclusions arrived at, at the end of each chapter in the thesis and provide some policy conclusions and suggestions as regards pricing and the usage of recycled water. Last but not least, directions for further research are given together with an account of the current research shortcomings.

6. References

Abu-Zeid M. (2001). Water Pricing in Irrigated Agriculture. *Water Resources Development*, **17**(4), 527-538.

Ali I. (1987). Wastewater criteria for irrigation in arid regions, *Journal Irrigation and Drainage Division*, ASCE, **113**(2): 173-183, In: Panoras, A. and Ilias, A. (1999). Irrigation with treated municipal wastewater, Salonica, Giachoudi-Giapouli, pp. 175.

Angelakis A.N. and Spyridakis S.V. (1996). The status of water resources in Minoan times - a preliminary study. In: *Diachronic Climatic Impacts on Water Resources with Emphasis on Mediterranean Region* (eds. A.N. Angelakis and A. Issar). NATO ASI Series, Vol. I 36, Heidelberg: Springer-Verlag, pp. 161-191.

Angelakis A.N., Paranychianakis N.V. and Tsagarakis, K.P. (2004). Natural treatment systems for municipal wastewaters. In: *Management of Municipal*

Wastewater (A.N. Angelakis Ed.), Union of Municipal Enterprises of Water Supply and Sewerage of Greece, ISBN 960-88318-0-6, pp. 157-202 (in Greek).

Angelakis A.N., Tsagarakis K.P., Kotselidou O.N. and Vardakou, E. (2000). *The Necessity for Establishment of Greek Regulations on Wastewater Reclamation and Reuse.* Report for the Ministry of Environment, Physical Planning and Public Works and Hellenic Union of Municipal Enterprises for Water Supply and Sewage. Larissa, Greece (in Greek), pp. 100.

Angelakis A.N., Tsagarakis K.P., Paranychianakis N.V., and Asano T. (eds) (2002). *Regional Symposium on Water Recycling in Mediterranean Region, International Water Association* (Proc.), National Foundation for Agricultural Research, Vols 1 and 2, pp. 695 and 180.

Angelakis A.N., Tsagarakis K.P., Salgot M., Marecos do Monte M.H.F., and Dialynas G. (2001). *Advanced Wastewater Treatment and Reuse. Design, Operation and Maintenance.* Training Material. National Agricultural Research Foundation, Iraklio, Greece, pp. 306.

Arrojo P. (1999). The impact of irrigation water pricing policy in Spain, In: *Pricing Water*. Economics, Environment and Society. Conference Proceedings, Sintra, 6-7 Sept. 1999, pp. 177-184.

Asano T. and Levine A.D. (1995). *Wastewater and Reuse: Past, Present and Future. Proceedings of 2nd International Symposium on Wastewater Reclamation and Reuse*, Iraklio, Crete, Greece, October 17-20, 1:3-17, In: Panoras, A. and Ilias, A. (1999). Irrigation with treated municipal wastewater, Salonica, Giachoudi-Giapouli, pp.175

Bonnis G. and Steenblik R. (1998). *Overview of the Main Issues and Policies*, OECD, Sustainable Management of water in Agriculture, Issues and policies,

The Athens Workshop, pp. 206.

Borboudaki K.E., Paranychianakis N.V. and Tsagarakis K.P. (2005). Integrated wastewater management reporting at tourist areas for recycling purposes including the case study of Hersonissos, Greece. *Environmental Management*, **36**(4), 610–623.

Chartzoulakis K.S., Paranychianakis N.V., Angelakis A.N. (2001). Water resources management in the island of Crete, Greece, with emphasis on the agricultural use. *Water Policy*, **3** (3), 193–205.

DEYAH (2004). Δ.Ε.Υ.Α.Η. Publication of the municipal enterprise of water supply and sewerage of Heraklio, Issue **6**, pp. 36 (in Greek).

DEYAH, (2005). Information guide, Issue 6, pp.35

Dialynas G.E., Kefalakis N., Dialynas E.G. and Angelakis A.N. (2002). Performance of the first free water surface constructed wetland in Crete, Greece. *Regional Symposium on Water Recycling in Mediterranean Region*, International Water Association (IWA), Iraklio, Greece, 26-29 September 2002, Vol **I**, 371-378.

Dinar A. and Subramanian A. (1998). Policy implications from water pricing experiences in various countries. *Water Policy*, **1**, 239-250.

Dobson S., Maddala G.S. and Miller E. (1989). *Microeconomics*, McGrawhill, pp. 378.

Doering O. (1998). *Summary of the Athens Workshop*, OECD, Sustainable Management of Water in Agriculture, France.

Doppler W., Salman A.Z., Al-Karablieh E. and Wolff H.P. (2002). The impact of water price strategies on the allocation of irrigation water: the case of the Jordan Valley. *Agricultural Water Management,* **55**, 171-182.

El Serafy S. and Lutz E. (1989). *Environmental and Natural Resource Accounting,* Environmental Management and Economic Development, (Schramm, G. and Warford, J.J., eds), World Bank Publication.

EU (1991). Council Directive of May 21, 1991. Concerning Urban Wastewaters Treatment (91/271/EEC). Official Journal of the European Communities, L135/40, May 30.

EU (2000). Council Directive of 23 October 2002, Establishing a framework for community action in the field of water policy (2000/60/EC) Official Journal of the European Communities, L327 (22 Dec.).

European Commission (1999). *Pricing Water Economics, Environment and Society*, Conference Proceedings, Sintra.

EYATH (2005). Water Supply and Sewerage Company for Thessaloniki, Water Rates [www.eyath.gr].

EYDAP (2005). Water Supply and Sewerage Company for the Capital, Water Rates [www.eydap.gr].

FAO (1991). *Wastewater management for irrigation*, R.N.E.A., Technical Bulletin Series, Land and Water No1, In: Panoras, A. and Ilias, A. (1999). Irrigation with treated municipal wastewater, Salonica, Giachoudi-Giapouli, pp.175.

FAO (1992). *Wastewater treatment and use in agriculture*, In: Pescod,M.B. (Ed.), FAO Irrigation and Drainage Paper 47, FAO Rome.

Garrido A. (1999). *Economics of water allocation and the feasibility of water markets in agriculture*, OECD, Sustainable management of water in agriculture, France.

Gleick P.H., Wolff G., Chalecki E.L. and Rayes R. (2002). *The New Economy of*

Water: The Risks and Benefits of Globalization and Privatization of Fresh Water, Pacific Institute, also available at: www.pacinst.org.

Gould P.J. and Lazear E.P. (1989). *Microeconomic Theory*, 6th edition, Richard Irwin, pp. 640.

Greek Ministry of External Affairs, (2000). Environmental policy- Protection measures, accessed at: http://www.mfa.gr/greek/greece/togay/environment/protection/html.

Greig J. (1998). Some practical perspectives on water pricing reform from an agricultural viewpoint, OECD, Sustainable Management of Water in Agriculture, France.

Hanley N., Shogren J.F. and White A.B. (2001). *Introduction to Environmental Economics*, Oxford University Press, pp.350.

Johansson R.C., Tsur Y., Roe T.L., Doukkali R. and Dinar A. (2002). Pricing irrigation water: a review of theory and practice. *Water Policy* **4**, 173-199.

Kapellakis I.E., Tsagarakis K.P. and Angelakis A.N. (2004). Performance of free Water surface constructed wetland for olive mill wastewater treatment, *9th IWA Conference on Wetland Systems for Wetland Pollution Control*, Avignon (France) 26 September-30 October 2004, Vol **I**, 113-121.

Kindler J. (1999). Managing water resources: some challenges, In: *Pricing water. Economics, Environment and Society*. Conference Proceedings, Sintra, 6-7 Sept. 1999, pp. 43-50.

Koundouri, P., Nauges, C. and V. Tsouvelekas (2006). Technology Adoption Under Production Risk: Theory and Application to Irrigation Technology. American Journal of Agricultural Economics (forthcoming).

Leverenz H., Tchobanoglous G. and Darby, J. (2002). *Review of Technologies for the Onsite Treatment of Wastewater in California.* Center of Environmental and Water Resources Engineering, Dept. of Civil and Environmental Engineering, Univ. of California, Report No. 0202. Davis, California.

Lumsden L.L., Stiles C.W. and A.W. Freeman (1915). *Safe Disposal of Human Excreta at Unsewered Homes*. Public Health Bulletin No. 68, United States Public Health Service, Government Printing Office, Washington, D.C.

Metcalf and Eddy (1991). *Wastewater Engineering: Treatment and Reuse*. 3rd Ed. New York: McGraw-Hill, Inc.

Methods for the Examination of Waters and Associated Materials (1989). Five Day Oxygen Demand (BOD_5); with Dissolved Oxygen in Waters, Amendments 1988, sec. (rev.) ed., Her Majesty's Stationery Office, London, GB.

Myers N. (1989). *The Environmental Basis of Sustainable Development, Environmental Management and Economic Development* (Schramm G. and Warford J.J., Eds.), World Bank Publication.

National Statistic Service of Greece (2004). Agricultural Statistics, pp.13.

OECD (1998). *Sustainable Management of Water in Agriculture, Issues and Policies*, The Athens workshop, Paris, France.

OECD (1999). *The Price of Water, Trends in OECD Countries*, Paris, France.

Panoras A. and Ilias A. (1999). *Irrigation with treated municipal wastewater*, Salonica, Giachoudi-Giapouli, pp. 175.

Papagrigoriou S., Kaemaki S., Niadas I., Gkouvatsou E., Perleros V., Drakopoulou E., Panagopoulos A., Papamastorakis D. and Kritsotakis M. (2003). Integrated

water resources management of Crete, In: *4th International Exhibition and Conference on Environmental Technology*, Conference Proceedings, Technical Chamber of Greece, HELECO, Vol. **A**: 240-248.

Pearce D. and Markandya A. (1999). *Marginal Opportunity Cost as a Planning Concept in Natural Resource Management*, *Environmental Management and Economic Development*, (Schramm G. and Warford J.J., Eds.), World Bank Publication.

Perman R., Ma Y., McGilvray J. and Common, M. (2003). *Natural Resource and Environmental Economics*, 3rd edition, Pearson Addison Wesley, pp. 699.

Porta F. (1999). The integral recovery of costs in water cycle pricing, In: *Pricing water*. Economics, Environment and Society. Conference Proceedings, Sintra, 6-7 Sept. 1999, pp. 165-169.

QG EPA, 2003. *Queensland Guidelines for the Safe Use of Recycled Water* (Public Consultation Draft). Environmental Protection Agency, pp.86 Queensland Government.

Region of Crete (2003a). Hydrological data of Moires Basin in central Crete. Division of Public Projects, Department of land reclamation (Unpublished data).

Region of Crete (2003b). Integrated water management in Crete; Summary and main findings, also available at: http://www.crete-region.gr/greek/fysikoi%20poroi/disa/perilipsi.htm.

Ringskong K. (2000). *International Trends in Water Pricing and Use*, Rijadh, Kingdom of Saudi Arabia.

Rogers P., Silva R. and Bhatia R. (2002). Water is an economic good: How to use prices to promote equity, efficiency, and sustainability. *Water Policy*, **4**, 1-17.

Roth E. (2002). *Water pricing in the EU. A Review*. The European Environmental Bureau. Also available at: www.eeb.org.

Safarikas N., Paranychianakis N.V., Kotselidou O., and Angelakis A.N. (2005). Drinking water policy in the frame of the directive 2000/60/EC with emphasis to drinking water prices. *Water Science & Technology: Water Supply*, (forthcoming).

Shelef G. and Halperin R., (2002). The development of wastewater effluent quality requirements for reuse in agricultural irrigation in Israel. Regional Symposium on Water Recycling in Mediterranean Region, International Water Association (IWA), Iraklio, Greece, 26-29 September 2002, Vol **I**, 443-449.

Socratous G. (2000). Water Pricing in Cyprus, Symposium: Water Resources Management. Efficiency, Equity and Policy. Water Development Department. Ministry of Agriculture Natural Resources and Environment, Cyprus, 22-24 Sept.

Technical Chamber of Greece (1993). Greek legislation on Water sector, Athens, pp.520, in Greek

Tsagarakis K.P. (2001). Biological wastewater treatment. In: *Advanced Wastewater Treatment and Reuse. Design, Operation and Maintenance* (Angelakis A.N. *et al.* Eds.). Training Material. National Agricultural Research Foundation, Iraklio, Greece, pp. 306.

Tsagarakis K.P. (2004). Recycled water valuation as a corollary of 2000/60/EC directive. *Agricultural Water Management*, **72**, 1-14.

Tsagarakis K.P. (1999). *The Treatment of Municipal Wastewater in Greece,* PhD. Thesis. University of Leeds, School of Civil Engineering, Leeds.

Tsagarakis K.P. and Angelakis A.N. (2004). Introduction to wastewater

management. In: *Management of Municipal Wastewater* (A.N. Angelakis Ed.), Union of Municipal Enterprises of Water Supply and Sewerage of Greece, ISBN 960-88318-0-6, pp. 1-12 (in Greek).

Tsagarakis K.P. and Georgantzis N. (2003). The role of information on farmers' willingness to use recycled water for irrigation. *Wat. Sci. Tech.: Water Supply* **3**(4), 105-113.

Tsagarakis, K.P., Mara, D.D., and Angelakis, A.N. (2001b). Wastewater treatment in Greece: experience and lessons for developing countries. *Wat. Sci. Tech.*, **44**(6), 163-172.

Tsagarakis K.P., Tsoumanis P., Charzoulakis K. and Angelakis A.N. (2001a). Water resources status including wastewater treatment and reuse in Greece: related problems and prospectives. *Water International*, **26**(2), 252-258.

Tsagarakis K.P. (2005). Personal communication, University of Crete.

Tsagarakis K.P., Dialynas G.E., and Angelakis A.N. (2004). Water resources management in Crete (Greece) and proposed quality criteria for use of recycled water in the Mediterranean region. *Agricultural Water Management*, **66**(1), 35-47.

Tzanakakis, E.V., Paranychianakis, N.V., Kyritsis, S., Angelakis, A.N., (2003). Wastewater treatment and biomass production by slow rate systems using different plant species. *Water Sci. Tech.: Water Supply* **3**(4), 185-192.

University of Macedonia (2005). Environmental Management Programme, Water Legislation, available at: http://afroditi.uom.gr/emas/nomothesis_atmosfaira.html.

US EPA (1980). *Onsite Wastewater Treatment and Disposal Systems.* Design Manual 625/1-80-012. Washington DC: United States Environmental

Protection Agency.

US EPA (2004). Guidelines for Water Reuse. EPA/625/R-04/108 September 2004. U.S. Environmental Protection Agency, Municipal Support Division, Office of Wastewater Management Office of Water Washington, DC.

Vakalis P. (1996). Factors influencing irrigation water demand, 4th Panhellenic Conference of Agricultural Economy, Salonica, 28-30 November 1996 (in Greek).

WHO (1989). Health Guidelines for the Use of Wastewater in Agriculture and Aquaculture. Report of a WHO Scientific, Geneva, Switzerland.

World Water Commission (2000). *A Water secure World.* UK: Thanet Press. [In: Rogers *et al.* (2002), referenced here].

WWF (2005d). Greek environmental legislation, available at: http://www.wwf.gr.

WWF Greece (2005a). Engagement without a policy; The environmental legislation in Greece, pp. 84, available at: www.wwf.gr.

WWF Greece (2005b). "Why does water policy in Greece rely on laws not yet in effect?" available at: www.wwf.gr.

WWF Greece (2005c). "Why does environmental crime in Greece remain unpunished? available at: www.wwf.gr.

WWF Greece (2003). "Prevention of water deterioration" duties, European Community Water Framework Directive (2000/60/EC). World Wide Fund For Nature Position Paper.

CHAPTER 2.

THE ROLE OF WATER IN THE PRODUCTION OF OLIVE OIL IN CRETE

1. INTRODUCTION

This chapter aims to display the position of water in Cretan agriculture, through data on the olive tree irrigation and general cultivation. In spite of the fact that if there were a social planner in Crete to allocate water to the uses where the highest value is achieved, he would not allocate it to agriculture (see section 1.5), still we are interested in studying water in this sector, because traditionally Crete has been an agricultural province of Greece with its agricultural share of GNP being, today, 31%.

1.1. Chapter structure

The chapter consists of five main parts and a conclusion. The first part is an introduction. It deals with a concise overview of Cretan economy and shows the place agriculture has in it. It provides information on the cultivation of the olive-tree, whose irrigation needs constitute the departure point of most of our analysis.

The second part provides information about the survey from where we derived the data this chapter has been built on.

The third part deals with the derivation of a water demand function for the irrigation of the olive tree. The demand curve study results, when combined with results from chapters 3 and 4 will signal more comprehensive policy and pricing results about recycled water.

The fourth part deals with the estimation of a production function and explains the data defects, which did not permit the estimation of a cost function that would otherwise have led to the estimation of a shadow price for water. The latter would constitute a very important piece of information both for water and recycled water pricing. Next, a short sensitivity analysis is performed on the available data, in order to pinpoint our data deficiencies.

Last, the fifth part illustrates the behavior of total, average and marginal products of fresh water, which provide useful insights for water productivity and efficiency in olive oil production.

1.2. Crete

This section shows the position of agriculture and olive- tree cultivation in the economic life of the island of Crete. It explains the irrigation needs of the olive-tree and prepares the reader for the necessity of recycled water introduction in the olive-tree irrigation by showing the sub-irrigation situation that characterizes this cultivation.

1.2.1. Island geography

Crete is situated in the most southern part of Europe, within almost equal distance from Central Europe, Asia and Africa. This geographical position shows the role it can play internationally. It is the largest Greek island with surface 8,336 km^2 and has

a population of 537,000 inhabitants (2001 census). This stands for 5.3% of total Greek population. Crete constitutes the 13th region of Creece and is divided in four prefectures: Chania, Rethimno, Heraklion and Lasithi. Crete is a mountainous island with only 37.8% of its surface being regarded as agricultural land. The largest part of agricultural land is found in Heraklion (44%) and the smallest in Chania (17%).

1.2.2. A brief survey of the Cretan economy

Below we summarize some facts that describe the Cretan economy and show the position of agriculture as compared with other sectors:

- Agricultural GNP for the whole Greece is 12% of total national GNP. Agricultural GNP in Crete is 31% of total Cretan GNP. Despite its large contribution to the macroeconomic figures, the agricultural sector is suffering from a long structural disability, due to the small and dispersed land parcels (see also section 1.2.3).
- As far as Cretan industry is concerned, Crete is specializing on food and beverage production as well as on building materials and plastics. It hosts only 1.8% of Greek heavy industry with only 25 factories having an annual turnover going beyond 3m euros.
- Tourism is a very dynamic sector of the Cretan economy. In the period of 1991-1994, the increase of tourist GNP was larger in Crete than in the whole of Greece. The tourist sector employs 8.5% of the working population. This number is double than in the rest of Greece and shows that more people rely on tourism for a living in Crete than in any other place in Greece. Table 2.1 shows the major turn that has taken place through the years in working force

groupings and the move from agriculture to other job sectors (mostly tourism) and industry.

Table 2.1. Number of people working in each sector in Crete from 1971-1991 (Science and Technology Park of Crete, 2005).

Occupation category	**1971**	**1981**	**1991**
Science	6,613	13,095	22,591
Services (mostly tourism)	18,086	28,952	45,443
Commerce	8,897	12,528	19,153
Agriculture	114,712	95,647	64,048
Workers/Technicians	34,326	38,338	48,240

1.2.3. Cretan Agriculture

Before proceeding with the description of agricultural crops based income sources, we need to pinpoint some facts about the Greek agriculture from which Cretan agriculture is not to be exempted. Greek agriculture is generally acknowledged to be in crisis (Economic and Social Council of Greece, 2005). Despite the farmers' income improvement in 80s due to EU subsidization, Greek agriculture today produces as much as in 70s. Farmers' income improvement came about from the decrease in the number of farmers and the EU subsidization. Although the number of Greek farmers is supposed to have decreased, still it remains one of the highest in Europe.

One other issue that characterizes Greek agriculture is that while farmers' number gradually decreases, farmers who have left their farming job, have not sold their land. They have kept it because they have kept agriculture as a second job or because they hope that some day this land will assume "site value" and thus they will sell it at high prices. So, land is dispersed at the hands of numerous people who may not be farmers in their basic occupation anymore.

In addition to the above, the same study (of Economic and Social Council of Greece, 2005) claims that Greek agriculture is characterized by youth and education shortage, meaning that the majority of farmers are of older age and have only been to primary school, or are illiterate.

1.3. Olive-tree cultivation in Crete

In this section, we are going to say a few words about the economic importance of the olive tree cultivation in Crete and then (in the following sub-section) we will proceed with a short discussion on the irrigation needs of this cultivation.

Olive trees together with vineyards are the two traditional cultivation types in Crete. Vegetables cover only 3% of total cultivated land, while Crete hosts 50% of greenhouse production in the whole country of Greece. Despite the low production per strema (this is the Greek unit of land measurement and equals to 0.1 ha) of cultivation (Table 2.2.), olive trees together with vineyards, are expected to remain the two basic types of cultivation in Crete (Region of Crete, 2003).

Table 2.2. Nominal yield and net value of agricultural production of main cultivation types in Crete (Region of Crete, 2003).

Cultivation type	Crop tn/strema of land*	Profit (€/tn)
Vineyards	1.15	112.10
Grains	1.35	396.18
Olive trees (olive oil)	0.275	1,881.14
Greenhouse vegetables	10	494.49
Vegetables	4.3	308.14
Fruit	3	72.78
Potatoes	4.5	32.28
Subtropicals	2.23	386.50

Note: 1 strema equals to 0.1 ha

From the union of olive oil producing municipalities in Crete (2005), we collected the following information about olive oil production: Olive tree cultivations have increased through the years and today they cover 65% of the agricultural land of the island. There are at least 35m olive trees on the island. Mean olive oil production increases by 3% yearly. Today, production is more than 150,000 tons. An olive tree, depending of course on its size, age and on whether it is a good or bad production year, can produce from 10-150kg of olive oil per year. The latter piece of information reveals the great variability of olive oil output and the fact that we cannot verify the truthfulness of our output data in the survey (to be described shortly), because output depends on various factors for which we have no information.

1.4. Olive-tree irrigation essentials

Irrigation is applied to 30-35% of Cretan olive-trees leaving a 65-70% un-irrigated. According to Charzoulakis (2002) olive trees can grow without irrigation in areas with a rainfall of 400-700mm. However for high olive-oil yield, 600-800mm are necessary. Irrigation is necessary because of the uneven rainfall during the year and the dry summer months. Charzoulakis (2002) refers to three crucial irrigation periods for olive-trees. The first is February - March when the new blossom appears. The second is April-June, when blossom matures and the third is July-September when the new olives are filled in full shape. During the third period there is no rain in Crete. This highlights the need for irrigation during that period. Table 2.3 provides the needs of an olive-tree for water in litres per day. The last raw of the Table gives the average irrigation needs of a tree per year. Because the plantation density of olive-trees is not known, we cannot derive the irrigation water needs per strema (0.1 ha). If we did this,

we could crosscheck the validity of water quantity data we have collected in our survey.

Table 2.3. Olive tree water needs in lt/tree per day (Charzoulakis, 2002).

Month	Olive-oil producing olive-tree	Edible olive producing olive-tree
May	30-40	40-50
June	40-50	70-80
July	50-60	80-100
August	50-60	80-100
September	40-60	60-70
October	-	50-60
Average	42-54	63-73
Average yearly irrigation (Average*180 days)	7.3-9.7	11.3-13.1

However, the same writer, when he discusses the irrigation needs of a special type of olive crops (koroneiki) he says that this need amounts to 200-250 m^3/0.1ha of land. We could use this figure to compare with our findings about the mean yearly water consumption we have received from our survey. Of course, once again, a representative comparison cannot be made, because we do not possess so detailed data as the type of olive tree cultivated by each farmer, evapotranspiration conditions, humidity conditions, soil synthesis, the density of plantation (number of trees per 0.1 ha), irrigation method, frequency etc. The mean irrigation water quantity of our sample was 95.91 m^3/0.1ha of land. We should note that the vast majority of the respondents admitted they had been irrigating for less than necessary but they could not give an estimation of how much less (the latter has been a separate question in the questionnaire but it had the highest non-response rate).

A study conducted in South Italy (Cavazza *et al.*, 2005), found that the olive tree was pretty much under-irrigated compared to other crops and that it had the largest difference between the ideal and practiced irrigation level from all crops. We mention this study because South Italy is also in the Mediterranean, close to Greece and its climatic conditions bear some resemblance to the Greek ones. Besides, given the inexistence or inaccessibility of such studies in Greece, we thought it would be appropriate to refer to this one. In 1991 the advised applied water depth for olive trees was 367.0 mm while the practiced one by farmers was 97.7 mm namely the practiced was almost only one third of the advised. Although this study does not show how much the olive oil yield is affected by such deviation, there is no doubt that irrigated agriculture is more productive than the non-irrigated one or, the less than ideally, irrigated one. Last, Latinopoulos (2005) refers to a piece of software called CROPWAT provided by FAO which estimates the crop loss due to inadequate irrigation, However, more sophisticated variables are necessary for it such as soil, climate and crop characteristics not available in our survey.

The fact of irrigated agriculture generally being more productive than the non-irrigated one is also reflected in the increase of irrigated land through the years. Field (1990) states that irrigated land was 40 m ha, while FAO (2000) report this amount to have soared to 271 m ha in 1998 worldwide. Shortle and Griffin (2001) state that today although irrigated land is only 17% of all cropland, it produces approximately 40% of world's food. These numbers support the argument that irrigated agriculture is more productive than the non-irrigated.

1.5. The value of water in different economic sectors in Crete

It is important to know the value water produces in each economic sector, because this way a hypothetical social planner could decide where to allocate it. Although, we could not have been able to perform such an analysis from scratch in the context of this PhD thesis, because this would require a considerable amount of work and would be out of the scope of this thesis, we can cite the results of an analysis conducted by the Region of Crete (2003) in which water use was ranked from the highest value generating one to the least value generating. These were:

1. Drinking (according to Law 1739/87).
2. Environment such as national gorges, natural monuments, protected landscapes (Law 996/1971), Natura or Corine areas (EU Directives 92/43 and 79/409) and landscapes of particular natural beauty.
3. Industrial use (it produces a very high value for a unit of water volume).
4. Stockbreeding (because of the small water quantities it uses and the importance of stock breeding from an economic, social and political point of view).
5. Irrigation (because it uses huge quantities of water and produces less value than the above sectors).

This published study gives only a ranking but it does not explicitly tell by how much industry water use exceeds the value added compared to the agriculture use.

2. THE SURVEY DESIGN

The data from this chapter have been collected through the "farmers' questionnaire" (An English version of this questionnaire, together with an explanation of its structure are presented as Appendix 7.1 at the end of this chapter). We use the term "farmers' questionnaire" to distinguish this from the consumers' questionnaire presented and analyzed in chapter 4.

The farmers' questionnaire was primarily and more importantly constructed in order to collect the Willingness to Pay (WTP) of Cretan farmers for recycled water for irrigation. Besides this, the questionnaire contained various other questions and it was divided in five parts: i) The introduction, ii) The first part contained warm up questions which also briefly captured the respondent's environmental profile, iii) The second part contained the very gist of the research, i.e. the farmers' WTP for recycled water. This part also provided the data for setting up the olive oil production function and the water demand relationship in this chapter (the data importance from this part is high, because despite the deficiencies we will discuss in the sections to follow, there are no official empirical data on olive oil irrigation and cultivation in Crete), iv) The third part contained respondents' demographics.

This survey (together with the consumers' one in chapter 4) was financed by the Greek Ministry of the Environment, Physical Planning and Public Works (ΕΤΕΡΠΣ) and was part of a larger project launched by the Ministry to create, increase and measure people's environmental awareness.

2.1. Sample size

We need to stress out that farmers' questionnaire encompasses two topics, one is the production function data, and the other is the Willingness to Use (WTU) and Willingness to Pay (WTP) question. Because the WTP was the focal point of this survey, we estimated the sample size based on WTP considerations and not on the production function inputs variation. Therefore, given this research orientation, we regard our sample size as satisfactory. The ideal sample size was calculated by the formula shown in Equation 2.1.

$$n = \frac{s^2 N + \sigma_{\bar{x}}^2 (N-1)}{s^2 + \sigma_{\bar{x}}^2 (N-1)} = 389 \qquad (2.1)$$

According to Cooper *et al.* (1995) *the sample size should be a function of the variation in the population parameters under study and the estimation precision needed by the researcher.* Thus, there is no golden rule as to how large the sample should be. The variables used in Equation 2.1 are explained as follows: *s*, standard deviation from a pilot sample (this was 10 cents in our sample), σ_x, is the ratio of the standard error of the sample mean to the critical value of Z-statistic, namely the number of standard errors a point is away from the mean. Suppose we want to achieve a 95% confidence interval which gives Z= 1.96. This gave 0.5/1.96=0.255, N, population size, 48,164 farmers in 2001 (Science and Technology Park of Crete, 2005).

Bateman *et al.* (2002) suggest a more sophisticated sample size estimation which is clearly cut for the context of a contingent valuation study (and the

subsequent elicitation of a WTP bid). They suggest the formula shown in Equation 2.2.

$$N = \frac{Z\hat{\sigma}}{\delta RWTP} \tag{2.2}$$

N being the needed sample size, RWTP the mean of the estimated WTP bids, δ the percentage difference between the true WTP and RWTP, $\hat{\sigma}$ and Z defined as above. The ideal sample size from this formula would be 312 observations (with Z=1.96, $\hat{\sigma}$ =0.255, δ=0.01 and RWTP=0.16 €). Our sample comprised 453 observations, namely more than those indicated by both formulae in Equations 2.1 and 2.2 and therefore it suffices for both the production function and the WTP application.

As far as the production function data are concerned, we should probably have looked for more observations, since we were interested in lots of parameters each one with a different variation and non-response rate. If a farmer did not answer one input, this invalidated the whole observation for reasons we will explain in part 4. Nevertheless, the survey budget and time were preordained and limited and no more could be done for this. From 453 observations we ended up making use only of 285 of them in the production function application.

2.2.The sampling design

Our sampling design was based on stratified random sampling. This type of sampling *is a two-step process in which the population is partitioned into mutually exclusive and collectively exhaustible strata. Next, elements are selected from each stratum by a random procedure, usually simple random sampling* (Malhotra, 1999).

Our application strata were East and West Crete farmers. East Crete is more arid and gathers large systematic olive oil cultivations (e.g. Messara valley). West Crete,

on the other side, has larger rainfall and less olive oil cultivations. We have directed the largest part of the research in East Crete (Messara valley, Heraklion). Hence our sample consisted almost 90% of East Crete farmers and 10% of West Crete ones. West Crete on the other side is more mountainous and was less important, from an olive tree cultivation point of view, more difficult and costly to access.

2.3. Survey description

Twelve people, including the thesis writer, participated in the collection of the agricultural sample of the data in the period between July-August 2002. Data came from 115 Cretan villages. Farmers were interviewed in the street, local cafes, shops and their houses throughout the day. An information session preceded the completion of the questionnaire, a booklet was given out and respondent's queries were catered for. Excluding the social interaction that sometimes was necessary in order to smooth the data extraction procedure, the pure mean interview time, together with the information dissemination, for farmers lasted for one hour.

3. REPRESENTATION OF IRRIGATION WATER DEMAND IN OLIVE-OIL PRODUCTION FUNCTION

The main aim of this section is the derivation of a water demand function for the irrigation of olive trees in Crete. Section 3.1 presents our sample results on water demand, while section 3.2 shows how we derived the actual demand function.

3.1. Irrigation water prices in farmers' sample

According to Figure 2.1, the largest part of water prices that farmers pay is within the intervals of 0.11-0.20 and 0.21-0.30 €/m^3. It is understood that prices differ even up to

215.66 % since they ranged from 0.03 to 6.5 € (Table 2.6). Huge price differences were also the reason we opted for the open-question format in the WTP question in chapter 3 since the initial twenty observation pilot survey could not give us an insight as to how to formulate closed-ended questions.

Water prices differ a lot not only between villages, but within villages too. Due to land dispersion, prices differ even within a farm, because a farmer buys water from a different seller for every different parcel he owns.

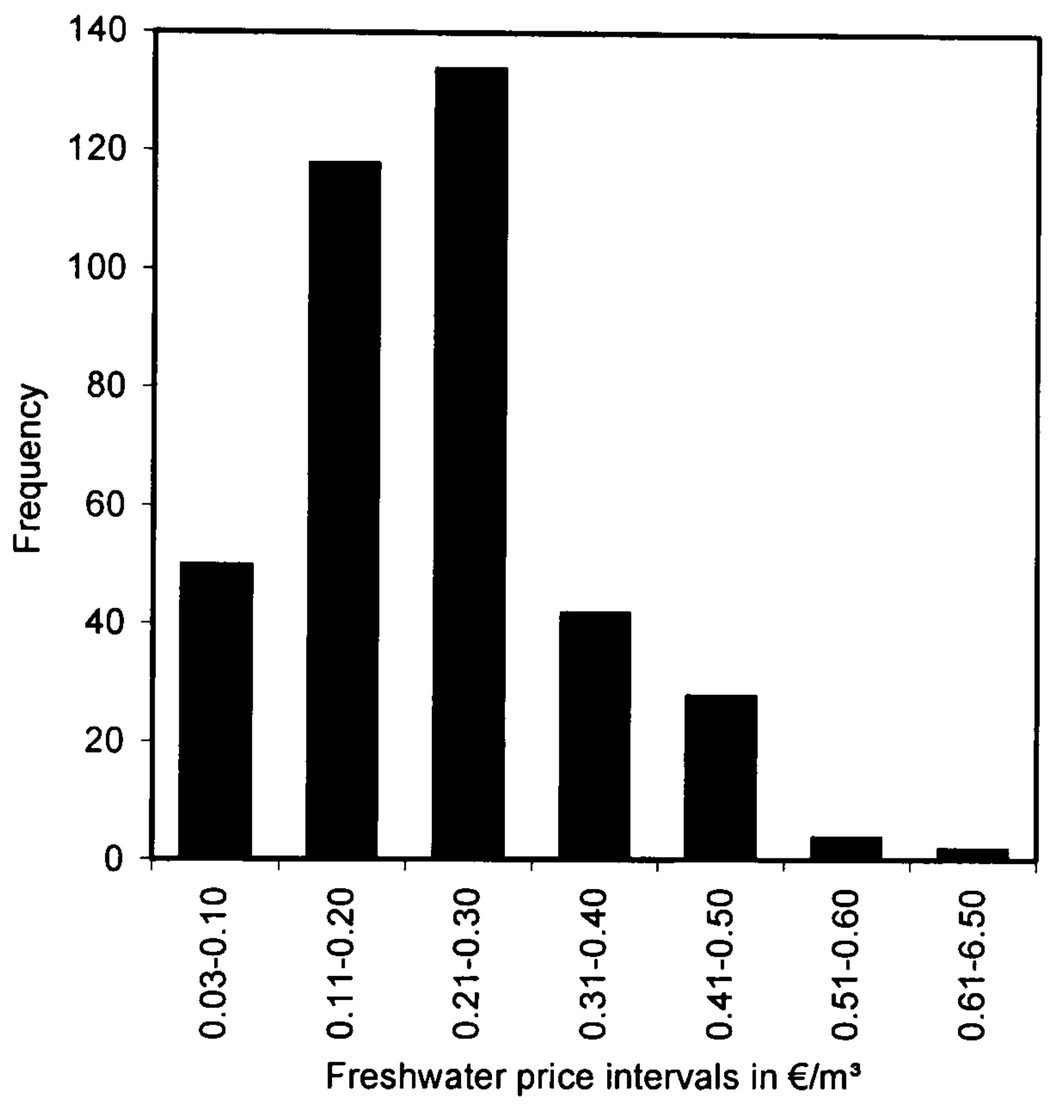


Figure 2.1. Frequency distribution of irrigation water prices, as stated by farmers.

Mean irrigation fresh water price (Table 2.4) is 0.27 €/m³, while mean WTP for recycled water of quality 2, as we will see in chapter 3, is 0.18 €/m³. This tells us that farmers would be willing to use recycled water if, on average, it were 9 cents cheaper than fresh water, namely if it cost one-third less the price of fresh water. Because of huge price differences, it might be useful to comment on the median and not the mean water price. In that case, farmers would be willing to use recycled water if it were 4

cents or 18% cheaper than fresh water. Notice that the high standard deviation of water price tells us exactly what we have stressed previously, that prices varied tremendously.

Table 2.4. Descriptive statistics of irrigation fresh water price (€/m³), n=285

Statistic	Water price
Mean	0.274196
Median	0.220000
Maximum	6.500000
Minimum	0.030000
Std. Dev.	0.418044
Skewness	12.62560
Kurtosis	180.2195

Note: Observations are those used in the estimation of the production function. They are fewer than the initial sample of 453 because we have left out non-irrigators, non-olive tree cultivators and farmers who gave zero values in other inputs.

3.2. Irrigation water demand

This section deals with the estimation of a demand function for irrigation water. To estimate a demand function, we would ideally need information about the supply function too. Most standard econometrics textbooks advise that we cannot consider the demand function in isolation when we are studying the relationship between quantity and price. We should bring the supply function into the picture and estimate demand and supply together as a simultaneous equation model. However, in this study we do not have any empirical water supply data at our disposition and hence we cannot estimate a water supply function. We can, though, approximately envisage the supply curve from the information we have on the structure of the water market (section 1.7, chapter 1).

3.2.1. Irrigation water supply

Our best estimate is that the supply curve looks like what we have drawn in Figure 2.2, i.e. it has a kinked shape.

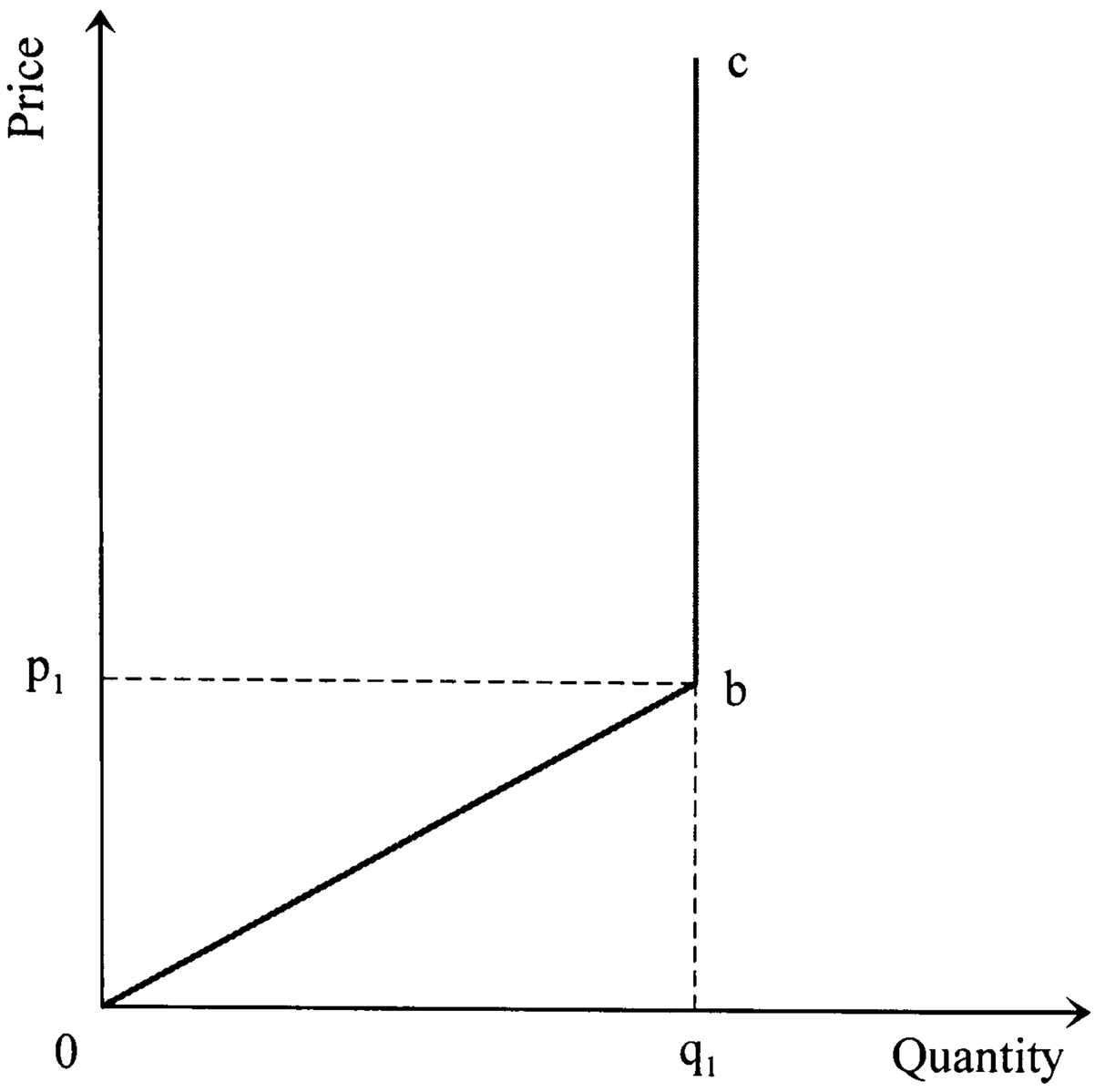


Figure 2.2. Hypothetical irrigation water supply

It starts with an upward slope (part *0b*) and then gradually becomes vertical (part *bc*) to the horizontal axis, namely it becomes perfectly inelastic. Given the fact that irrigation water is a limited resource, all of it can be potentially demanded and consumed. Therefore, for the part *0b*, the supplied quantity becomes larger as prices get higher. For larger water quantities, i.e part *bc*, the quantity supplied will reach a maximum (q_1), beyond which it cannot go, no matter how high the water price will be. Now that we have an idea of what the supply curve looks like, we can go back to our discussion of the demand function and justify the demand function representation we choose.

3.2.2. Irrigation demand function representation

Maddala (1992) suggests that when supply is upward sloping or perfectly horizontal, then the demand function should be represented as

$$q = a + \beta p + u \tag{2.3}$$

namely the equation is normalized with respect to q. The disturbance term denotes random shifts in the demand function, q is the water demand expressed in m^3, p is the fresh irrigation water price in €. When supply is vertical, the demand function (inverse demand function) should be represented as

$$p = a' + \beta' q + u' \tag{2.4}$$

namely the equation should be normalized with respect to p. However, Maddala stresses the fact that whichever normalization we adopt, the estimation methods we use, should produce the same results.

According to the supply function in Figure 2.2, both representation ways (Equations 2.3 and 2.4) would be justifiable to use, on the grounds that the supply curve consists of two distinctive parts, *0b* and *bc*. Before proceeding to show the results from the two representations, we need to note that if the supply curve is upward sloping or perfectly horizontal, then the error term is correlated with p in Equation 2.4 and hence the estimation with least squares produces inconsistent estimates of the parameters. The same happens with u and q in Equation 2.3. However, we have to bear with this defect because we cannot work in a simultaneous equations context (with two stage least squares), which would remedy this. Estimation of Equation 2.3 gives (for a full output see Table 2.21 in appendix 7.2.1 of this chapter):

$$q = \underset{(0.00)}{2950.55} - \underset{(0.04)}{3345.02}\, p \ , \ R^2=0.02 \tag{2.5}$$

This is a significant relationship (The p-value for the F statistic is less than 0.05). Also price is significant. This relationship assumes price as exogenous and translates into that a 1 € increase in price will on average cause the demand to reduce by 3345.02 m³ per year. Of course, a 1 € increase is too big and would mean that the mean price would triple. Since the mean demanded water quantity is 2269.44 m³/yr (Table 2.9), then the amount of the above demand reduction, means that farmers would almost rather "go the arid way" than having to pay such a high price. Note: The estimation of Equation 2.5 with price expressed in pence instead of euros has also been tried, but results did not show anything different (Table 2.30 in appendix 7.2.1). Figure 2.3 depicts the demand function estimated by Equation 2.5.

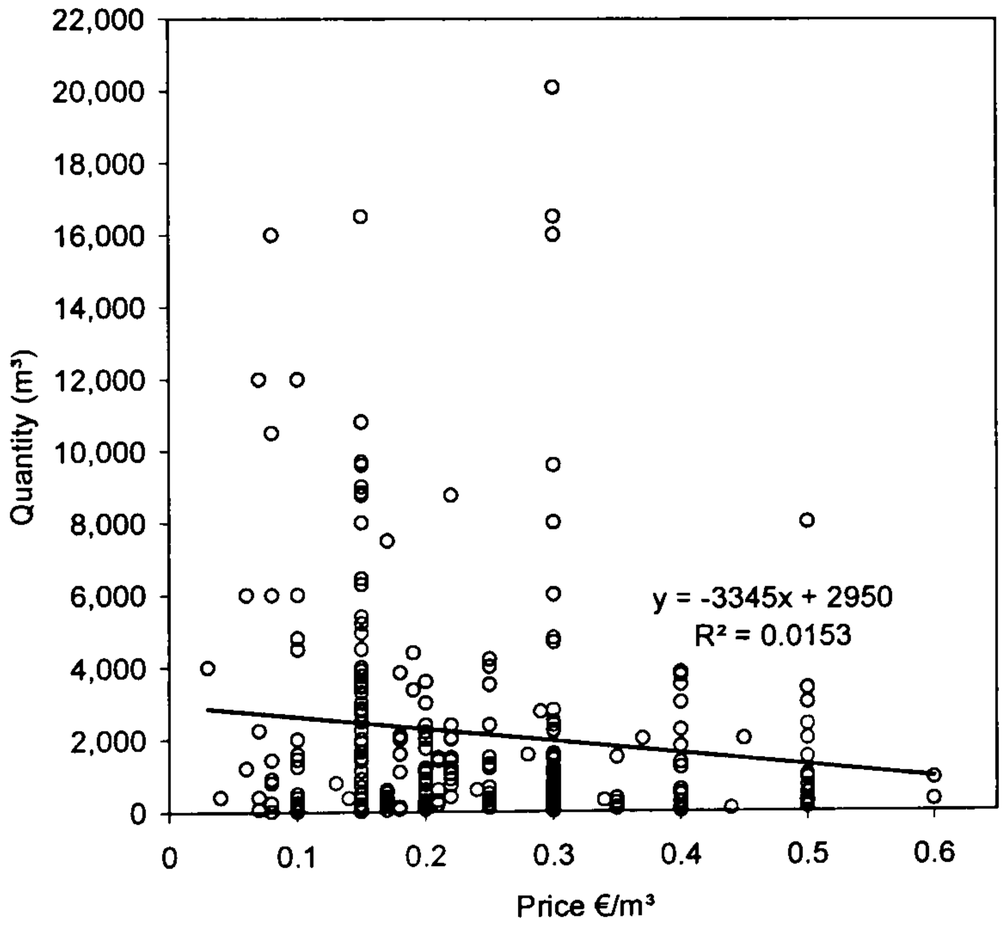


Figure 2.3. Irrigation water demand curve with respect to quantity.

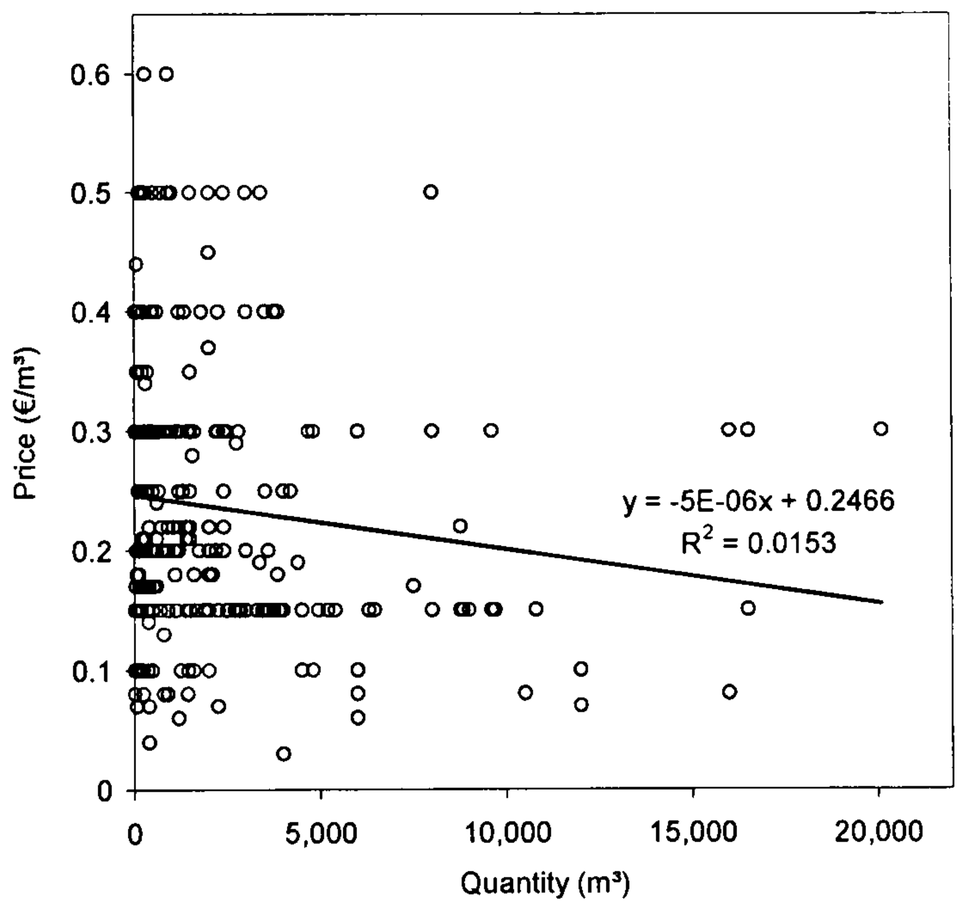


Figure 2.4. Irrigation water inverse demand curve.

We now continue with the estimation of Equation 2.4, which is applicable in the vertical part of the supply curve. This gives (Table 2.22 in appendix 7.2.1):

$$p = \underset{(0.00)}{0.25} - \underset{(0.04)}{0.00}\,q\,,\ R^2=0.02 \qquad (2.6)$$

Both coefficients are significant and the relationship as a whole is significant too. The relationship represented in Equation 2.6 assumes quantity as exogenous and tells that if the demanded quantity increases by 1 m^3, then price will not, on average, fall. Or that 1 m^3 is too small to affect price. Figure 2.4 depicts the inverse demand function estimated in Equation 2.6.

3.2.3. Comparison of various demand function specifications

If we solve Equation 2.5 with respect to p, we end up with $p = 0.88 - 0.00q$ which approximates the result from Equation 2.6. Hence, both specifications would do to represent irrigation water demand in Crete.

Apart from the specifications in Equations 2.5-2.6, which for brevity we call Models 1 and 2 respectively, we also have tried those in Models 3 and 4 (Table 2.5) with a dummy variable included for the water origin. The reason we set up Models 3 and 4 is that market conditions are different under case 1 and 2 water origin scheme (as already described in section 1.7.1 in chapter 1). We thought that these different market conditions might be better captured in different demand functions.

However, farmers do not buy water exclusively from one seller type. They use combinations of them depending on the proximity of their olive tree field with the water source. Since each farmer's land is dispersed in various spots, each farmer buys water from a different seller for each of his fields. So, the dummy has assumed values as follows: 1 if among other sources, farmer buys from case 1 or 2, while 0 if otherwise. Results in Table 2.5 show that the dummy was not significant in Model 3 but it was in Model 4. This means that when water origin is under case 1 or/and 2, there is a different inverse demand function than when water origin is under the rest of the cases, namely quantity affects price in a different way when the water seller is

the municipality or the union. This could be revealing that these water sellers assign higher prices to larger quantities of water, something that private well owners do not do because they cannot provide very large quantities of water.

Furthermore we have tried exponential and logarithmic specifications for both the demand and the inverse demand function, but results were not any better (see Figures 2.12, 2.13, 2.14 and 2.15 in appendix 7.2.2).

Table 2.5. Summary of irrigation water demand models.

	Model 1 $q = a + \beta p + u$		Model 2 $p = a' + \beta' q + u'$	
Dependent variable	Quantity (q)		Price (p)	
	Constant	2950.55 (0.00*)	Constant	0.24 (0.00*)
	Price (p)	-3345.02 (0.03*)	Quantity (q)	0.00 (0.03*)
	R-squared	0.02	R-squared	0.02
	F-statistic	4.36 (0.00*)	F-statistic	4.36 (0.00*)
	Model 3 $q = a + \beta p + D_i + u$		Model 4 $p = a' + \beta' q + D_i + u'$	
Dependent variable	Quantity (q)		Price (p)	
	Constant	3623.08 (0.00*)	Constant	0.25 (0.00*)
	Price (p)	-3355.24 (0.03*)	Quantity (q)	-0.00 (0.00*)
	D_i	-797.35 (0.10*)	D_i	-0.00 (0.00*)
	R-squared	0.02	R-squared	0.01
	F-statistic	3.48 (0.03*)	F-statistic	2.20 (0.11*)

D_i is a dummy variable with 1 if the farmer's irrigation water origin is, among others, in cases 1 or 2 and 0 if otherwise. Figures in parenthesis are p-values. Stars indicate significance at 5%. Full outputs of all demand models can be found in appendix 7.2.2 (also Tables 2.21, 2.22, 2.23,2.24) of this chapter.

The shape of the demand curves we have derived bears similarities with the ones typical in literature. Varela-Ortega *et al.* (1998), Latinopoulos (2005) and Tsur *et al.* (2002) have derived demand functions with water price on the vertical axis, and quantity on the horizontal one where the curve starts with an inelastic segment (at high prices), then an elastic one (at lower prices) and finishes with an inelastic again (at the very low prices). See Figure 2.5 for a visual representation on this. Demand is

inelastic for low prices and does not become price responsive until higher prices are attained. Latinopoulos (2005) attributes the first inelastic part (from the right) to the gradual adjustment to less water demanding crops in agriculture. However, this water demand curve is for agriculture generally and not exclusively for a specific crop type or for the olive tree. Tsur *et al.* (2002) add that farmers' response to water prices depends on various endogenous (crop mix) and exogenous conditions (soil type, water supply reliability, existing water institutions, prices of other inputs and outputs, extension and availability of appropriate technologies, production quotas, access to market and credit).

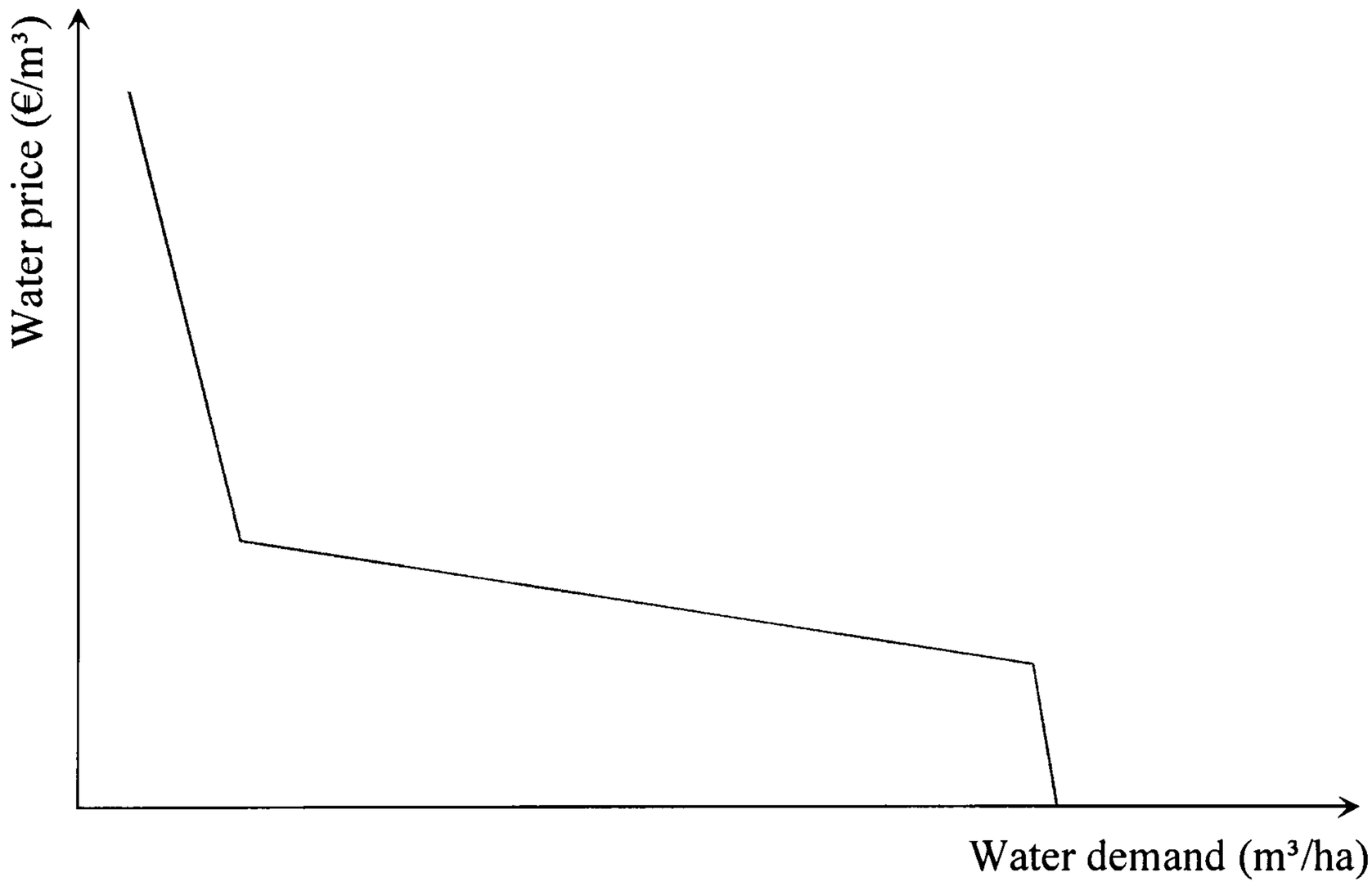


Figure 2.5. Typical water demand function in agriculture (by Latinopoulos, 2005).

3.2.4. Measurement error in water demand

We cannot oversee the fact that water demand data are not absolutely reliable, because they are based on farmers' personal judgment. A lot of farmers could not express in m³ the water quantity they used; instead they could tell this amount in

hours of irrigation or in another form of measurement. Consequently, they had to take pains in translating this amount in m^3. This transformation, given the generally poor educational level of farmers on the one side, and the interview context (respondents felt the pressure of time in a long interview such as this) on the other side, contains error. Of course, this assumption does not reveal the direction of the error. Is the stated demand inflated or deflated? Have farmers understated or overstated this amount?

A good instrumental variable is supposed to give some insights about the measurement error, but unfortunately we do not have this. Question 6 in the farmers' questionnaire that could make a good instrumental variable for this case, had one of the largest non-response rates. This question came right after the one, which inquired about the yearly consumed water quantity and was inquiring about the appropriate quantity that should be used for irrigation, on the condition that farmers had admitted that they had faced problems finding the water they needed in the past three years (question 5.2).

In the absence of a good instrumental variable, Maddala (1992) suggests finding estimates of the bounds within which a certain variable coefficient falls, so that we get an estimate of how influential the measurement error is. In our application this translates into estimating for example Equation 2.4 as we have done, then estimate the reverse relationship, namely Equation 2.3 and solve the latter with respect to p, so that we can compare the slope coefficients (quantity coefficients) of the two equations. This produces an interval within which the quantity slope falls. As is seen in section 3.2.2, this interval is very narrow for the coefficient of q but very wide for p (-2222,22, -3345,02), just showing that there is measurement error in

quantity. We must repeat here that in this paragraph, we only admit the existence of the error, but we cannot handle with it because we do not know its direction.

4. REPRESENTATION OF OLIVE OIL PRODUCTION WITH A TRANSLOG FUNCTION

This part explains how the production function application has been implemented, the problems encountered with the data, the adaptations we had to make and the results we got from it. Below we spend some time discussing why we needed a production function model in the first place. Sections 4.1–4.2 discuss the production function setup while the remaining 4.3–4.7 discuss the estimated models and the reliability of their results.

A production process can be examined from many aspects. For example, a large part of recent production function literature is concentrated on efficiency analysis using frontier production functions (a frontier production function is a regression that is fit with the recognition of the theoretical constraint that all observations lie below it). The distance of each farm from the frontier is caused by a mixture of interactions among all the observed inputs and other invisible inputs such as management etc. By efficiency analysis we mean that we focus our interest on whether producers have produced as much as possible with the inputs they have actually employed and whether they have produced that output at minimum cost. Therefore, in this framework, interest lies in finding out how far each farmer is from the ideal production rate (the frontier) while the parameters of the production function are of secondary importance (Greene, 2003).

However, the initial orientation of this study was not on efficiency but on valuation (derivation of the shadow price for irrigation water). Given the limiting circumstances we describe in the following paragraph though, we can only study what the role of water in the production process is.

In our analysis, we use the production function in the way it is applied in neoclassical theory, i.e. as the maximum amount, which can be produced by certain input quantities, under a given technology. Initially we hoped we would be able to work under the profit maximization framework or (by Shepard's duality) the equivalent cost minimization framework. The profit maximization approach involves unconstrained maximization of profit with the maximization of $\pi = R - C$, π is profit, R is revenue and C is cost. The first order condition of profit maximization is the marginal revenue product, which is the demand for a factor (on the condition that the second order condition for profit maximization holds). The cost minimization method begins with the augmented objective function (Lagrange function) and minimizes the total cost function subject to the production function. This approach gives the expansion paths along which a firm achieves the least-cost factor combinations. With the profit maximization approach we would have been able to derive factor demand equations and with the cost minimization approach, we would have been able to discuss input substitution and last compare the shadow price of water with the market one. Data limitations will not allow us to do these things though.

Data limitations impeded the construction of a cost function. We realized, maybe too late to do something about this, that Crete was too small a place for fluctuations in the prices of certain inputs; there were no fluctuations in the price of labor for example. Olive oil labor market in Crete consists mainly of Albanian workers who work for a standard day wage every season. The same applies for the

prices of other variable inputs. For some inputs there are fluctuations but they are still very subtle. Besides, the fact that we have sampled heavily from East Crete and in particular from Heraklion municipality, which is an area with large systematic olive oil cultivations, makes the chance for input price variation even smaller. So, this data deficiency cancelled one of the main objectives of this chapter part.

4.1. Why the translog production function

The translog function introduced by Christensen, Jorgenson and Lau (1973) constitutes an important and the most recent development in the theory of production and its applications. Kim (1992) enumerates the cases for which the translog function has been used: to examine input substitution, separability and aggregation, technical change, productivity growth and productive efficiency. We ended up using the translog because of its so-called "superiority" compared to other functions e.g. the Cobb Douglas or Leontief production functions.

Chung (1994) supports the translog specification by stating that *the flexible nature of the translog production function has proven useful in bridging the gap between theoretical and empirical research*, i.e. it imposes no a priori restrictions on elasticities of substitution and returns to scale; it assumes neither homotheticity nor separability as the Cobb-Douglas, for example, does. If homotheticity applies, this means that the output shares of inputs are independent of the output (or that the optimal input ratio on the linear expansion path is independent of output levels). If separability applies, this means that if for example we have three inputs x_1, x_2 and x_3, then x_1 and x_2 are partitioned from x_3 such that input x_3 does not affect the marginal rate of technical substitution between inputs x_1 and x_3 (the technical definitions of homotheticity and separability are presented in Chung (1994) who also provides the

technical details for checking these conditions). Technical details for the latter are also reported in Sauer (2005).

The limitations of the Cobb-Douglas and Leontief production functions, which are also popular in agricultural applications, are discussed in this and the following paragraph. Starting from the Cobb-Douglas production function, homotheticity and separability apply, and thus the Allen-Uzawa partial elasticities of substitution between any pair of inputs must be constant, something which is not assumed for the translog function. The Allen-Uzawa partial elasticity of substitution, is defined as:

$$\sigma_{ij} = \frac{C\left(\partial^2 C / \partial w_i \partial w_j\right)}{\left(\partial C / \partial w_i\right)\left(\partial C / \partial w_j\right)} \quad i \neq j \ , \tag{2.7}$$

w_i is the cost of an input and C is the cost function. However, this assumption for the Cobb-Douglas is supposed to be restrictive and unrealistic.

On the other hand the Leontief production function is based on some logic clearly cut for the agriculture. It permits fixed proportions of inputs to determine output and it implies zero substitution between inputs (isoquants are L-shaped) if an output is produced by one particular activity. Zero substitution effects are not realistic either.

For all the above-explained advantages, we decided to use the translog function, but we can only estimate the production function and not the cost function, for reasons already mentioned.

Chung (1994) suggests that *empirical researchers should always check a posteriori that regularity conditions (monotonicity and convexity) hold in the translog production function.* Of course he additionally states that *the quadratic nature of the*

translog production function ensures it is monotonic and convex at least locally. However, as we know, we need the knowledge of regularity conditions only for facilitating maximization. Since in the context of the present application (remember out data deficiencies) we are unable to work in the profit maximization framework, we do not need to know whether our production function is monotonic or convex.

As far as separability conditions are concerned, these are tested econometrically in Tables 2.14 in text and 2.32 (for a full output in appendix 7.3.1). Without separability, the translog production function can accommodate a wide range of substitutabilities. *If however the underlying production structure is separable, so that all the relevant cross-product terms of inputs vanish from the translog equation, then the corresponding Allen-Uzawa cross partial elasticity of substitution is unity and remains so for any pair of inputs. This returns us to the Cobb-Douglas form* (Chung, 1994). Again however, given that we cannot go any further calculating substitution rates for the various inputs, checking whether separability holds, serves only to know which functional form is more appropriate to use, the translog or the Cobb-Douglas.

4.2.The sample size and input variables

The farmers'sample comprised initially 453 observations. We had to leave out farmers who did not irrigate at all (they had zero irrigated land) and those who had not answered in one or more of the input quantity questions. A number of farmers have been reported with zeros in some of their input responses, because they could not make an estimation of them. Zeros however prevented us from estimating the translog formulation since the log form requires positive numbers. Hence the deletion of those observations. Therefore, we ended up with a sample of 285 observations since we

decided to avoid the computational effort of bootstrapping techniques. Furthermore, the solution of replacing the zero input responses with a very small number, namely 0.001 that would be enough not to invalidate an observation (it worked with the log formulation necessary in the translog function) was soon abandoned because this would destroy both the mean and variance properties of the data and the numeric coefficients we would get, would be meaningless (Malley, 2004).

The particularities of data collection did not allow us much freedom in the representation of the production function. Due to the way input questions had been formulated in the questionnaire, some variables were expressed in money terms and others in physical terms The following variables were expressed in physical terms: olive oil output (kg), land (0.1 ha), water (m^3) and labor (days), while fertilizers-pesticides and capital in money terms (€). The difference in input measurement is also due to the fact that we wanted to facilitate reporting for farmers. It was easy for them to remember how much fertilizers cost them last year rather than the quantity of fertilizers they had used.

Physically expressed variables can be easily transformed in monetary amounts, because olive oil price, land and labor prices are the same across the sample. First for output, due to the market structure, olive oil cultivators sell to co-operatives, which more or less, buy the oil at the same price from producers. Below (Table 2.6) the Ministry of Agricultural Development presents, among others, a common yearly olive oil price for all producers. Prices are available until 2002, which is the year we sampled. Therefore, if we were going to use the output in money terms, we would only have to multiply the physical output amount by 2.04 €. Therefore, if we used the value output in the production function regression, we would only have inflated output by the same number.

Table 2.6. Olive oil production and price in the years 1993-2002.

Year	Number of trees	Production (tn)	Price (€/kg)	Net value of production
1993	106.248.762	268.000	1,74	466.866,6
1994	110.772.732	357.785	1,95	700.009,1
1995	114.003.029	407.450	2,33	950.342
1996	117.905.650	454.640	3,17	144.548,2
1997	121.182.101	453.000	2,46	111.659,3
1998	122.481.028	466.000	1,97	922.290,2
1999	130.769.382	413.000	2,08	859.561,2
2000	129.053.238	430.000	1,85	795.642
2001	135.505.900	451.500	1,94	835.424,1
2002	142.281.195	474.075	2,04	877.195,3

Source: Ministry of Agricultural Development and Food, Department of Agricultural Statistics

Olive oil producers sell their output to local co-operatives whose prices are predetermined for each type of olive oil. There are six such co-operatives in Crete shown in Table 2.7 with their price configuration from 4 April - 16 May 2005.

Table 2.7. Olive oil price (from 4 April-16 May) in the largest six co-operatives in Crete (Union of olive-oil producing municipalities in Crete, 2005).

Co-operative	4 April	18 April	25 April	3 May	9 May	16 May
EAS Kolimvari	2.76	2.76	2.67	2.67	2.67	2.67
Kolimvari S.A.	2.79	2.70	2.70	2.73	2.73	2.73
A.B.E.A.	2.73	2.73	2.67	2.67	2.67	2.73
EAS Rethimno	2.73	2.73	2.73	2.73	2.73	2.73
EAS Irakleio	2.73	2.73	2.73	2.73	2.73	2.73
EAS Peza	2.70	2.70	2.70	2.70	2.70	2.70

As it is obvious, prices offered by the six co-operatives differ only slightly on a certain day. For example on 4th April the range between the highest and the lowest price was nine cents, i.e. 3.3% of the lowest price. In our research we have not asked the farmers how much they sold their olive oil, because we knew there are not large fluctuations on this, and we could take this amount to be uniform for everybody.

As for land, according to data on subjective land values from Internal Revenue, they, too, are the same across Crete. Of course land prices may differ in real market conditions because they are subject to demand and supply rules. Olive land costs 3 €/m² (Ministry of Finance, 2000).

Last, labor price is again the same across Crete. Olive oil labor market works mostly with Albanian workers with a uniform wage for all of them. This wage is established through a silent agreement of all Albanian agricultural workers and it is black work. Workers can be met at specific labor market points (the city central square or the city exit etc) where they are picked up from their employers. An olive oil producer can hire different people every day.

Another data limitation is that we did not manage to separate the inputs and output quantity between irrigated and non-irrigated production. This would have been very cumbersome for the interviewee. The only variable that farmers had been asked to separate was land. The right thing to do would have been to estimate two separate production functions, one for the irrigated production and another one for the non-irrigated.

To recapitulate, we have adopted a physical approach in the production function through which we are seeking to observe the position water has in the cultivation of the olive tree compared to other inputs. The ideal situation would have been to estimate the production function with all inputs and output expressed as physical quantities. Given the fact that we cannot do the ideal thing, we have estimated a translog production function with output, land, water and labor in physical terms and fertilizers and capital in money terms. This does not distort our results in the same fashion the measurement scale in which a variable is expressed, would not change things much.

From standard econometric textbooks, we understand that the above is permissible. Maddala (1992) estimates a production function with data[1] on American output, labor and capital (for the years 1929-1967), with output expressed in dollars, labor in number of persons engaged in the production process and capital expressed in capital stock adjusted for rates of utilization. Then he re-estimates it with labor expressed as a labor index (number of persons adjusted for hours of work and educational level) and capital as capital stock in dollars. The results are not much different. He finally opts for the second model only because it has a slightly better R-squared and not for any other reason. According to this finding, it is legitimate to use a mixture of physical and money expressed inputs.

Besides, the estimation of the translog production with all variables expressed in money terms, would mean that we would inflate physical output by the uniform olive oil price, labor by a common wage and land by a common selling price. When we tried this (Table 2.42 in appendix 7.3), we received very high t-values, an R^2 equal to 1 and evidence of heteroskedasticity. Since remedying this would require to deflate all variables by a certain scalar (based on the assumptions done on the error variance form), inflating the physical input variables by their prices causes more problems than it solves. This is why the physical variable specification is regarded as the best to use. Table 8 provides a presentation of the variables we are going to use in the production function.

[1] His data came from L.R. Christensen and D.W. Jorgensen, "U.S. Real Product and Real Factor Input 1929-67" Review of Income and Wealth, march 1970 In Maddala (1992), Introduction to Econometrics, Prentice Hall, USA

Table 2.8. List of variables.

Variable name	Description
O = Output	Yearly olive oil output in kilograms
L = Land	Total olive land (both irrigated and non-irrigated) in 0.1 ha
W = Water	Yearly water quantity in m^3
F = Fertilizers	Yearly fertilizers and pesticides expenditure in €
La = Labor	Yearly labor in working days
C =Capital	Yearly capital expenditure in €

Table 2.14 provides the descriptive statistics of variables in Table 2.8. It is interesting to have a picture of them in mind, because it helps getting a better feel of the data at hand.

Table 2.9. Descriptive statistics of the inputs and output of the translog production function.

Statistics	L	W	F	La	C	O
Mean	28.2	2269.4	758.2	143.6	2099.9	3076.5
Median	20.0	1080.0	470.0	90.0	1200.0	2500.0
Maximum	400.0	37500.0	9094.0	2400.0	10836.7	30000.0
Minimum	1.0	12.5	6.0	4.3	100.0	150. 0
Std. Dev.	36.0	3713.9	1005.5	231.7	2291.3	2913.5

High standard deviations in Table 2.9 show the size of differences in input quantity responses. A relatively small standard deviation exists in land, which is a variable that can be easily and objectively calculated by the farmer. All the other input variables definitely contain a measurement or reporting error. The latter is summarized in what Chowdhury *et al.* (1975) state about the labor input measurement error: *A farmer will generally report that he works for twelve months per year. He is unlikely to concede that he is idle part of the time*. We believe that a similar situation is valid for all the input variables. We say more about this in the conclusions of this chapter.

It would be interesting to be able to confirm the truthfulness of the means of the variables reported in Table 2.9 by comparing them with official data. However, the only data we could get hold of, were the mean land size. In Table 2.10 we get this to

be 42.25 0.1ha in Crete, while based on our sample findings we receive it to be 28.17 0.1 ha.

Table 2.10. Number of agricultural holdings, their utilized agricultural area and average area per holding, by Region (National Statistics Service, 2004).

Region of Greece	Holdings with utilized agricultural area	Utilized agricultural area (rough grazings also included)	Average area per holding (in strema)
Total Greece	811,318	35,831,852.7	44.16
East Macedonia- Thrace	63,373	3,548,881.9	56.00
Central Macedonia	115,404	6,351,012.8	55.03
West Macedonia	29,100	2,076,891.3	71.37
Thessaly	78,215	4,110,156.1	52.55
Epirus	42,745	1,243,086.0	29.08
Ionian islands	31,521	850,431.9	26.98
West Greece	92,099	3,167,722.9	34.39
Sterea Elada	79,332	3,506,375.4	44.20
Peloponnesus	103,385	3,825,913.4	37.01
Attica	25,901	539,528.4	20.83
North Aegean	34,490	1,561,470.6	48.06
South Aegean	23,858	1,083,645.2	45.42
Crete	93,895	3,966,736.8	42.25

Another way of checking the truthfulness of our data is through factor cost contribution to total cost of production. Table 2.11 presents such an allocation. If we translate all the mean variable inputs of Table 2.9 in money terms (two of them already are in this form), i.e. we multiply them with the total factor prices we have, we get that the mean yearly olive oil production cost is 93,000.78 €. From this amount 5.4% goes to labor. The largest part, 90% goes to land while 2.25% goes to capital. Comparing our findings with those of Table 2.11 we see there are large deviations. In Table 2.11, land cost is taken to be the land rent. In our sample we have included only landowners and we have used the selling price of land to be its cost. This is much higher than the rent and of course and it inflates the total cost amount. Furthermore, in the capital calculation of our sample, we have not included farmers' debt and

buildings. The latter occurred because there are not any buildings built for business use in Cretan agriculture. Farmers store their machines and crops in their houses. Last, management has not been included as an input, but it is one (Cramer *et al.*, 1997).

Table 2.11. Yearly remuneration indices for factors of production in agriculture, base year 2000 (Greek statistics service, 2004).

Factors of agricultural production	Weighting coefficient	
General index	10.000	100%
1. Labour (daily wages)	2.917	29%
2. Land (land- rents)	2.190	22%
3. Capital	4.893	48%
- Capital rents	2.909	
- Loan servicing	1.984	

Now we will resume the discussion with the estimation of a translog production function.

4.3. Model 1

Least squares is used for the estimation of the following relationship:

$$O = f(L, W, F, La, C) \tag{2.8}$$

Variable names have been explained in Table 2.8. With *f* we represent the relationship between the dependent and the independent variables, which will be the translog specification for reasons mentioned in section 4.1. Chung (1994) writes an the n-input production function of the form:

$$\ln y = \ln a_0 + \sum_{i=1}^{n} a_i \ln x_i + \frac{1}{2}\sum_{i=1}^{n}\sum_{j=1}^{n} \beta_{ij} \ln x_i \ln x_j,\ i \neq j;\ i,j=1,\ \ldots,n \tag{2.9}$$

y is the output and x_i is input *i*. The results we obtained are presented in Table 2.12. The production function has been estimated with land, water and labor as physical inputs, capital and fertilizers as money inputs and output in physical form. Significant terms are in bold.

Table 2.12. Model 1; Translog production function with physical inputs (land in 0.1ha) and output. Capital and fertilizers expressed in €.

	Coefficient	Std. Error	t-Statistic	Prob.
Log (Constant)	3.813328	1.395204	2.733168	0.0067
Log (Land)	0.643560	0.412639	1.559621	0.1200
Log (Water)	0.048906	0.219434	0.222874	0.8238
Log (Labour)	-0.240628	0.337252	-0.713497	0.4762
Log (Fertilizers)	0.730945	0.243923	2.996625	**0.0030**
Log (Capital)	-0.250483	0.253692	-0.987353	0.3244
Log(Land)*Log(Water)	-0.158819	0.059125	-2.686135	**0.0077**
Log(Land)*Log(Labour)	0.256352	0.106403	2.409252	**0.0167**
Log(Land)*Log(Fertilizers)	0.159743	0.112257	1.423008	0.1559
Log(Land)*Log(Capital)	-0.238888	0.112828	-2.117277	**0.0352**
Log(Water)*Log(Labour)	0.090792	0.063085	1.439201	0.1513
Log(Water)*Log(Fertilizers)	-0.127570	0.068105	-1.873125	0.0621
Log(Water)*Log(Capital)	0.143314	0.064252	2.230505	**0.0265**
Log(Labour)*Log(Fertilizers)	-0.238754	0.093163	-2.562763	**0.0109**
Log(Labour)*Log(Capital)	0.110576	0.095862	1.153490	0.2497
Log(Fertilizers)*Log(Capital)	0.015489	0.068702	0.225456	0.8218
R-squared	0.655315	Adjusted R-squared		0.636094

Note: Full output in Table 2.26 in appendix 7.3.1

Based on Table 2.12, the following variables were significant: Fertilizers and the interaction of land with water, land with labor, water with capital and labor with fertilizers. The log expressions can lead us speak of the elasticity of output with respect to an input cost. This means for example that if fertilizers *ln* expenditure increases by 1 €, then output will be increased by (0.73-0.23*ln*(L)) kg. Assuming for convenience of calculation that L=e ≈ 2.7 € then ln(L)=1. So, output will be increased by 0.73-0.23=0.5kg or 500gr of olive oil.

Water, in which we are most interested, was not significant by itself, but only through the interaction with other variables. We also see that among all the significant interactions, water interactions with other variables had the smallest coefficients.

4.4. Robustness of Model 1

Robustness of Model 1 is examined through: i) Wald test for significance of the total model. According to Table 2.52, Model 1 is significant as a whole. Wald test rejects the null hypothesis that all coefficients (except constant) are jointly zero, so our model is significant, and ii) The adj R^2=0.63 (Table 2.12) which is regarded as satisfactory.

In order to make sure that we have a model capable to rely on for predictions, we also need to check for the presence of heteroskedasticity. We thought there might be some since we have sampled from farmers with small and large farms and they could be expected to give distinctively different answers. If they did, the error variance would not be constant for both groups of farmers, and this would mean that we should have two production function models, one for "small" and one for "big" farmers. However the White test that follows in Table 2.13 and the residuals graph in Figure 2.16 (appendix 7.3.2), do not confirm the existence of heteroskedasticity at 5%. The null hypothesis of no heteroskedasticity against heteroskedasticity of some unknown general form could not be rejected at 5% in Table 2.13. Therefore, we resumed the analysis with a common production function containing both "small" and "big" farmers. The dividing line among "small" and "big" farmers would have been taken to be the output size.

Table 2.13. White heteroskedasticity test for Model 1.

White Heteroskedasticity Test:			
Obs*R-squared	8.354073	Probability	0.594294

Note: Full output in Table 2.27 in appendix 7.3

The statistic shown in Table 2.13 is the number of observations multiplied by the R^2 of the regression shown in Table 2.27 of appendix 7.3.1. The White's test statistic is asymptotically distributed as a χ^2 with degrees of freedom equal to the number of slope coefficients in the test regression. Inexistence of heteroskedasticity is also confirmed through a view of the regression residuals graph (Figure 2.16 in appendix 7.3.2) and a residuals normality test (Figure 2.6). Figure 2.16 does not show the so-called "fan" shape we expect to see when heteroskedasticity is present but the normality test (just to double check) shows that the residuals do not approximate the bell shape of the normal distribution.

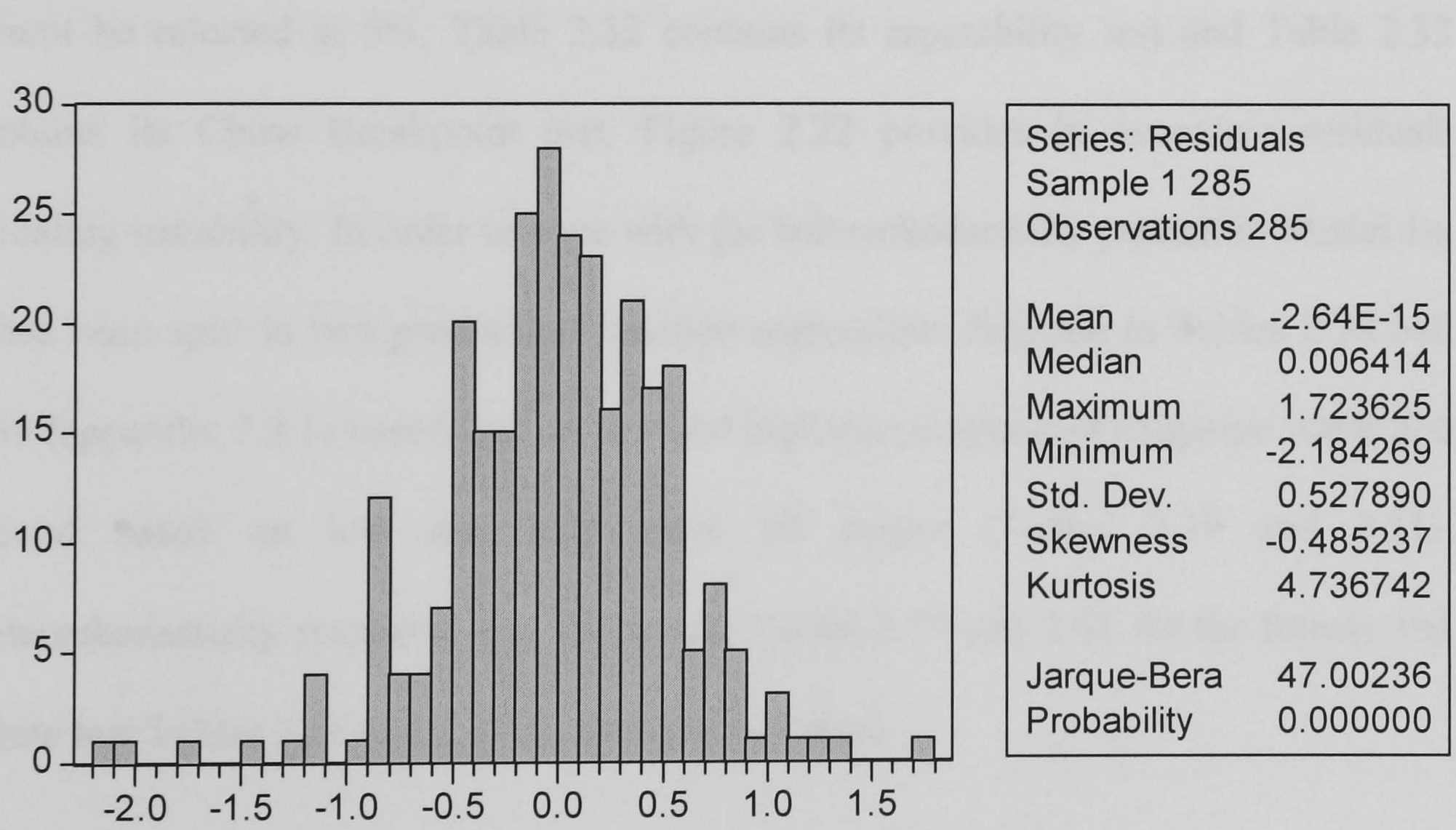


Figure 2.6. Normality test of Model 1 regression residuals.

Now we continue our discussion by checking the separability conditions of the translog production function, namely we examine whether the interaction terms in Model 1 vanish and whether the translog function collapses to the Cobb-Douglas

specification. Table 2.14 shows that we can decisively reject the null hypothesis that the coefficients of all interaction term variables are zero. Hence our estimated production function does not collapse to the Cobb-Douglas.

Table 2.14. Wald test on separability conditions in Model 1.

Test Statistic	Value	df	Probability
F-statistic	3.690650	(10, 269)	0.0001
Chi-square	36.90650	10	0.0001

Note: Full output in Table 2.28 in appendix 7.3.1

Last, we have also estimated a version of Model 1 with irrigated land as percentage of total land (Table 2.30 in appendix 7.3.1). Let us call it from now on Model 1a. Results from this model are not any better than Model 1. Figure 2.17 (appendix 7.3.2) is the residuals graph for Model 1a. Table 2.31 (in appendix 7.3.1) is its White test for heteroskedasticity, according to which the null hypothesis of heteroskedasticity cannot be rejected at 5%. Table 2.32 contains its separability test and Table 2.33 contains its Chow Breakpoint test. Figure 2.22 provides its recursive residuals revealing instability. In order to cope with the heteroskedasticity present in Model 1a, it has been split in two production function regressions depicted in Tables 2.38 and 2.39 (appendix 7.3.1) based first on low and high consumption of irrigation water and second based on low and high olive oil output (Tables 2.39 and 2.31). Heteroskedasticity persisted. See White test Tables 2.39 and 2.41 for the former and White test Tables 2.35 and 2.37 for the latter solution.

4.5. Model 2

We continue with the estimation of the production function with all inputs and output expressed in money terms. Estimation results are provided in Table 2.15.

Table 2.15. Translog production function with monetary inputs and output.

	Coefficient	Std. Error	t-Statistic	Prob.
Log (Constant)	0.712950	5.82E-12	1.22E+11	0.0000
Log (Land)	8.50E-12	8.78E-13	9.679706	0.0000
Log (Water)	-3.33E-12	5.20E-13	-6.394086	0.0000
Log (Labour)	7.75E-12	9.20E-13	8.422668	0.0000
Log (Fertilizers)	7.78E-14	9.72E-13	0.080094	0.9362
Log (Capital)	1.000000	9.98E-13	1.00E+12	0.0000
Log(Land)*Log(Water)	-3.42E-13	1.25E-13	-2.727838	0.0068
Log(Land)*Log(Labour)	-9.29E-13	2.22E-13	-4.190746	0.0000
Log(Land)*Log(Fertilizers)	-1.41E-13	2.30E-13	-0.612313	0.5408
Log(Land)*Log(Capital)	-1.00E-12	2.23E-13	-4.502775	0.0000
Log(Water)*Log(Labour)	1.05E-12	1.38E-13	7.562088	0.0000
Log(Water)*Log(Fertilizers)	5.23E-14	1.29E-13	0.404517	0.6862
Log(Water)*Log(Capital)	4.09E-13	1.35E-13	3.026293	0.0027
Log(Labour)*Log(Fertilizers)	-9.99E-13	1.47E-13	-6.787362	0.0000
Log(Labour)*Log(Capital)	-4.48E-13	1.97E-13	-2.276626	0.0236
Log(Fertilizers)*Log(Capital)	9.03E-13	2.00E-13	4.518228	0.0000
R-squared	1.000000	Adjusted R-squared		1.000000

Note: Full output in Table 2.42 in appendix 7.3.1

The money value variables gave significant results for most of the regression terms and an R-squared equal to unity, which cannot be realistic. In addition to this, the null hypothesis of heteroskedasticity cannot be rejected at 5%, so this model is not to be relied on for predictions. In addition to the usual White test, the residuals normality test (Figure 2.7) shows that their distribution is not the bell-shaped one but rather more left skewed.

Table 2.16. White heteroskedasticity test for Model 2.

White Heteroskedasticity Test:			
Obs*R-squared	37.02111	Probability	0.000056

Because, the presence of heteroskedasticity could be due to the fact that different groups of farmers have given distinctively different input or output variables, e.g. this could mean that the production function of small farmers is different to the one of big farmers, we divided the sample in two parts again; Division of big and small farmers

based on their output size was no improvement either (Tables 2.44 and 2.45) i.e. heteroskedasticity persisted.

Remedying heteroskedasticity is a complicated situation and in our case it appears that this money transformation of variables causes more problems than it solves. To be more precise, there are two broad categories of heteroskedasticity solution. One solution concerns making particular assumptions about the σ^2 of the error. For example the error variance may be known up to a multiplicative constant, i.e.

$$V(u_j) = \sigma^2 z_i^2 \tag{2.10}$$

Heteroskedasticity solution would mean to divide all independent and the dependent variable by z_i and then estimate a new regression of the type

$$\frac{y_i}{z_i} = a\frac{1}{z_i} + \beta\frac{x_i}{z_i} + v_i \tag{2.11}$$

The other solution is more general; It is about dividing all regressors and regressand with any regressor variable we see fit (by trial and error). This would deflate all variables by the size of the deflator with the same purpose as above, i.e. to obtain more efficient estimates. However, as mentioned previously deflation may itself cause unreal correlations between regressors and then create additional problems. In our case, we thought it would be a redundant exercise to proceed with such treatments, because we already have estimated a robust production function (Table 2.12). Hence we conclude that Model 1 is the best to keep and our discussion from this point on concentrates on it.

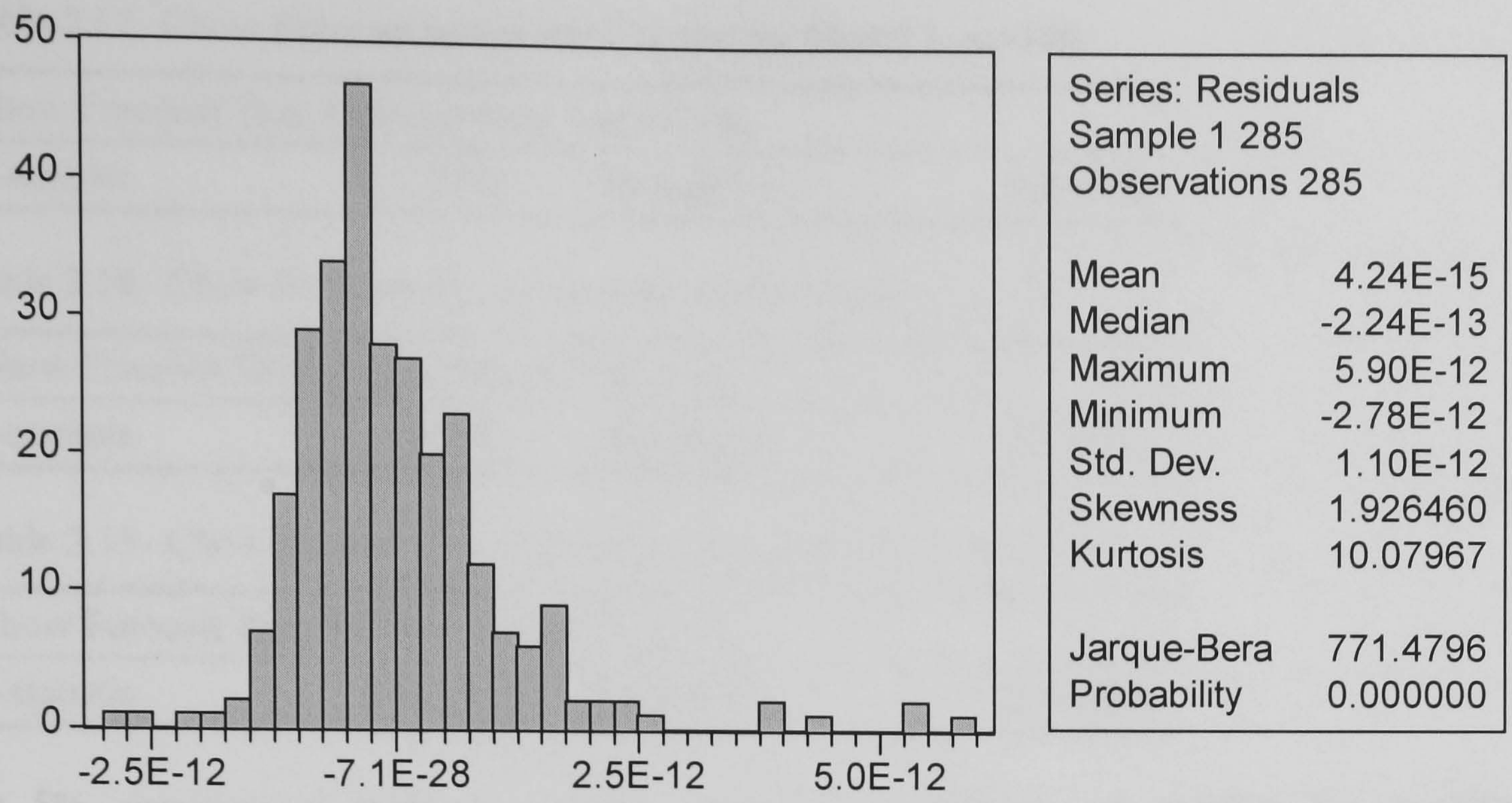


Figure 2.7. Normality test of residuals from Model 2.

4.6. Stability of Model 1

It is common in multiple regression analysis to be concerned with the stability of the estimated relationship, across sub-samples. We use the Chow test to check the stability of Model 1. The idea behind this is that we use the first $n_1$observations to estimate the regression equation and then use it to get predictions for the next n_2 observations. Then we test the hypothesis that the prediction errors have mean zero. The F- test is given by

$$F = \frac{(RSS - RSS_1)/n_2}{RSS_1/(n_1 - k - 1)} \qquad (2.12)$$

which has an F distribution with degrees of freedom n_2 and n_1-k-1. RSS is the residual sum of squares from the regression based on n_1+n_2 observations; this has (n_1+n_2)-(k+1) degrees of freedom. RSS_1 is the residual sum of squares from the regression based on n_1 observations; this has n_1-k-1 degrees of freedom.

Table 2.17. Chow Forecast test as stability test for Model 1, n_1=180.

Chow Forecast Test: Forecast from 180 to 285			
F-statistic	1.259456	Probability	0.092327

Table 2.18. Chow Forecast test as stability test for Model 1, n_1=200.

Chow Forecast Test: Forecast from 200 to 285			
F-statistic	1.135544	Probability	0.237781

Table 2.19. Chow Forecast test as stability test for Model 1, n_1=250

Chow Forecast Test: Forecast from 250 to 285			
F-statistic	1.024847	Probability	0.436886

At 5% significance level we cannot reject the hypothesis of stability for n_1=180 n_1=200 or 250 (as seen in Tables 2.17, 2.18 and 2.19). Therefore there is stability in Model 1.

4.7. Sensitivity analysis of Model 1

Observing the large variance in all input coefficients and the non-significant variables, we naturally worry about how trustworthy these input variable data are and if they are not, how this situation can be rectified. This question can be answered through sensitivity analysis. A point that has to be clarified is that in our case, since data collection has been done and finished, the results of a sensitivity analysis would only constitute a topic for further research, since we do not use these results in a prognostic but a diagnostic way.

To begin with a definition (European Commission, 2005): *Sensitivity analysis (SA) is the study of how much the variation in the output of a model can be apportioned qualitatively or quantitatively to different sources of variation.* Saltelli *et al.* (2005) quote from Leamer (1990) on the usefulness of sensitivity analysis : '*I have proposed a form of organised sensitivity analysis that I call ' global sensitivity*

analysis' in which a neighbourhood of alternative assumptions is selected and the corresponding interval of inferences is identified. Conclusions are judged to be sturdy only if the neighbourhood of assumptions is wide enough to be credible and the corresponding interval of inferences is narrow enough to be useful'.

Some of the most common reasons why one would like to perform sensitivity analysis, (European Commission, 2005) are i) The model resemblance with the process under study and the quality of model definition, ii) factors that mostly contribute to output variability, iii) the region in the space of input factors for which model variation is maximum, iv) interaction between factors etc. We are interested in examining the second, third and fourth points as we have already mentioned in section 4.2 and this one. As far as the first point is concerned, we have explained in section 4.1 why we have persisted in the translog function. The choice of the sensitivity analysis method depends on the problem the investigator is trying to address, the characteristics of the model under study and the computational cost that the investigator can afford. To answer questions such as ii, iii and iv, we need to calculate first order and total sensitivity indexes for the output variable.

4.7.1.The first order sensitivity index

A measure of sensitivity of Y to an individual input variable X_i is: $V\left[E\left(Y/X_i\right)\right]$, i.e. the expected amount of variance that would be removed from the total output variance, if we were able to learn the true value of X_i. This is called main effect. If we divide the main effect by the unconditional variance, we obtain the first order sensitivity index for variable X_i written as:

$$S_i = \frac{V[E(Y/X_i)]}{V(Y)} \tag{2.13}$$

A high value of S_i corresponds to an input variable i giving a consistent contribution to the model output variance. This will tell us where we need to focus our further research e.g. get more observations, get a proxy for a certain variable etc.

4.7.2. The total effect sensitivity index

This index is used to identify unessential variables, i.e. those that are not important. It is given by:

$$S_{T_i} = \frac{E[V(Y/X_{-i})]}{V(Y)} \tag{2.14}$$

The nominator is the expected amount of output variance that would remain unexplained (residual variance) if X_i were left free to vary over its uncertainty range, all the other variables having been learnt (X_{-i} are all the input variables except X_i). Input variables with a low effect sensitivity index can be frozen to any value within their range of uncertainty.

We performed our sensitivity analysis in SimLab 2.2 (Simulation Environment for uncertainty and sensitivity analysis). This is piece of software designed specifically for Monte Carlo- based uncertainty and sensitivity analysis. The procedure we followed was to set up an 800 sample (the program did not work for a smaller sample), which would resemble the distribution properties (mean and

variance) of the variables we had in model 1. Then we specified the relationship between the variables and we fed this with the sample elements we had created. These models evaluations created a mapping from the space of inputs to the space of the results and it is this mapping that is used as a basis for subsequent uncertainty and sensitivity analysis. We have employed the FAST method for sensitivity analysis, which calculates the first order sensitivity indices and the total ones.

Uncertainty analysis determines the uncertainty in the estimates for the dependent variables of interest. Sensitivity analysis determines how much of this uncertainty is due to each of the variables. If the uncertainty in the dependent variable is within acceptable bounds, there is no reason why we should continue with sensitivity analysis. Because, however, we do not know what the acceptable bounds of uncertainty are, we will proceed with sensitivity analysis anyway and we will answer which of the variables contributes more to the variability of the output. Table 2.20 contains the first and total order indexes of the outcome variable.

Table 2.20. First and total order indexes for input variables of model 1.

	First order index, S_i	Total order index, S_{Ti}	$S_{Ti} - S_i$
Land	7.54e-0.05*	0.02	≈ 0.02
Water	0.6698	0.71	0.04
Fertilizers	0.03	0.05	0.02
Labor	0.0044	0.05	0.04
Capital	0.2715	0.31	0.03

* This is a very small number

When $S_{Ti} \approx 0$, then the input variable i does not influence the model. Therefore the variable i can be frozen to any value within the range of variation, because it does not contribute to the output variance. This is land in our application (pairwise correlation among pairs of inputs and output in Figure 2.23 in appendix 7.3.2 cannot reveal this).

A high value of S_i corresponds to an input variable giving a consistent contribution to the model output variance. Water is such a variable in our application. According to this finding, new research should be directed to these variables, in order to reduce their uncertainty.

The difference S_{Ti}- S_i indicates the strength of the pure interaction in which variable i can be involved. This shows that water and labor may be involved in interactions with other variables. This is true for model 1 (also capital appears significant in interactions).

Last the cobweb plot in Figure 2.25 (in the appendix) shows the production inputs as vertical bars, while the sample units are depicted as polylines touching all the factors. Simlab does not visualize the entire sample set, it selects randomly 100 sample units of those generated. Obviously, the set we have picked up is not uniformly spread on the 90% intervals of each factor, showing that more observations should be sought to cover the right hand side of each interval.

5. FRESH WATER AVERAGE AND MARGINAL PRODUCTS IN OLIVE OIL PRODUCTION

According to standard microeconomic theory, total product curves (TP) are approximately bell-shaped (Figure 2.8a). They increase at first, reach a maximum, then decrease. Since both the average product (AP) and the marginal product (MP) are derived from TP, there is a known relationship among them. Furthermore, when MP is above AP, the latter will be increasing and when MP is below AP, the latter will be decreasing. If MP and AP intersect at all, the MP curve intersects the AP curve at the maximum of the latter. This is described in Figure 2.8b.

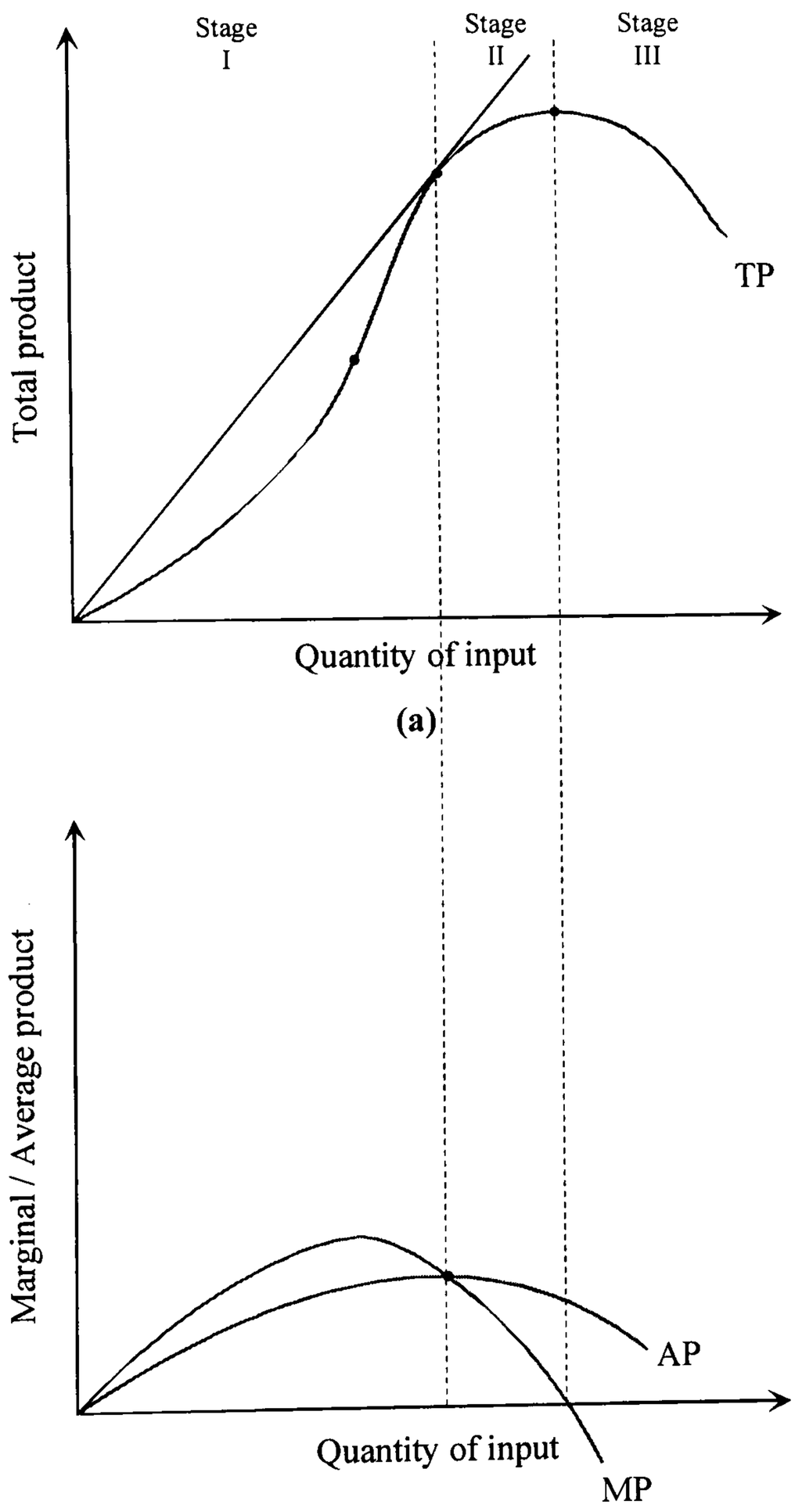


Figure 2.8. Total, average and marginal product in the "three stages of production".

Based on the classical three-stage separation of production, we are going to find out in which stage of production olive oil producers work in. According to Dobson *et al.* (1989), it is unwise and inefficient to stop production in stage I, because producers can increase productivity of all input units since a large quantity of the fixed input (land, capital, labour and fertilizers in this case) is underused (of course Dobson *et al.* as well as most writers of standard microeconomics textbooks use the labor input in their examples) whose nature is different from scarce water (which is the object of our study).

In stage III, TP is diminishing and thus MP is negative. At this stage there is unused quantity of the variable input. Stage III should also be avoided because here more output can be produced by using less input or differently phrased a large quantity of labor is underused in an analogous pattern fixed input was underused in stage I. Gould and Lazear (1989) say that *such inefficiencies will always be avoided in cases of scarce inputs,* like irrigation fresh water in our case. In stage 2 marginal productivity of the variable input is smaller than the average i.e. we have the opposite from what we observed in stage I. This stage starts at a point where marginal product equals the average and ends where marginal product becomes zero. Thus, for inputs other than scarce ones, stage II is the only efficient one to produce in. However, for irrigation fresh water, both stages II and III are efficient.

Although the traditional classical framework is restrictive from many aspects e.g. the one-input assumption, and the fact that it is usually used for pedagogical purposes, the quality of the data at hand prevented us from more sophisticated handlings of them. We refer to the handicaps of the data and how they came about, in part 4 of this chapter. In sections 5.1, 5.2 and 5.3 we present and comment on the TP, AP and MP curves for irrigation fresh water.

5.1. Fresh water total product

We have plotted total product (in kg), namely output, with water input in m^3 and we have fitted a hyperbolic trend line to show the relationship between them, because it had a better fit that the linear one or the exponential and others. According to the line equation in Figure 2.9, if the water input increases by 1 m^3, then output increases by $0.2204 * 1^{1.0726} = 0.22$ kg. In other words, an increase of 0.27 € water worth (this is the mean water price per m^3 paid by our sample), produces a 0.22 olive oil kg worth which makes 46 cents. Obviously a unit increase in input corresponds to less than a unit-increase in output.

According to this finding, the situation with water shortage is not so bad after all. If a unit increase in water input caused a unit or higher increase in output, that would make water's contribution to output increase, larger. This situation may be explained by the fact that throughout the year, water is adequate after all. Scarcity is felt during the summer months, because there is no infrastructure to store winter rainwater and use it in the summer or early autumn. Farmers have difficulty in finding the water they need during the aforementioned period and this can destroy their cultivations or seriously reduce their yield. This could be eloquently described with an example from human beings. If humans do not drink water for five days, they die, in spite of the fact that they had been drinking adequate water all the year before the five days abstention. It is the same with olive trees, only that the olive tree has a longer endurance to water abstention. In conclusion this is the reason why, on the one hand farmers complain about water shortage and on the other hand, water does not appear as inadequate.

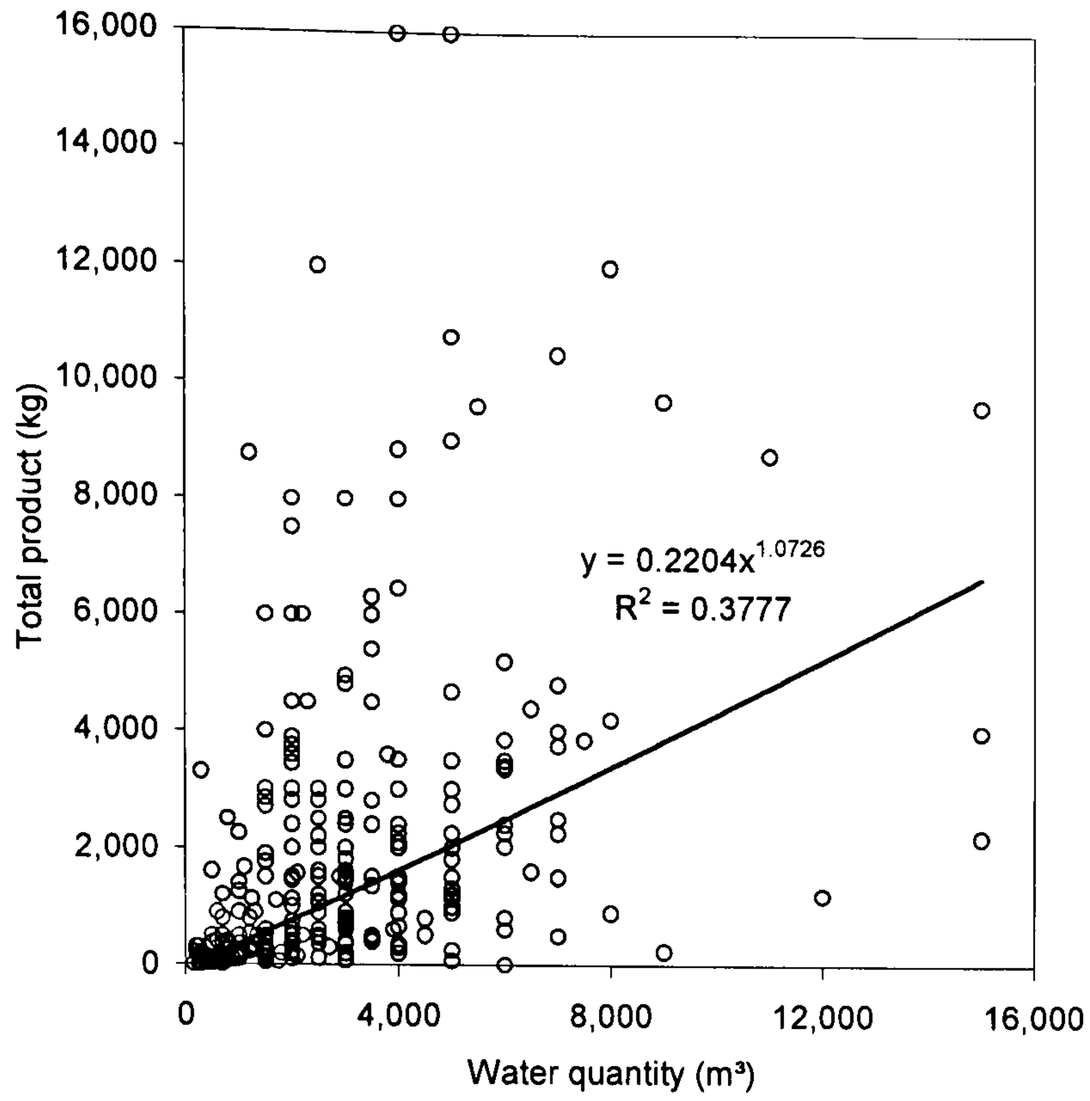


Figure 2.9. Total product of fresh water.

5.2. Fresh water average product

Average product of water is the quotient of total product divided by the water quantity. It is output per 1m³ of water. In Figure 2.10, it is diminishing first steeply and then more smoothly. Finally it becomes almost stable, and approaches zero. This tells us that the output rate of increase is smaller than the water demand rate. From quantity 2500m³ onwards, AP stabilizes to a very small amount, telling us that it is probably other factors beyond water that can increase output. It could be more fertilizers or more labor or even better quality of land etc. Or we should abide by the reasoning we gave in section 5.1, namely that water scarcity during a specific period of time in summer reduces output size, which ends up being too small, compared to the large quantities of water required to produce it.

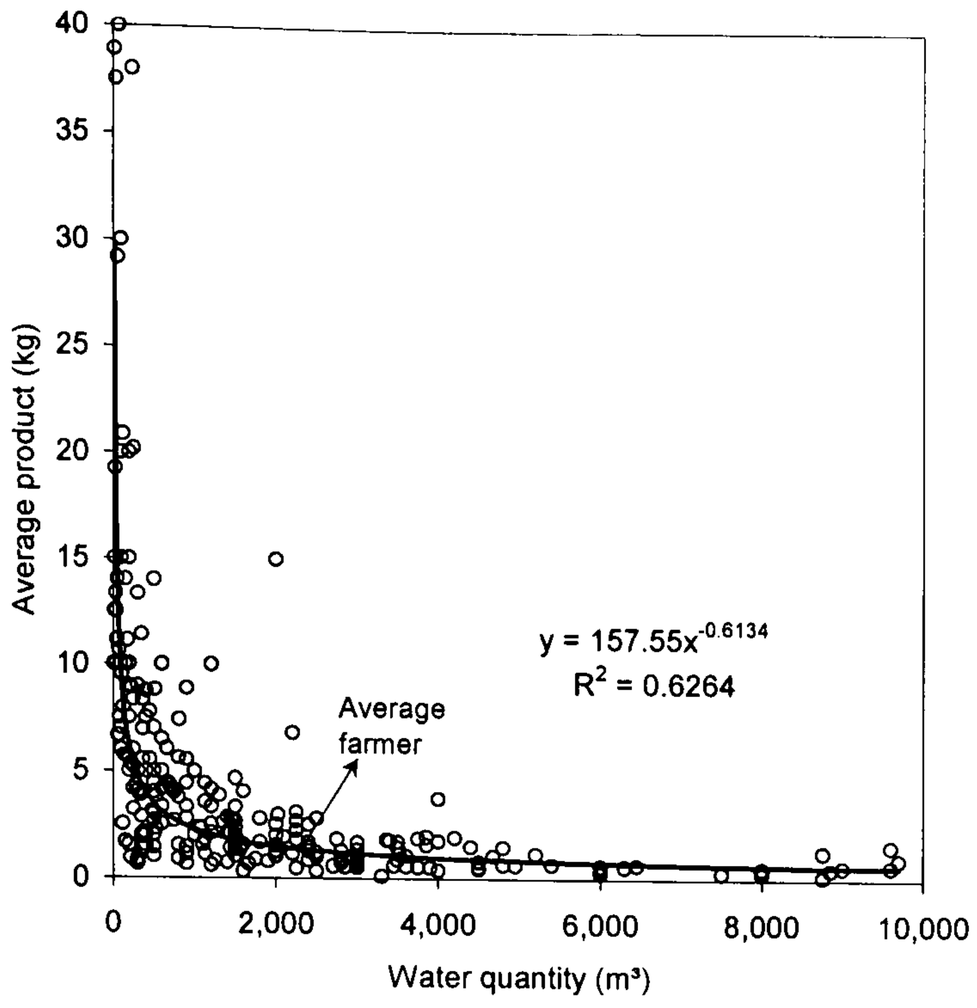


Figure 2.10. Average product of fresh water.

5.3. Fresh water marginal product

MP is given by the first derivative of the production function with respect to water quantity. So, from the production function in Table 2.17 that derivative was:

$$\frac{\partial Output}{\partial Water} = 0.04 * \left(\log(W)\right)' - 0.15 * \log(L) * \left(\log(W)\right)' + 0.09 * \log(La) * \left(\log(W)\right)' - 0.12 * \log(F) * \left(\log(W)\right)' + 0.14 * \log(C) * \left(\log(W)\right)' \quad (2.15)$$

where W stands for water, L for land, La for labor, F for fertilizers and C for capital.

This relationship is condensed to:

$$\frac{\partial Output}{\partial Water} = 0.04 * \frac{1}{W} * \left(-0.15\log(L) + 0.09\log(La) - 0.12\log(F) + 0.14\log(C)\right) \quad (2.16)$$

In Figure 2.11, MP has been represented with a logarithmic trend line because this type of line had the best fit (among others such as the linear etc). The MP line follows almost the same pattern as the AP does. In addition to this, it takes negative values. Normally under standard microeconomic theory assumptions, MP first increases then

reaches a maximum and starts declining due to diminishing returns. The first derivative of the production function with respect to water input tells us how much output will change if there is an infinitesimally small change in water input. Thus the shape in Figure 2.11 tells us that effect will be decreasing, showing that a consecutively small increase in water input will decrease output. Moreover, there is evidence of diminishing returns (because of the negative values in MP), which shows that cultivations could not absorb more water.

Furthermore, in this analysis (juxtaposing Figures 2.10 and 2.11) AP is always found above MP. As we observe from Figures 2.9, 2.10 and 2.11 for the behavior of total, average and marginal products respectively, they do not follow the distinctive patterns of the three stages of production as dictated by standard microeconomic theory. Rather they appear to fall "more" under the 2nd stage of production. The reason we say "more" is that they are not exactly what the 2nd stage of production in standard microeconomic theory prescribes, because AP and MP do not meet. The fact that olive oil production characteristics resemble more the ones in stage II, means that it is efficient as regards water. Because water is a scarce input, production would be efficient even at stage III, because less water would be necessary for the production of more olive oil.

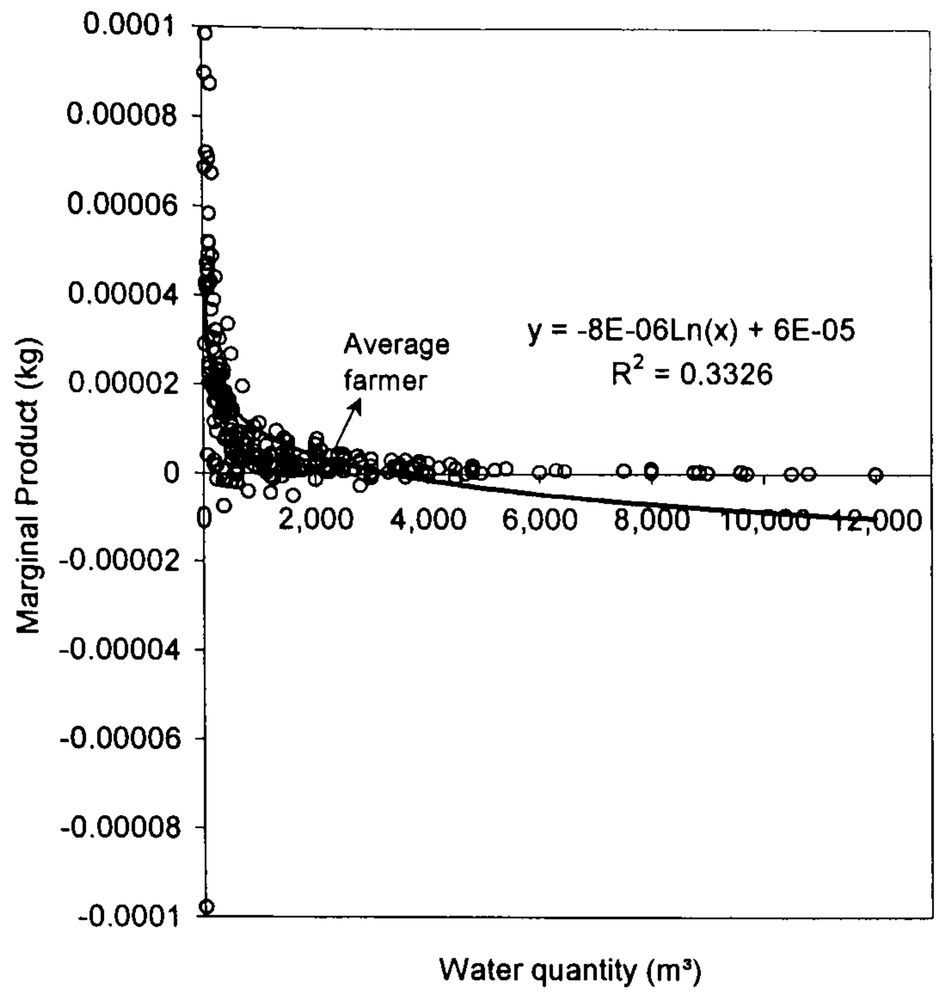


Figure 2.11. Marginal product of fresh water

Mean irrigation water demand is 2269 m³. The arrows in Figures 2.10 and 2.11 show at which point on the AP and MP curves the average farmers is. This is 1.37 kg for AP and almost zero for MP.

6. CONCLUSION

Given the data limitations we were confronted with (and we have discussed in section 4), we had to continue with the second best approach, which was a more descriptive analysis through a production function alone (without the corresponding cost function) and a demand function.

As far as the latter is concerned, the huge water price variation and the fact that quantity has been expressed on a yearly basis and not for the three arid summer month period, have led to a not so accurate representation of the problem of water shortage, which happens to be the departure point of the present analysis. Fresh water shortage causes searching other irrigation solutions such as recycled water.

Therefore, as far as fresh water demand for irrigation is concerned, there is a very weak relationship between quantity and price. The very small demand slope coefficient reveals the little responsiveness of quantity to price changes and of price to quantity changes. For large water quantities demanded, price stabilizes to 0.24 €/m³. At this price, every possible quantity is demanded. The almost horizontal demand curve reveals the water scarcity. Also, we deduce that the price of 0.24 €/m³ maybe appears as a minimum threshold price. A policy result that comes from this observation is that if farmers (in chapter 3) declare themselves as willing to use recycled water (we will find out that they do), then recycled water price could start from 0.24 €/m³ and below. Vakalis (1996) in his study on the factors that affect irrigation water demand found that prices were the least important factor. The most important factors have been water saving technology, irrigation methods and cultivation expected yield.

MP is decreasing first abruptly and then it becomes almost a straight line. This shows that water has not reached the point where it can be regarded as so abundant in olive oil production that an extra unit of it will decrease output. The almost straight line MP, tells that an extra unit of water will not increase output either, but it will keep it constant. This shows a situation where water is abundant, despite the statement of 53% of farmers that in the past three years they had faced problems in finding the water they needed. We should note here that water may be adequate as a yearly whole, but it is inadequate at a specific summer period, which is crucial for the development of olive crops. This peculiar situation becomes clear with an eloquent example derived from the human organism. If humans do not drink water for five days, they die, in spite of the fact that they had been drinking adequate water all the year before the five days abstention. It is the same with olive trees, only that the olive tree has a longer endurance to water abstention.

The decreasing average product further strengthens the above explanation. The per-unit increase in water produces less output. This shows that water contribution to output production has reached a saturation point. More water will not increase output. It is other production inputs or a specific combination of them that can probably achieve that. As regards this point, when we estimated the translog production function, the only inputs that were significant were fertilizers by themselves and the interaction of water with land and with capital.

The author believes that the above findings have been affected by the data deficiencies and special handlings we did at various points and have discussed throughout the chapter (see part 4). They are additionally affected by:

i) The sample synthesis we used to estimate the production function. We have isolated 286 observations from the 453 initial available ones, because only those 286

farmers were both irrigators and had given values for all the other inputs (farmers with zero water quantity or zeros in other inputs could not be included in the translog specification because this function type contains log transformations and thus zeros are undefined). The excluded 167 farmers were either non-irrigators, due to water lack in the areas where their fields are, or they had not given values for one or more of the other inputs. If the 167 excluded farmers had been included in analysis, results could be different.

ii) The production function data suffer from measurement and reporting errors which are due to the low educational level of farmers (answering some of the questions demanded cognitive skills from their part, e.g. they could not transform hours of irrigation in water m^3).

iii) The data probably suffer from strategic bias, since farmers probably are very likely to have tried to conceal the real size of their olive oil output (by stating a smaller amount) and inflate the size of inputs (by stating high quantities and high prices). This may have happened because despite the researchers' reassurance towards farmers, the latter still had the suspicion that this data would be crosschecked with Inland Revenue or other government departments relative to farmers.

iv) Survey question structure with respect to water quantity used. Interest should probably have been focused on water demand in summer months only.

v) Lack and inability to collect more sophisticated data such as soil synthesis, density of plantation, type and age of olive oil, evapotranspiration conditions, humidity etc.

Due to all the above reasons, water shortage is not making itself clearly felt in the total, average and marginal product analysis of olive oil production. However, as

evidence in favor of a water shortage situation in agriculture, we have 53% of all the enquired farmers (sample of 453) who admitted they had faced problems in finding the water they needed for their cultivations in the last three years. Last, the sample of irrigators has mean irrigated land (as a percentage of total land) to be 84%. This proves that even farmers who appeared as irrigators, leave some of their land to be unirrigated due to water shortage.

Thus, additional irrigation water is necessary and more than welcome by many farmers. It remains to see in the following two chapters, whether farmers and consumers are willing to use and pay for recycled water as an alternative and supplementary irrigation solution.

References

Bateman I.J., Carson R.T., Brett D., Hanemann M., Hanley N., Hett T., Jones-Lee M., Loomes G., Mourato S., Özdemiroğlou E., Pearce D., Sugden R. and Swanson J. (2002). *Economic Valuation with Stated Preference Techniques. A Manual*, Edward Elgar, pp. 458

Cavazza L., Patruno A., Rossi P., DeSeneen M.O. and Gammino M. (2005). Evaluation of an irrigation scheduling programme for providing advice to farmers (available at: http://www.fao.org/docrep/W4367E/w4367e0f.htm, accessed 10.05.2005)

Census (2001). Greek Statistics Service, also available at: http://www.statistics.gr

Chartzoulakis K. (2002). Irrigation of olive tree; Water needs and water quality, *Agriculture-Stockbreeding*, 7, pp. 46-51 (in Greek).

Chowdhury S.R., Nagadevara V. and Heady E.O. (1975). A Bayesian Application on Cobb-Douglas Production Function, *Amer. J. Agr. Economics*, May, pp. 361-363.

Christensen L.R., Jorgenson D.W. and Lau L.J. (1973). Transendental Logarithmic Production Functions. *Review of Economics and Statistics*, **55**, 28-45.

Chung J.W.(1994). *Utility and Production Functions, Theory and Applications*, Blackwell Publishers, USA.

Cooper D.R. and Emory C.W. (1995). *Business Research Methods*, 5th edition, IRWIN, McGraw-Hill Companies, pp.681.

Cramer G.L., Jensen C.W. and Southgate D.D.Jr. (1997). *Agricultural Economics and Agribusiness*, 7th edition, John Wiley & Sons, Inc., pp.546.

Dobson S., Maddala G.S. and Miller E. (1989). *Microeconomics*, McGrawhill, pp. 378.

Economic and Social Council of Greece (2005). ESE, available at: http://www.oke.gr/greek/OKE13.HTM.

European Commission (2005). Joint Research Centre of Ispra, available at: http://www. sensitivity-analysis.jrc.cec.eu.iut, accessed at 20.05.2005.

Field W. (1990). World Irrigation, *Irrigation and Drainage Systems*, **4**, 91-107 In: Irrigated agriculture and the Environment (2001) edited by Shortle, J.S. and Griffin, R.C., Edward Elgar.

Food and Agricultural Organization, (2000), available at: http://apps.fao.org/lim500/nph-wrap.p1? Irrigation & Domain=LUI, accessed 31 May 2000 In: Irrigated agriculture and the Environment (2001) edited by Shortle, J.S. and Griffin, R.C., Edward Elgar.

Gould P.J. and Lazear E.P. (1989). *Microeconomic Theory*, 6th edition, Richard Irwin, pp. 640.

Greene W.H. (2003). *Econometric Analysis*, 5th ed., Prentice Hall, pp.1026.

Hanley N. (2002). University of Glasgow, personal communication.

Hanley N., Shogren J.F. and White B. (2001). *Introduction to Environmental Economics*, Oxford University Press.

Hussain I., Raschid L., Hanjra M.A., Marikar F. and Van der Hoek W. (2002). Wastewater Use in Agriculture, Review of Impacts and Methodological Issues in Valuing Impacts, Working Paper 37, IWMI.

Kim H.Y. (1992). The translog production function and variable returns to scale, The Review of Economics and Statistics, pp. 546-552

Latinopoulos D. (2005). Derivation of irrigation water demand functions through linear and non-linear optimization models: Application to an intensively irrigated area in northern Greece. *Water Science & Technology: Water Supply* (forthcoming).

Leamer E.E. (1990). *Sensitivity Analysis would help in Modelling Economic Series*, C.W.J.Granger, ed. Oxford Clarendon Press, In: Saltelli, A., Ratto, M., Tarantola, S. and Campolongo, F., European Commission, Joint Research Centre of Ispra, available at: http://www. sensitivity-analysis.jrc.cec.eu.iut

Maddala G.S. (1992). *Introduction to Econometrics*, 2nd edition, Prentice Hall.

Malhotra N.K. (1999). *Marketing Research; An Applied Orientation*, 3rd edition, Prentice Hall, pp.763.

Malley J. (2004). University of Glasgow, Personal communication.

Ministry of Finance, General Administration of Public Property and National Bequests, Department of objective land price definition, (2001). Tables of objective land prices, Vol.III, Prefectures of Sterea Elada, Peloponissos, North Egeo, South Egeo and Crete, pp.920 (in Greek).

Ministry of Agricultural Development and Food. Department of Agricultural Statistcics, Tables on the evolution of olive tree cultivations from 1961- 2002 (in Greek).

National statistics service in Greece (2004). Agricultural price indices, pp.11.

National statistics service in Greece, available at: http://www.statistics.gr, accessed various times within 2005.

National Statistics Service of Greece (2004). Agricultural Price Indices, pp.13, Athens, (in Greek).

National Statistics Service of Greece (2004). Agricultural Statistics, pp.13, Athens (in Greek).

National Statistics Service of Greece (2004). Labor Statistics, pp.13, Athens, (in Greek).

Paranychianakis N. (2005). National Institute of Agricultural Research. Personal communication.

Region of Crete (2003). Integrated water management in Crete; Summary and main findings, also available at: http://www.crete-region.gr/greek/fysikoi%20poroi/disa/ perilipsi.htm.

Sahoo B.K., Mohapatra P.K.J. and Trivedi M.L. (1999). A comparative application of data envelopment analysis and frontier translog production function for

estimating returns to scale and efficiencies. *International Journal of Systems Science*, **30**(4), 379-394.

Saltelli A., Ratto M., Tarantola S. and Campolongo F. (2005). Sensitivity Analysis Practices, Strategies for model-based inference, RESS Review, available at: http://www. sensitivity-analysis.jrc.cec.eu.iut, accessed on 20.05.2005

European Commission (2005). Joint Research Centre of Ispra available at: http://www. sensitivity-analysis.jrc.cec.eu.iut, accessed in May 2005

Sauer J. (2005). Theory Matters!- Efficiency measurement and water utilities. *Water Science & Technology: Water Supply* (forthcoming).

Science and Technology Park of Crete (2005). Available at: http://stepc.gr/ritts-crete/par-krhth.htm.

Shortle J.S. and Griffin R.C. Eds (2001). *Irrigated agriculture and the Environment*, Edward Elgar, pp.272.

Tsur Y., Dinar A., Doukkali R.M. and Roe T.L. (2002). Efficiency and Equity Implications of Irrigation Water Pricing, International conference "*Les politiques d'irrigation. Considerations micro et macro economiques*", Agadir, Morocco.

Union of olive-oil producing municipalities in Crete (2005). Available at: http://www.sedik.gr, accessed on May 2005.

Vakalis P. (1996). Irrigation water demand factors, *4th Panhellenic conference on agricultural economy*, Salonica 28-30th November 1996.

Varela-Ortega C., Sumpsi J.M., Garrido A., Blanco M. and Iglesias E. (1998). Water pricing policies, public decision making and farmers' response: implications for water policy. *Agricultural Economics*, **19**, 193-202.

7. APPENDICES

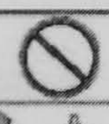
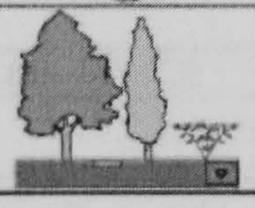
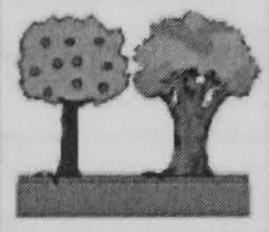
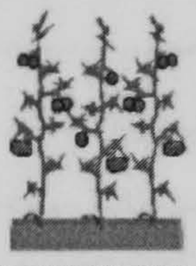
7.1. Farmers' questionnaire

NATIONAL FOUNDATION OF AGRICULTURAL RESEARCH
HERAKLION INSTITUTE
P.B. 2229, 71307 Heraklion Crete
2810 245851, Fax: 2810 245873
Responsible for the project: Dr. Tsagarakis Konstantinos

INTRODUCTION

The Greek Ministry of Environment, Physical Planning and Public Works (MEPPPW) has assigned this project to the National Foundation of Agricultural Research, the Technological Institute of Crete (TEI) and the Union of Cretan Municipalities (TEDK) with the purpose of information collection for the formation of recycled water policy. This is why your answers must be honest and true (based on what you really believe and can afford). Your answer will be anonymous and confidential.

What is recycled water? Each household consumes water for the house cleanness, toilet etc. which, through the wastewater network, ends up in the wastewater treatment plant of the region. There, through special processes, it is cleaned (there are 5 cleanness levels which are presented below) and has been proved scientifically that this water is appropriate for irrigation and outdoor cleanness, but not for drinking. Nevertheless this water ends up in the sea and rivers. Water recycling is an imposing need, because water shortage becomes more intensive year by year.

WATER QUALITY STARS	EXPLANATION	APPROPRIATE USES	
0	**Unprocessed wastewater:** polluted wastewater in the form it is found in the wastewater network	None!	
1 ★	**Primary treatment:** Wastewater has been subject to a first cleaning stage. The pollution level (organic load and pathogens) has been reduced by 30-40%.	Appropriate for the irrigation of forestland in a controlled way (on land with limited access) on surface or sub-surface.	
2 ★★	**Secondary treatment:** Wastewater has been subject to a second cleaning stage. The pollution level (organic load) has been reduced by 95%. Usually this type of water has received disinfection.	It is appropriate for surface tree irrigation such as olive trees, vineyards, industrial trees and other trees where water does not come in touch with the crops.	
3 ★★★	**Tertiary treatment:** Wastewater has been subject to a third cleaning stage. The pollution level (organic load) is minimized up to 99%. Disinfection has taken place and there are no pathogens.	Appropriate for the irrigation of cultivations, which are consumed by the human being on the condition that the edible parts do not come in touch with this water.	
4 ★★★★	**Potable water**	Appropriate for the irrigation of every type of human use and irrigation.	

It is stressed that if respondents majority answer that they do not wish to use recycled water or that they wish it but they will not support it financially, then the state will not use it but they will go on throwing it into the sea. This means a) that we leave recycled water-a natural resource (which contains nutrients for the cultivations), unexploited while simultaneously we will continue using fresh water for irrigation, thus aggravating the environment more and b) we will not have fully exploited the investments done in the wastewater treatment plants, which have been paid by all Greek tax-payers. *It is noted that the construction of the wastewater treatment plants has cost (today's prices) 500 m. euros (i.e. roughly 170 b. GRD).*

P A R T A

1. How informed do you think you are on environmental problems?

☐ Absolutely informed
☐ Very well informed
☐ Well informed
☐ Little informed
☐ Very little informed
☐ Not at all informed

2. Put in circle the degree of significance for the following environmental problems (1: the least important and 5: the most important).

Forest fires	1	2	3	4	5
Rare species extinction	1	2	3	4	5
Sea petrol smears	1	2	3	4	5
Uncontrolled rubbish dropping	1	2	3	4	5
Water shortage	1	2	3	4	5

3. How much do environmental problems worry you?

☐ Very much
☐ A lot
☐ Little
☐ Very little
☐ Not at all

4. Which of the following do you do to save the environment?

☐ I always separate my house rubbish in glass, paper and metal and I put them in separate bins.
☐ I keep my car (and every other vehicle I own) in a good mechanical condition, so that I will not pollute the environment with exhaust fumes or noise.
☐ I never throw rubbish in the environment.
☐ I try as much as I can, to reduce water consumption in my house.
☐ Other .....
☐ I do not do any action to save the environment.

P A R T B

5. Fill in the following table carefully. All financial amounts are expressed in euros, the water volume is expressed in cubic metres and the surface in 0,1 ha.

QUESTION	ANSWER
1. How many 0,1ha of irrigated land do you own (or lease)? **α.** Privately owned **β.** Leased	
2. How many 0,1ha of non-irrigated land do you own (or lease)? **α.** Privately owned **β.** Leased	
3. a) Which types of cultivations do you have in your land? b) How many 0,1ha is each cultivation?[1].	
4.1. a) Which types of cultivations do you have in your non-irrigated land? b) How many 0,1ha is each cultivation[2]?	
4.2. **(It is answered only by those who have non-irrigated land)** State the reasons for not irrigating.	
5.1. What is the yearly quantity of irrigation water you use per 0,1ha? (Refer to each cultivation type separately).	
5.2. Did you have any problems in finding the water you need for your cultivations in the last 3 years?	
6. If answer to question 5.2 is yes, which additional quantity would your cultivations need?	
7. a) Where does the water you consume come from[3]? and b) in what quantities?	
8. What is the water price you pay per cubic metre (in €);	

[1] A= olive-tree, B= vineyard, C= vegetables, D= orchants, E= cereals, F= other (specify)
[2] A1= olive-tree, B1= vineyard, C1= vegetables, D1= orchants, E1= cereals, F1= other
[3] A2= Public well, B2= Private well, C2= Privately owned well, D2= Potable water, E2= Other

9. What is the yearly expenditure (in €) for (a) fertilizers and (b) pesticides used for every type of cultivation you have?	
11. What is the number of working days you spend on your cultivations yearly? (Refer separately on each type of cultivation you have).	
12. 12.1. Do you have your own machinery (e.g. tractor, plough etc)? 12.2. How much do these machines cost in order to be bought new today? 12.3. How many years have you had these machines and how many years do you believe you are going to have them in the future? 12.4. How much do you spend on the yearly maintenance of these machines? 12.5. If you do not own machinery, how much do you spend on their annual leasing?	☐ Yes ☐ No ☐+☐=
13. What is the average 3 last year production (in kg)? Refer separately to each type of cultivation.	

6. Knowing that fresh water is a scarce natural resource, would you use 2 star recycled water for tree irrigation such as olive-trees.

☐ Yes ☐ No (Explain the reason) ☐ I do not know/ I do not answer

.....

.....

6.1. If in the previous question you have answered positively, how much would you spend to buy it?

☐ More than fresh water ☐ As much as fresh water ☐ Less than fresh water

6.2. If you have answered "more than fresh water", what price would you pay (The answer is given in conjunction with what has been answered in sub-question 8 of question 5). .....€.

6.3. If you have answered "less than fresh water", what price would you pay (The answer is given in conjunction with what has been answered in sub-question 8 of question 5). .....€.

7. Would you use 3 star-recycled water

a) for the irrigation of the olive tree **(it is answered only by those answering no to question 6).**

☐ Yes ☐ No (Explain the reason) ☐ I do not know/ I do not answer

.....

.....

b) for the irrigation of cultivations such as the tomato

☐ Yes ☐ No (Explain the reason) ☐ I do not know/ I do not answer

.....

.....

7.1. If you have answered positively in question 7a or 7b, how much would you spend to buy it?

☐ More than fresh water ☐ As much as fresh water ☐ Less than fresh water

7.2. If you have answered "more than fresh water", what price would you pay? (The answer is given in conjunction with what has been answered in sub-question 8 of question 5). .....€.

7.3. If you have answered "less than fresh water", what price would you pay? (The answer is given in conjunction with what has been answered in sub-question 8 of question 5). .....€.

8. Would you like, if you were asked, to participate in a next phase of this research which will take place at a weekend during the following semester, outside your village/town? The participants will be compensated with the daily amount of €30. **If you are sure that you can participate, leave your phone number.**

☐ NO ☐ YES

Name: ..... Tel.: .....

P A R T C

9. AGE

☐ 18-24
☐ 25-34
☐ 35-44
☐ 45-54
☐ 55-64
☐ 65-and above

10. EDUCATIONAL LEVEL

☐ Illiterate
☐ Primary school
☐ Junior high school
☐ Senior high school
☐ Tertiary education (AEI-TEI)
☐ Post-graduate

11. MONTHLY FAMILY INCOME (In €):

Α. 0-300
Β. 301-600
Γ. 601-900
Δ. 901-1.200
Ε. 1.201-1.500
ΣΤ. 1.501- 1.800
Η. 1.801- 2.100
Θ. 2.101- 2.400
Ι. 2.401-2.700
Κ. 2.701- …

12. SEX

☐ Male ☐ Female

13. NUMBER OF CHILDREN .....

Date of questionnaire completion .....

Area of completion .....

Researcher's code .....

Researcher's code (briefly mention your impressions from the interview you took).....
.....
.....
.....
.....
.....
.....
.....
.....
.....

7. 2. Questionnaire structure

This section describes all the questions of farmers' questionnaire with detail.

7.2.1. Questionnaire introduction

The purpose of the questionnaire introduction was first to notify to the respondents the organizations supporting and funding this research: These are the Ministry of Environment, Physical Planning and Public Works, The National Agricultural Research Foundation (NAGREF), The Local Union of Municipalities of Crete and the Technological Educational Institute of Crete. This was done with the purpose of strengthening the seriousness and acceptability of the research for respondents and consequently to make respondents be honest with their answers. The statement that all replies would remain confidential was made to induce respondents to reveal their true answers and personal data, such as WTP, preferences, income etc.

Furthermore, this part announced the purpose of the questionnaire, which was to find out the WTP for recycled water that would help towards establishing policies for recycled water. We did not reveal that this information would contribute to deriving a price for recycled water. We disguised this underlying purpose in order to reduce respondents' strategic behavior, i.e. farmers (or consumers in chapter 4) underbidding their WTP for recycled water in the hope of buying it for less.

The introduction continues with a brief, but succinct definition of recycled water, which tries to explain the term in an understandable and colloquial style. Also, at this point respondents are warned that if they do not give a reasonably high WTP, recycled water will not be used for irrigation, but it will go on being dropped into the sea. These statements are supposed to be reducing the hypothetical market error. We

try to sooth strategic behavior phenomena by rendering this experiment as a serious citizen mission, which relies heavily on each one's honesty and good mood, in order for it to be successful. Reminding respondents what will happen if they do not support the use of recycled water, will make them think twice before answering and will prevent them from giving superficial answers. Reporting the size of the wastewater treatment plant investments in Greece, is supposed to work positively towards that direction too.

We need to add that the introduction was accompanied by a visual aid for the respondent. This visual aid comprised: i) A table on the various qualities of recycled water and their advisable uses. The advisable uses are explained both verbally and pictorially ii) A series of photographs and information that were presented and given out to the respondent in an eight page booklet. The information was about the water situation in Greece, about what a wastewater treatment plant is, what the contents of recycled water are, what the safe application of recycled water is as well as examples of other countries use etc. This information is also presented in chapter 1, in the form of a technical primer on recycled water (this is why a booklet copy has not been annexed in the thesis).

7.2.2. Part A

The first part of the questionnaire, composed of four questions, aims at finding out the information the respondent has on environmental problems. In general, the reasoning behind this part is that if a person is very informed and sensitive on environmental affairs, he will probably declare a high WTP for recycled water later. Therefore, the answers given in the first four questions predispose the interviewer to the answers he will receive in the other parts of the questionnaire.

- Question 1. This question asks the respondent directly how informed he believes he is on environmental problems.

- Question 2. The interviewee is asked to rate separately each of the various environmental problems he is presented with on a scale from 1 to 5, by assigning rate 1 to the least important problem and rate 5 to the most important one. If a person rates the problem of water shortage with a 5, then he is supposed to regard water as a very important source of life and he could be expected to give a high WTP for recycled water. At the same time, this question serves as a reminder of the dimensions environment degradation has reached, and subconsciously will induce the interviewee to take the completion of the questionnaire seriously.

- Question 3. It asks the interviewee how worried he feels about the environmental problems in Crete. A person, who is very worried about environmental problems in Crete, is expected to give a high WTP.

- Question 4. It asks the respondent which of three environmental friendly actions he performs. These were: good car maintenance for exhaust-fumes reduction, rubbish throwing and reduction of domestic water consumption. Besides its role as an independent question, it also works as a filter question. It somehow confirms the truthfulness of the answers given in questions 3 or 2 e.g. If an interviewee states in question 3 that he is worried about environmental degradation in Crete, then he will probably have engaged himself into at least one or two actions performed to improve and save the environment. If instead, the interviewee answers that he does nothing towards that direction, then he is not supposed to have answered that he is extremely worried about the environment. This question could of course have been structured as an open-ended question. Instead, several options-examples of environmental friendly behavior together with an open-ended

option are cited, in order to explain the interviewee, how he is approximately expected to model his answer. *Note*: The thesis author realized later that this question should not have been posed in the way it was. It should have better asked which environmental friendly actions the respondent knew the other people were doing. The reason it is said so, is that respondents may not reveal the truth about their habits but they do it more easily when it is about other people.

7.2.3. Part B

Part B is the main part of the questionnaire and its questions aim at the gist of our research, namely enquiring on farmers' WTP on recycled water.

- Question 5. It consists of twelve sub-questions, which concern the input and output quantities of farmer's production. The inputs in the production process are land, capital, labor, water, fertilizers and/or pesticides. We wished that the respondent would not be burdened with any cumbersome mathematical calculations at the time of answering (because this could put him off from participating in the research or merely could reduce his interest towards it). Therefore, we have tried to make the questions as simple in wording and formulation as possible. However, some sub-questions did demand a numerical answer. For those cases the interviewer had been equipped (see question 5.5.1 for an example) with a set of clarifying questions, which stimulated the answer to each question. Namely, if a question enquired on something, which the respondent had never before, spent any time to reflect on, then the interviewer indicated some cognitive steps of thought for him.

- Questions 5.1 and 5.2. They enquire on the size (in strema) of irrigated and non-irrigated land respectively. One strema equals 0.1 ha.

- Question 5.3. It asks what types of cultivations exist in the irrigated land.
- Question 5.4.1. It asks what types of cultivations exist in the non-irrigated land.
- Question 5.4.2. It asks what the reasons of non-irrigation are (It is answered only if question 5.4.1 has been replied). It aims at grasping the occasions where farmers do not irrigate because there is no available water or if there is, it is so expensive that it is uneconomical to irrigate.
- Question 5.5.1. It asks the water quantity (yearly m^3) used for irrigation. Some respondents did not have this number ready in their minds. Interviewers facilitated the respondent with a somewhat differently articulated question: "How often do you irrigate and how much water (in m^3/strema) do you use each time?" From pilot testing it was noted that some irrigators could tell the quantity of water per tree but not the quantity per strema. Some other respondent could tell the duration of irrigation but not the quantity, i.e. he could tell that he irrigated twice per month for 10 hours each time. In those cases, the interviewer was ready to ask some follow-up questions, which helped the farmer, express the amounts given in the terms the questionnaire demanded.
- Question 5.5.2. This question aimed at grasping the cases where the farmer was forced to use less water than necessary because there was no water to irrigate. Crete experiences long dry summers when some farmers refrained from irrigation, because water was literally non-existent. Some other times water was existent but scarce and expensive which rendered irrigation a quite costly practice. This forced farmers to skip irrigation sessions, which if they had pursued, would have given them a richer yield.

- Question 5.6. This question complemented question 5.5.2 asking what the advisable irrigation frequency is and of course it is filled in only in cases where a farmer admitted that he did not provide his cultivations with the adequate quantity of water. The farmer was also expected to say how much the shortage was. Note: Unfortunately this question turned out to have a very high non-response rate because of its hypothetical nature and cognitive demand.

- Question 5.7. It asks about the origin of irrigation water.

- Question 5.8. It asks what the price per m^3 for irrigation water is.

- Question 5.9. It aims at finding out what the annual expenditure on fertilizers and pesticides was per strema (separately for fertilizers and pesticides). This was one of the inputs in the production function. However, the vast majority of farmers could not announce these amounts separately. Therefore we have included both fertilizers and pesticides as one amount. This reduced the accuracy of the representation of the olive oil production process.

- Question 5.10. It asked what the annual expenditure on labor was. A simpler formulation of the question was about how many workers worked on the farmers agricultural business and for how long. Thus we were able to estimate the working days, which were multiplied with the agricultural worker's daily market wages[2]. The latter are the same all over Crete.

- Question 5.11. The question aimed at finding out what the annual expenditure on capital equipment was. Because this question would have been difficult to answer if it had been formulated in this way, it was split in four other questions. So, the

[2] Cretan agriculture employs mostly Albanian workers. When a farmer wants to hire workers, he goes to specific haunts and picks up his workers. The established daily wages for picking up olives are currently 30 €. This price was taken in person by the thesis writer.

variable under research was calculated as follows: Each machine's today price (as brand new) was divided by its lifetime to get its annual value. The sum of all machines was taken to get the annual expenditure on capital as a factor of production.

- Question 5.12. It enquired on the output (kilograms of olive oil) produced. The average of the last three years was sought in order to balance bad and good yields.

- Question 6. It asked respondents whether they would use recycled water of quality 2 for the irrigation of the olive tree. The definition of this type of water was given in the table shown to the respondent at the beginning of the interview. The table was also there for the respondent to watch and consult during the interview.

- Question 6.1. If respondents had answered affirmatively in the previous question, (i.e. they had answered they would use that type of recycled water) they would then be asked how much they would be willing to buy it. If they answered options "a" or "c" (they stand for "more than fresh water price" or "less" respectively, then they went to questions 6.2 and 6.3.

- Question 6.2. This is an open-ended question, which is linked to the answer given in sub-question 5.8. Given the price farmers state that they pay in question 5.8, they are then asked to state how much above that price they would pay for recycled water. This was left to be an open-ended question, because during our pilot survey we realized that fresh water prices for irrigation varied vastly among them. So, it was impossible to construct reasonable closed ended questions.

- Question 6.3. It works exactly the same way as question 6.2, only that it is destined for farmers who have answered they would pay less than fresh water in order to buy recycled water.

- Question 7.1. It asks farmers whether they would use recycled water of quality 3 for the irrigation of olive trees. Only those having answered negatively in question 6, answer this question. With this we want to see whether they would react differently to a better water quality (thus we examine the existence of scope effects).

- Question 7.2. It asks farmers whether they would use recycled water of quality 3 for the irrigation of cultivations such as tomatoes and other vegetables. Farmers are assured that crops in this case will not come in touch with recycled water, i.e. they are assured that irrigation safety guidelines will be followed. Everybody is asked to reply this.

- Questions 7.3, 7.4 and 7.5. They work in the same fashion as questions 6.1, 6.2 and 6.3. They differ only in that they ask about recycled water of quality 3 for the irrigation of tomatoes.

- Question 8. It asks whether respondents would like to participate in a citizen jury. Hardly any farmer wanted to participate in this. Probably the 30 € promised as a daily compensation was not enough to lure them, or it is the poor educational level of farmers that does not let them see the importance of such an activity.

7.2.4. Part C

The questionnaire ends with respondent's demographics and personal data such as age, educational level, disposable family or personal income, gender and number of children. We did not ask directly somebody how much he earned. We showed income groups represented with alphabet letters and asked respondents to tell the letter they fell in. This was done in order to avoid making people feel awkward revealing this amount (Hanley, 2002).

7.2. Eviews Demand function appendix

This appendix contains: i) a Tables appendix (7.2.1), ii) a Figures appendix (7.2.2).

7.2.1. Tables appendix

Table 2.21. EVIEWS full output of demand function normalized with respect to quantity.

Dependent Variable: Quantity
Method: Least Squares
Sample(adjusted): 1 282
Included observations: 282 after adjusting endpoints

Variable	Coefficient	Std. Error	t-Statistic	Prob.
Constant	2950.547	420.7837	7.012026	0.0000
Price	-3345.022	1601.979	-2.088056	0.0377
R-squared	0.015333	Mean dependent var		2158.654
Adjusted R-squared	0.011816	S.D. dependent var		3079.409
S.E. of regression	3061.162	Akaike info criterion		18.89804
Sum squared resid	2.62E+09	Schwarz criterion		18.92387
Log likelihood	-2662.624	F-statistic		4.359980
Durbin-Watson stat	1.526251	Prob(F-statistic)		0.037696

Table 2.22. EVIEWS full output of demand function normalized with respect to price.

Dependent Variable: Price
Method: Least Squares
Sample(adjusted): 1 282
Included observations: 282 after adjusting endpoints

Variable	Coefficient	Std. Error	t-Statistic	Prob.
Cconstant	0.246632	0.008246	29.91080	0.0000
Quantity	-4.58E-06	2.20E-06	-2.088056	0.0377
R-squared	0.015333	Mean dependent var		0.236738
Adjusted R-squared	0.011816	S.D. dependent var		0.113993
S.E. of regression	0.113317	Akaike info criterion		-1.510187
Sum squared resid	3.595413	Schwarz criterion		-1.484358
Log likelihood	214.9363	F-statistic		4.359980
Durbin-Watson stat	0.628587	Prob(F-statistic)		0.037696

Table 2.23. EVIEWS full output of demand function normalized with respect to price with a dummy on water origin.

Dependent Variable: Price

Method: Least Squares

Sample(adjusted): 1 282

Included observations: 282 after adjusting endpoints

Variable	Coefficient	Std. Error	t-Statistic	Prob.
Constant	0.250884	0.018034	13.91138	0.0000
Quantity	-4.64E-06	2.21E-06	-2.100323	0.0366
Dummy on water origin	-0.004917	0.018540	-0.265232	0.7910

R-squared	0.015581	Mean dependent var	0.236738
Adjusted R-squared	0.008524	S.D. dependent var	0.113993
S.E. of regression	0.113506	Akaike info criterion	-1.503347
Sum squared resid	3.594507	Schwarz criterion	-1.464603
Log likelihood	214.9719	F-statistic	2.207926
Durbin-Watson stat	0.632875	Prob(F-statistic)	0.111846

Table 2.24. EVIEWS full output of demand function normalized with respect to quantity with a dummy on water origin.

Dependent Variable: Quantity

Method: Least Squares

Sample(adjusted): 1 282

Included observations: 282 after adjusting endpoints

Variable	Coefficient	Std. Error	t-Statistic	Prob.
Constant	3623.080	592.7508	6.112316	0.0000
Price	-3355.243	1597.490	-2.100323	0.0366
Dummy on water origin	-797.3504	496.3772	-1.606340	0.1093

R-squared	0.024356	Mean dependent var	2158.654
Adjusted R-squared	0.017362	S.D. dependent var	3079.409
S.E. of regression	3052.560	Akaike info criterion	18.89593
Sum squared resid	2.60E+09	Schwarz criterion	18.93467
Log likelihood	-2661.326	F-statistic	3.482458
Durbin-Watson stat	1.525891	Prob(F-statistic)	0.032074

Table 2.25. EVIEWS full output of demand function normalized with respect to quantity (price expressed in pence).

Dependent Variable: Quantity

Method: Least Squares

Sample(adjusted): 1 282

Included observations: 282 after adjusting endpoints

Variable	Coefficient	Std. Error	t-Statistic	Prob.
Constant	2950.547	420.7837	7.012026	0.0000
Price in pence	-33.45022	16.01979	-2.088056	0.0377

R-squared	0.015333	Mean dependent var	2158.654
Adjusted R-squared	0.011816	S.D. dependent var	3079.409
S.E. of regression	3061.162	Akaike info criterion	18.89804
Sum squared resid	2.62E+09	Schwarz criterion	18.92387
Log likelihood	-2662.624	F-statistic	4.359980
Durbin-Watson stat	1.526251	Prob(F-statistic)	0.037696

7.2.2. Figures appendix

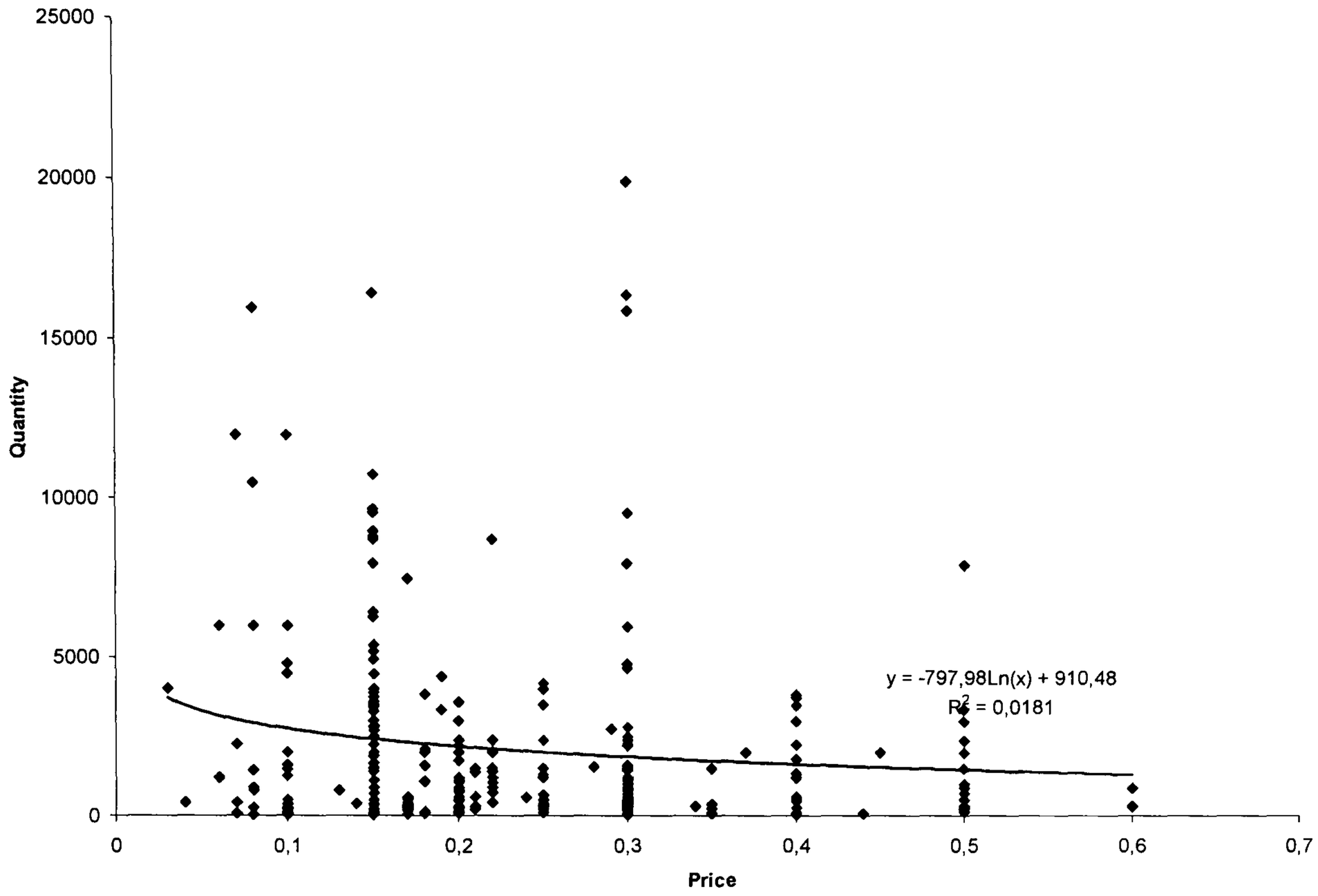


Figure 2.12. Logarithmic demand function normalized with respect to quantity.

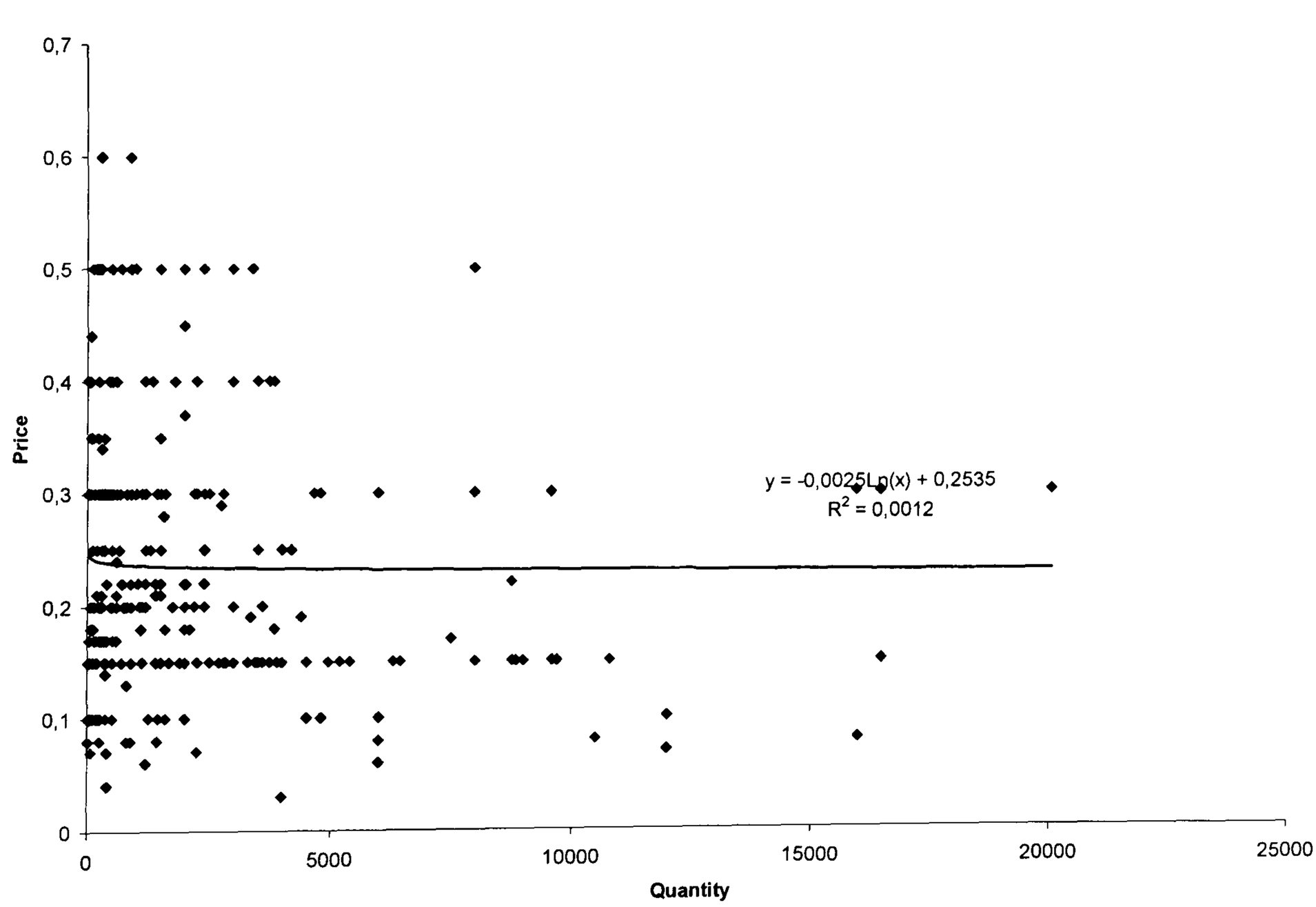


Figure 2.13. Logarithmic demand function normalized with respect to price.

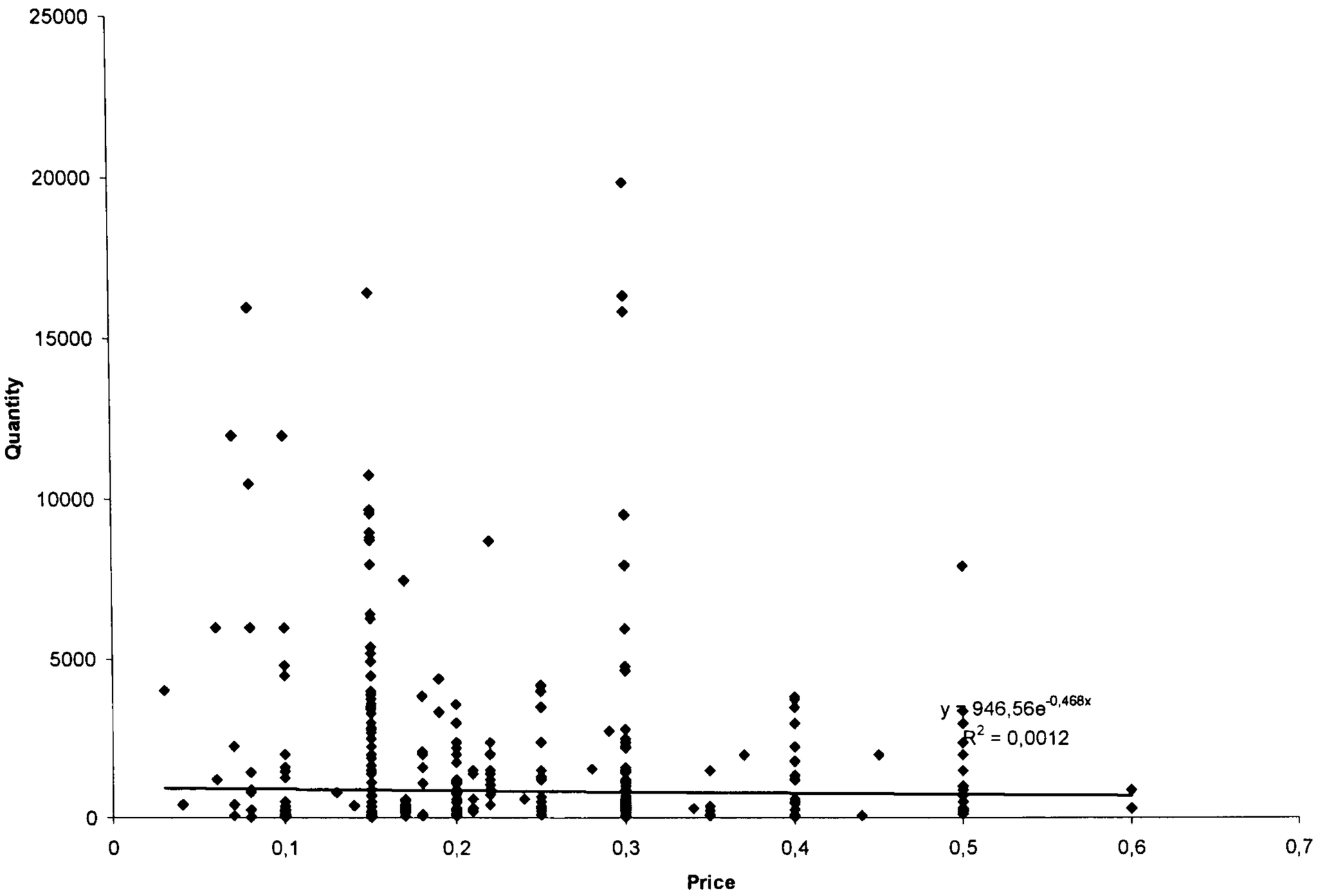


Figure 2.14. Exponential demand function with respect to quantity.

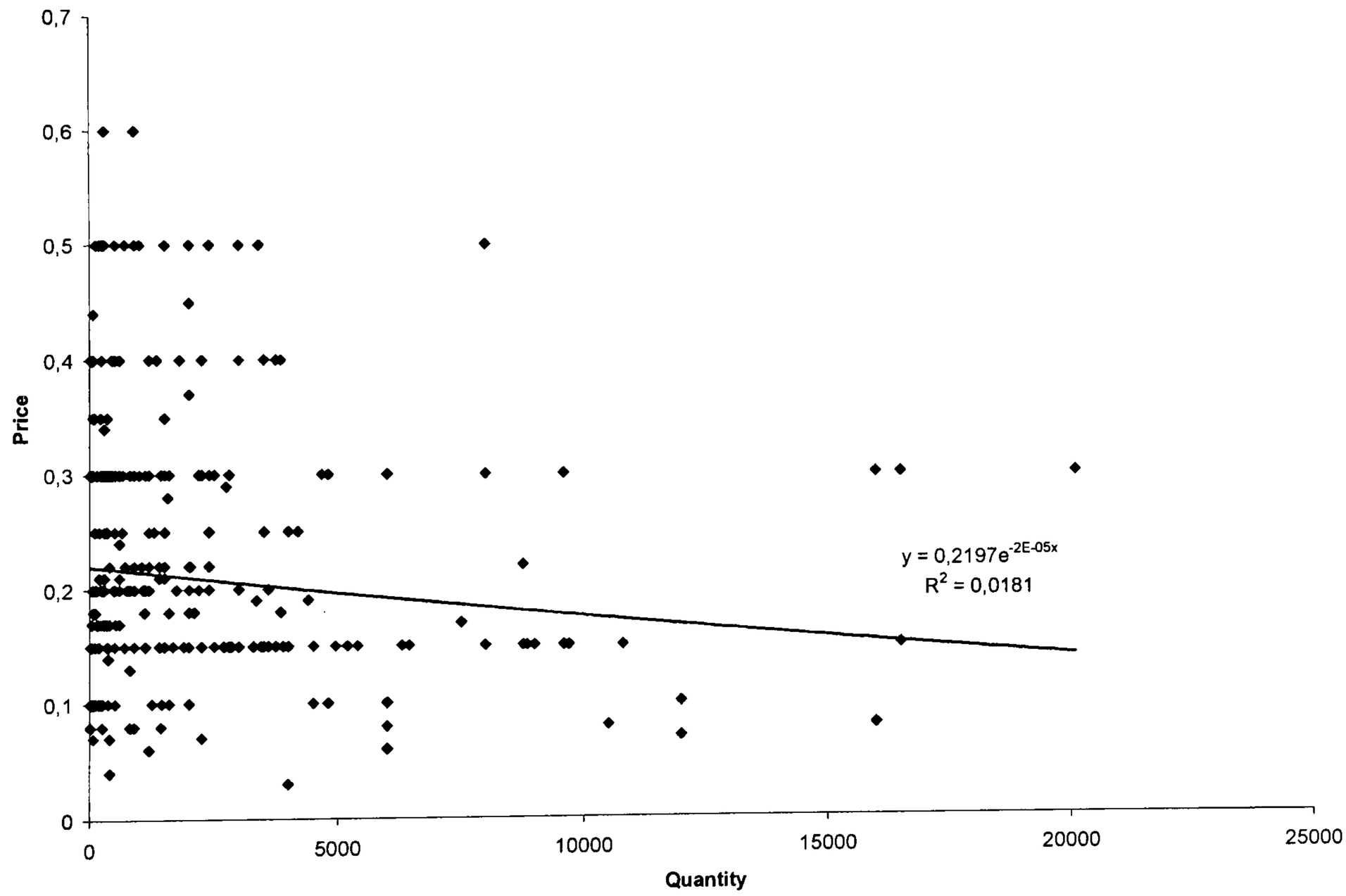


Figure 2.15. Exponential demand function with respect to price.

7.3. EViews production function appendix

7.3.1. Tables appendix

Table 2.26. Model 1; Translog production function with land (in 0.1.ha), labor, water in physical form, capital and fertilizers expressed in euros.

Dependent Variable: LOG(Output in kg)

Method: Least Squares

Sample(adjusted): 1 285

Included observations: 285 after adjusting endpoints

	Coefficient	Std. Error	t-Statistic	Prob.
Constant	3.813328	1.395204	2.733168	0.0067
Log (Land)	0.643560	0.412639	1.559621	0.1200
Log (Water)	0.048906	0.219434	0.222874	0.8238
Log (Labour)	-0.240628	0.337252	-0.713497	0.4762
Log (Fertilizers)	0.730945	0.243923	2.996625	0.0030
Log (Capital)	-0.250483	0.253692	-0.987353	0.3244
Log (Land*Water)	-0.158819	0.059125	-2.686135	0.0077
Log (Land*Labour)	0.256352	0.106403	2.409252	0.0167
Log (Land*Fertilizers)	0.159743	0.112257	1.423008	0.1559
Log (Land*Capital)	-0.238888	0.112828	-2.117277	0.0352
Log (Water*Labour)	0.090792	0.063085	1.439201	0.1513
Log (Water*Fertilizers)	-0.127570	0.068105	-1.873125	0.0621
Log (Water*Capital)	0.143314	0.064252	2.230505	0.0265
Log (Labour*Fertilizers)	-0.238754	0.093163	-2.562763	0.0109
Log (Labor*Capital)	0.110576	0.095862	1.153490	0.2497
Log (Fertilizers*Capital)	0.015489	0.068702	0.225456	0.8218

R-squared	0.655315	Mean dependent var	7.676962
Adjusted R-squared	0.636094	S.D. dependent var	0.899150
S.E. of regression	0.542409	Akaike info criterion	1.668910
Sum squared resid	79.14180	Schwarz criterion	1.873962
Log likelihood	-221.8196	Durbin-Watson stat	1.572125

Table 2.27. White Heteroskedasticity test in Model 1.

White Heteroskedasticity Test:

F-statistic	0.827417	Probability	0.602484
Obs*R-squared	8.354073	Probability	0.594294

Test Equation:

Dependent Variable: RESID^2

Method: Least Squares

Sample: 1 285

Included observations: 285

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	0.300537	0.067457	4.455250	0.0000
Land	0.002563	0.002414	1.061922	0.2892
Land^2	-5.57E-06	7.05E-06	-0.790629	0.4298
Water	-1.82E-05	1.91E-05	-0.951466	0.3422
Water^2	3.30E-10	6.88E-10	0.479529	0.6319
Labour	-0.000610	0.000373	-1.635847	0.1030
Labour^2	2.17E-07	1.79E-07	1.215269	0.2253
Fertilizers	5.58E-05	8.08E-05	0.691478	0.4899
Fertilizers^2	-3.18E-09	1.21E-08	-0.262296	0.7933
Capital	-2.71E-05	4.51E-05	-0.600467	0.5487
Capital^2	4.42E-09	4.97E-09	0.888696	0.3749

R-squared	0.029313	Mean dependent var	0.277691
Adjusted R-squared	-0.006114	S.D. dependent var	0.537738
S.E. of regression	0.539380	Akaike info criterion	1.641037
Sum squared resid	79.71489	Schwarz criterion	1.782011
Log likelihood	-222.8478	F-statistic	0.827417
Durbin-Watson stat	1.931070	Prob(F-statistic)	0.602484

Table 2.28. Separability test in Model 1.

Wald Test:			
Equation: EQ01			
Test Statistic	Value	df	Probability
F-statistic	3.690650	(10, 269)	0.0001
Chi-square	36.90650	10	0.0001
Null Hypothesis Summary:			
Normalized Restriction (= 0)		Value	Std. Err.
Log (Land*Water)		-0.158819	0.059125
Log (Land*Labour)		0.256352	0.106403
Log (Land*Fertilizers)		0.159743	0.112257
Log (Land*Capital)		-0.238888	0.112828
Log (Water*Labour)		0.090792	0.063085
Log (Water*Fertilizers)		-0.127570	0.068105
Log (Water*Capital)		0.143314	0.064252
Log (Labour*Fertilizers)		-0.238754	0.093163
Log (Labor*Capital)		0.110576	0.095862
Log (Fertilizers*Capital)		0.015489	0.068702
Restrictions are linear in coefficients.			

Table 2.29. Chow forecast test for Model 1.

Chow Forecast Test: Forecast from 180 to 285

F-statistic	1.259456	Probability	0.092327
Log likelihood ratio	170.5170	Probability	0.000072

Test Equation:

Dependent Variable: LOG(Output in kg)

Method: Least Squares

Sample: 1 179

Included observations: 179

	Coefficient	Std. Error	t-Statistic	Prob.
Constant	8.076420	2.549666	3.167638	0.0018
Log (Land)	0.511578	0.568783	0.899426	0.3698
Log (Water)	-0.325997	0.362600	-0.899054	0.3700
Log (Labour)	-0.461203	0.538379	-0.856651	0.3929
Log (Fertilizers)	0.093520	0.378496	0.247082	0.8052
Log (Capital)	-0.349145	0.329717	-1.058922	0.2912
Log (Land*Water)	-0.014267	0.090430	-0.157769	0.8748
Log (Land*Labour)	0.017124	0.154872	0.110570	0.9121
Log (Land*Fertilizers)	0.348494	0.161904	2.152476	0.0328
Log (Land*Capital)	-0.396043	0.131988	-3.000593	0.0031
Log (Water*Labour)	0.212699	0.110479	1.925247	0.0559
Log (Water*Fertilizers)	-0.158740	0.100381	-1.581367	0.1157
Log (Water*Capital)	0.143246	0.083928	1.706769	0.0898
Log (Labour*Fertilizers)	-0.181971	0.164292	-1.107603	0.2697
Log (Labor*Capital)	0.113033	0.137740	0.820624	0.4131
Log (Fertilizers*Capital)	0.117499	0.079316	1.481399	0.1404

R-squared	0.512244	Mean dependent var	7.740674
Adjusted R-squared	0.467359	S.D. dependent var	0.707899
S.E. of regression	0.516641	Akaike info criterion	1.602198
Sum squared resid	43.50762	Schwarz criterion	1.887104
Log likelihood	-127.3968	Durbin-Watson stat	1.586585

Table 2.30. MODEL 1a; Translog production function with output, land[3] (%), water, labor expressed in physical terms and fertilizer and capital costs expressed in euros.

Dependent Variable: LOG(Output in kg)

Method: Least Squares

Sample(adjusted): 1 285

Included observations: 285 after adjusting endpoints

	Coefficient	Std. Error	t-Statistic	Prob.
Log (Constant)	2.139247	1.283540	1.666678	0.0967
Log (Land)	0.036999	0.630859	0.058649	0.9533
Log (Water)	0.368407	0.195167	1.887646	0.0601
Log (Labour)	-0.316074	0.310034	-1.019482	0.3089
Log (Fertilizers)	0.958255	0.240467	3.984973	0.0001
Log (Capital)	-0.039149	0.253056	-0.154706	0.8772
Log (Land*Water)	-0.100741	0.114488	-0.879929	0.3797
Log (Land*Labour)	0.010719	0.199659	0.053684	0.9572
Log (Land*Fertilizers)	-0.124194	0.173240	-0.716890	0.4741
Log (Land*Capital)	0.142031	0.171147	0.829875	0.4073
Log (Water*Labour)	0.090931	0.061685	1.474116	0.1416
Log (Water*Fertilizers)	-0.154222	0.056866	-2.712022	0.0071
Log (Water*Capital)	0.033959	0.060236	0.563769	0.5734
Log (Labour*Fertilizers)	-0.079340	0.085442	-0.928581	0.3539
Log (Labor*Capital)	0.124256	0.091512	1.357805	0.1757
Log (Fertilizers*Capital)	-0.046861	0.068984	-0.679307	0.4975

R-squared	0.600943	Mean dependent var	7.676962
Adjusted R-squared	0.578691	S.D. dependent var	0.899150
S.E. of regression	0.583624	Akaike info criterion	1.815382
Sum squared resid	91.62581	Schwarz criterion	2.020434
Log likelihood	-242.6919	Durbin-Watson stat	1.573700

[3] In this Table, land is irrigated land as percentage of total land

Table 2.31. White heteroskedasticity test for Model 1a.

White Heteroskedasticity Test:

F-statistic	3.159899	Probability	0.000754
Obs*R-squared	29.46905	Probability	0.001046

Test Equation:

Dependent Variable: RESID^2

Method: Least Squares

Sample: 1 285

Included observations: 285

Variable	Coefficient	Std. Error	t-Statistic	Prob.
Constant	1.592143	0.283308	5.619825	0.0000
Irrigated land as percentage of total land	-3.269207	0.960722	-3.402864	0.0008
Irrigated land as percentage of total land ^2	1.966899	0.720383	2.730351	0.0067
Water	-3.06E-07	2.07E-05	-0.014752	0.9882
Water ^2	-1.96E-10	7.96E-10	-0.246643	0.8054
Labour	-0.000641	0.000428	-1.498667	0.1351
Labour ^2	2.39E-07	2.06E-07	1.155625	0.2488
Fertilizers	4.77E-05	9.16E-05	0.521302	0.6026
Fertilizers ^2	3.22E-09	1.39E-08	0.231464	0.8171
Capital	1.02E-05	5.30E-05	0.192962	0.8471
Capital ^2	-1.23E-09	5.82E-09	-0.211132	0.8329

R-squared	0.103400	Mean dependent var	0.321494
Adjusted R-squared	0.070678	S.D. dependent var	0.653377
S.E. of regression	0.629864	Akaike info criterion	1.951207
Sum squared resid	108.7037	Schwarz criterion	2.092180
Log likelihood	-267.0470	F-statistic	3.159899
Durbin-Watson stat	2.058397	Prob(F-statistic)	0.000754

Table 2.32. Separability test for Model 1a.

Wald Test:

Equation: EQ01

Test Statistic	Value	df	Probability
F-statistic	2.463695	(10, 269)	0.0078
Chi-square	24.63695	10	0.0061

Null Hypothesis Summary:

Normalized Restriction (= 0)	Value	Std. Err.
Log (Land*Water)	-0.100741	0.114488
Log (Land*Labour)	0.010719	0.199659
Log (Land*Fertilizers)	-0.124194	0.173240
Log (Land*Capital)	0.142031	0.171147
Log (Water*Labour)	0.090931	0.061685
Log (Water*Fertilizers)	-0.154222	0.056866
Log (Water*Capital)	0.033959	0.060236
Log (Labour*Fertilizers)	-0.079340	0.085442
Log (Labor*Capital)	0.124256	0.091512
Log (Fertilizers*Capital)	-0.046861	0.068984

Restrictions are linear in coefficients.

Table 2.33. Chow Breakpoint test for Model 1a.

Chow Breakpoint Test: 160

F-statistic	13.97101	Probability	0.000000
Log likelihood ratio	180.4490	Probability	0.000000

Table 2.34. Model 1a; Translog production function with output, land (%), water, labor expressed in physical terms and fertilizer and capital costs expressed in euros (small farmers i.e. low output).

Dependent Variable: LOG(Output in kg)

Method: Least Squares

Included observations: 159 after adjusting endpoints

	Coefficient	Std. Error	t-Statistic	Prob.
Constant	0.218689	1.507696	0.145049	0.8849
Log (Land)	-0.329197	0.948090	-0.347221	0.7289
Log (Water)	0.523010	0.243009	2.152222	0.0331
Log (Labour)	0.018177	0.441922	0.041132	0.9672
Log (Fertilizers)	1.261493	0.300374	4.199740	0.0000
Log (Capital)	0.145102	0.297152	0.488309	0.6261
Log (Land*Water)	-0.116082	0.156957	-0.739575	0.4608
Log (Land*Labour)	0.144467	0.237372	0.608612	0.5437
Log (Land*Fertilizers)	0.004932	0.375017	0.013151	0.9895
Log (Land*Capital)	0.115934	0.240042	0.482974	0.6299
Log (Water*Labour)	0.020446	0.084548	0.241832	0.8093
Log (Water*Fertilizers)	-0.098952	0.067885	-1.457651	0.1471
Log (Water*Capital)	-0.039503	0.073904	-0.534520	0.5938
Log (Labour*Fertilizers)	-0.195361	0.130689	-1.494849	0.1372
Log (Labor*Capital)	0.196128	0.126427	1.551310	0.1230
Log (Fertilizers*Capital)	-0.137901	0.098291	-1.402989	0.1628

R-squared	0.548892	Mean dependent var	7.074659
Adjusted R-squared	0.501573	S.D. dependent var	0.695652
S.E. of regression	0.491126	Akaike info criterion	1.510966
Sum squared resid	34.49228	Schwarz criterion	1.819787
Log likelihood	-104.1218	Durbin-Watson stat	1.002578

Table 2.35. Model 1a; White heteroskedasticity test for Model 1a (small farmers i.e. low output).

White Heteroskedasticity Test:

F-statistic	0.823788	Probability	0.606280
Obs*R-squared	8.383513	Probability	0.591430

Test Equation:

Dependent Variable: RESID^2

Method: Least Squares

Sample: 1 159

Included observations: 159

Variable	Coefficient	Std. Error	t-Statistic	Prob.
Constant	0.721215	0.257244	2.803624	0.0057
Irrigated land as percentage of total land	-1.248358	0.865863	-1.441749	0.1515
Irrigated land as percentage of total land^2	0.761793	0.651159	1.169902	0.2439
Water	-1.05E-05	3.59E-05	-0.293617	0.7695
Water ^2	-2.51E-10	2.88E-09	-0.087230	0.9306
Labour	-0.000620	0.001059	-0.585780	0.5589
Labour ^2	2.18E-07	2.31E-06	0.094404	0.9249
Fertlizers	8.38E-05	0.000120	0.696231	0.4874
Fertlizers ^2	-8.83E-09	1.40E-08	-0.628946	0.5304
Capital	-4.50E-06	5.65E-05	-0.079547	0.9367
Capital ^2	2.50E-10	6.20E-09	0.040377	0.9678

R-squared	0.052726	Mean dependent var	0.216933
Adjusted R-squared	-0.011278	S.D. dependent var	0.409303
S.E. of regression	0.411605	Akaike info criterion	1.129166
Sum squared resid	25.07391	Schwarz criterion	1.341480
Log likelihood	-78.76866	F-statistic	0.823788
Durbin-Watson stat	1.868044	Prob(F-statistic)	0.606280

Table 2.36. Model 1a; Translog production function with output, land (%), water, labor expressed in physical terms and fertilizer and capital costs expressed in euros (big farmers i.e. high output).

Dependent Variable: LOG(Output in kg)

Method: Least Squares

Sample(adjusted): 1 126

Included observations: 126 after adjusting endpoints

	Coefficient	Std. Error	t-Statistic	Prob.
Log (Constant)	10.82191	2.710115	3.993155	0.0001
Log (Land)	-1.876582	0.802957	-2.337088	0.0212
Log (Water)	-0.428767	0.273140	-1.569770	0.1193
Log (Labour)	-0.635384	0.382086	-1.662937	0.0992
Log (Fertilizers)	0.166693	0.428709	0.388826	0.6982
Log (Capital)	-0.349066	0.389186	-0.896913	0.3717
Log (Land*Water)	0.176744	0.107388	1.645848	0.1026
Log (Land*Labour)	-0.154911	0.227144	-0.681996	0.4967
Log (Land*Fertilizers)	-0.209803	0.120564	-1.740182	0.0846
Log (Land*Capital)	0.550299	0.169615	3.244409	0.0016
Log (Water*Labour)	0.100659	0.060300	1.669309	0.0979
Log (Water*Fertilizers)	-0.048409	0.065626	-0.737643	0.4623
Log (Water*Capital)	0.125329	0.069556	1.801855	0.0743
Log (Labour*Fertilizers)	0.043315	0.072436	0.597980	0.5511
Log (Labor*Capital)	0.061601	0.095295	0.646431	0.5193
Log (Fertilizers*Capital)	-0.027097	0.083830	-0.323233	0.7471

R-squared	0.375882	Mean dependent var	8.437012
Adjusted R-squared	0.290774	S.D. dependent var	0.425930
S.E. of regression	0.358700	Akaike info criterion	0.905504
Sum squared resid	14.15319	Schwarz criterion	1.265667
Log likelihood	-41.04674	Durbin-Watson stat	0.682936

Table 2.37. Model 1a; White heteroskedasticity test for Model 1a (big farmers i.e. high output).

White Heteroskedasticity Test:

F-statistic	1.619415	Probability	0.109552
Obs*R-squared	15.55300	Probability	0.113163

Test Equation:

Dependent Variable: RESID^2

Method: Least Squares

Sample: 1 126

Included observations: 126

Variable	Coefficient	Std. Error	t-Statistic	Prob.
Constant	0.363293	0.145693	2.493558	0.0141
Irrigated land as percentage of total land	-0.604588	0.474227	-1.274892	0.2049
Irrigated land as percentage of total land^2	0.245318	0.355279	0.690493	0.4913
Water	9.48E-06	8.91E-06	1.064600	0.2893
Water ^2	-2.96E-10	3.06E-10	-0.966722	0.3357
Labour	9.77E-05	0.000186	0.523782	0.6014
Labour ^2	-5.28E-08	8.66E-08	-0.609541	0.5434
Fertlizers	-2.75E-05	4.99E-05	-0.550149	0.5833
Fertlizers ^2	1.12E-08	1.13E-08	0.982935	0.3277
Capital	2.36E-05	2.58E-05	0.915262	0.3620
Capital ^2	-2.14E-09	2.69E-09	-0.794337	0.4286

R-squared	0.123437	Mean dependent var	0.112327
Adjusted R-squared	0.047214	S.D. dependent var	0.214920
S.E. of regression	0.209785	Akaike info criterion	-0.202216
Sum squared resid	5.061110	Schwarz criterion	0.045396
Log likelihood	23.73960	F-statistic	1.619415
Durbin-Watson stat	1.155236	Prob(F-statistic)	0.109552

Table 2.38. Model 1a;Translog production function with low quantity of water.

Dependent Variable: LOG(Output in kg)

Method: Least Squares

Sample(adjusted): 1 130

Included observations: 130 after adjusting endpoints

	Coefficient	Std. Error	t-Statistic	Prob.
Log (Constant)	2.799336	2.244527	1.247183	0.2149
Log (Land)	-0.821106	0.866224	-0.947913	0.3452
Log (Water)	0.761569	0.473245	1.609247	0.1103
Log (Labour)	-0.275535	0.685286	-0.402073	0.6884
Log (Fertilizers)	0.696163	0.371057	1.876164	0.0632
Log (Capital)	-0.357715	0.461420	-0.775249	0.4398
Log (Land*Water)	0.204729	0.256166	0.799206	0.4258
Log (Land*Labour)	-0.131394	0.289023	-0.454612	0.6503
Log (Land*Fertilizers)	0.282031	0.462815	0.609382	0.5435
Log (Land*Capital)	-0.076857	0.283292	-0.271298	0.7867
Log (Water*Labour)	0.056878	0.165037	0.344638	0.7310
Log (Water*Fertilizers)	-0.115612	0.129894	-0.890048	0.3753
Log (Water*Capital)	-0.073997	0.165705	-0.446560	0.6560
Log (Labour*Fertilizers)	-0.187785	0.158397	-1.185535	0.2383
Log (Labor*Capital)	0.223417	0.169289	1.319735	0.1896
Log (Fertilizers*Capital)	0.076328	0.115996	0.658022	0.5119

R-squared	0.549672	Mean dependent var	7.195954
Adjusted R-squared	0.490419	S.D. dependent var	0.887254
S.E. of regression	0.633366	Akaike info criterion	2.039280
Sum squared resid	45.73133	Schwarz criterion	2.392207
Log likelihood	-116.5532	Durbin-Watson stat	2.113152

Table 2.39. Model 1a; White heteroskedasticity test (in low quantity of water).

White Heteroskedasticity Test:

F-statistic	1.760615	Probability	0.075242
Obs*R-squared	16.75473	Probability	0.079970

Test Equation:

Dependent Variable: RESID^2

Method: Least Squares

Sample: 1 130

Included observations: 130

Variable	Coefficient	Std. Error	t-Statistic	Prob.
Constant	1.290884	0.353398	3.652780	0.0004
Irrigated land as percentage of total land	-2.978767	1.341694	-2.220154	0.0283
Irrigated land as percentage of total land^2	1.755389	1.031515	1.701758	0.0914
Water	0.001709	0.000978	1.747061	0.0832
Water ^2	-1.99E-06	1.22E-06	-1.623206	0.1072
Labour	-0.001992	0.001088	-1.829785	0.0698
Labour ^2	1.35E-06	8.96E-07	1.502422	0.1356
Fertlizers	6.38E-06	0.000176	0.036158	0.9712
Fertlizers ^2	5.38E-09	2.18E-08	0.246115	0.8060
Capital	0.000128	9.32E-05	1.369244	0.1735
Capital ^2	-1.87E-08	1.04E-08	-1.802452	0.0740

R-squared	0.128883	Mean dependent var	0.351779
Adjusted R-squared	0.055679	S.D. dependent var	0.663371
S.E. of regression	0.644638	Akaike info criterion	2.040564
Sum squared resid	49.45143	Schwarz criterion	2.283202
Log likelihood	-121.6367	F-statistic	1.760615
Durbin-Watson stat	1.985521	Prob(F-statistic)	0.075242

Table 2.40. Model 1a; Translog production function with high quantity of water.

Dependent Variable: LOG(Output in kg)
Method: Least Squares
Sample(adjusted): 1 155
Included observations: 155 after adjusting endpoints

	Coefficient	Std. Error	t-Statistic	Prob.
Log (Constant)	1.992951	4.482121	0.444645	0.6573
Log (Land)	-1.014477	2.141235	-0.473781	0.6364
Log (Water)	0.052964	0.518893	0.102070	0.9188
Log (Labour)	0.043835	0.647809	0.067667	0.9461
Log (Fertilizers)	0.075370	0.544172	0.138504	0.8900
Log (Capital)	0.842889	0.570728	1.476866	0.1420
Log (Land*Water)	0.879721	0.475469	1.850218	0.0664
Log (Land*Labour)	-0.904371	0.390843	-2.313902	0.0221
Log (Land*Fertilizers)	-0.396652	0.184581	-2.148932	0.0334
Log (Land*Capital)	0.201268	0.339322	0.593149	0.5540
Log (Water*Labour)	0.072500	0.144570	0.501489	0.6168
Log (Water*Fertilizers)	0.054103	0.111504	0.485209	0.6283
Log (Water*Capital)	-0.039980	0.113341	-0.352744	0.7248
Log (Labour*Fertilizers)	0.017322	0.105458	0.164252	0.8698
Log (Labor*Capital)	-0.042380	0.119769	-0.353850	0.7240
Log (Fertilizers*Capital)	-0.100273	0.090763	-1.104782	0.2712

R-squared	0.497012	Mean dependent var	8.080389
Adjusted R-squared	0.442733	S.D. dependent var	0.687315
S.E. of regression	0.513083	Akaike info criterion	1.600742
Sum squared resid	36.59234	Schwarz criterion	1.914902
Log likelihood	-108.0575	Durbin-Watson stat	2.154013

Table 2.41. Model 1a; White heteroskedasticity test (in high quantity of water).

White Heteroskedasticity Test:

F-statistic	0.698796	Probability	0.724386
Obs*R-squared	7.173641	Probability	0.708957

Test Equation:

Dependent Variable: RESID^2

Method: Least Squares

Sample: 1 155

Included observations: 155

Variable	Coefficient	Std. Error	t-Statistic	Prob.
Constant	0.564627	0.459612	1.228486	0.2213
Irrigated land as percentage of total land	-0.577690	1.393667	-0.414511	0.6791
Irrigated land as percentage of total land^2	0.246622	0.977268	0.252358	0.8011
Water	1.46E-05	1.93E-05	0.754379	0.4519
Water ^2	-5.60E-10	6.68E-10	-0.838279	0.4033
Labour	-0.000168	0.000399	-0.419931	0.6752
Labour ^2	3.49E-08	1.84E-07	0.189848	0.8497
Fertlizers	-4.79E-05	0.000106	-0.451915	0.6520
Fertlizers ^2	9.03E-09	2.52E-08	0.358157	0.7208
Capital	-3.63E-05	4.88E-05	-0.744043	0.4581
Capital ^2	7.43E-09	5.34E-09	1.391768	0.1661

R-squared	0.046282	Mean dependent var	0.236080
Adjusted R-squared	-0.019949	S.D. dependent var	0.457551
S.E. of regression	0.462093	Akaike info criterion	1.362221
Sum squared resid	30.74827	Schwarz criterion	1.578206
Log likelihood	-94.57214	F-statistic	0.698796
Durbin-Watson stat	2.055675	Prob(F-statistic)	0.724386

Table 2.42. Model 2; Translog production function with all inputs and output expressed in money terms.

Dependent Variable: LOG(Output in €)

Method: Least Squares

Sample(adjusted): 1 285

Included observations: 285 after adjusting endpoints

	Coefficient	Std. Error	t-Statistic	Prob.
Log (Constant)	0.712950	5.82E-12	1.22E+11	0.0000
Log (Land expressed in its objective monetary price)	8.50E-12	8.78E-13	9.679706	0.0000
Log (Water cost)	-3.33E-12	5.20E-13	-6.394086	0.0000
Log (Fertilizers cost)	7.75E-12	9.20E-13	8.422668	0.0000
Log (Capital cost)	7.78E-14	9.72E-13	0.080094	0.9362
Log (Labour cost)	1.000000	9.98E-13	1.00E+12	0.0000
Log (Land expressed in its objective monetary price *Water cost)	-3.42E-13	1.25E-13	-2.727838	0.0068
Log (Land expressed in its objective monetary price *Fertilizers cost)	-9.29E-13	2.22E-13	-4.190746	0.0000
Log (Land expressed in its objective monetary price * Capital cost)	-1.41E-13	2.30E-13	-0.612313	0.5408
Log (Land expressed in its objective monetary price * Labour cost)	-1.00E-12	2.23E-13	-4.502775	0.0000
Log (Water cost* Fertilizers cost)	1.05E-12	1.38E-13	7.562088	0.0000
Log (Water cost* Capital cost)	5.23E-14	1.29E-13	0.404517	0.6862
Log (Water cost*Labor cost)	4.09E-13	1.35E-13	3.026293	0.0027
Log (Fertilizers cost* Capital cost)	-9.99E-13	1.47E-13	-6.787362	0.0000
Log (Fertilizers cost*Labor cost)	-4.48E-13	1.97E-13	-2.276626	0.0236
Log (Capital cost*Labour cost)	9.03E-13	2.00E-13	4.518228	0.0000

R-squared	1.000000	Mean dependent var	8.820978
Adjusted R-squared	1.000000	S.D. dependent var	1.057781
S.E. of regression	1.13E-12	Akaike info criterion	-52.11659
Sum squared resid	3.46E-22	Schwarz criterion	-51.91154
Log likelihood	7442.614	Durbin-Watson stat	1.840212

Table 2.43. White heteroskedasticity test in Model 2.

White Heteroskedasticity Test:

F-statistic	4.090584	Probability	0.000029
Obs*R-squared	37.02111	Probability	0.000056

Test Equation:

Dependent Variable: RESID^2

Method: Least Squares

Date: 05/30/05 Time: 22:02

Sample: 1 285

Included observations: 285

Variable	Coefficient	Std. Error	t-Statistic	Prob.
Constant	1.83E-24	4.35E-25	4.193933	0.0000
Log (Land expressed in its objective monetary price)	-2.69E-30	4.93E-30	-0.545574	0.5858
Log (Land expressed in its objective monetary price)^2	1.40E-35	4.94E-36	2.835839	0.0049
Log (Water cost)	-9.87E-28	4.90E-28	-2.013603	0.0450
Log (Water cost ^2	8.96E-32	5.48E-32	1.636866	0.1028
Log (Fertilizers cost)	1.11E-28	5.23E-28	0.211448	0.8327
Log (Fertilizers cost)^2	4.44E-32	7.85E-32	0.565270	0.5724
Log (Capital cost)	-1.74E-28	2.95E-28	-0.589072	0.5563
Log (Capital cost)^2	2.67E-32	3.23E-32	0.826539	0.4092
Log (Labour cost)	-6.94E-29	6.03E-29	-1.150703	0.2509
Log (Labour cost)^2	8.93E-34	7.25E-34	1.233032	0.2186

R-squared	0.129899	Mean dependent var	1.22E-24
Adjusted R-squared	0.098143	S.D. dependent var	3.68E-24
S.E. of regression	3.49E-24	Sum squared resid	3.34E-45
F-statistic	4.090584	Durbin-Watson stat	1.990601
Prob(F-statistic)	0.000029		

Table 2.44. Model 2; Translog production function with small farmers (low output).

Dependent Variable: LOG(Output in €)

Method: Least Squares

Sample(adjusted): 1 131

Included observations: 131 after adjusting endpoints

	Coefficient	Std. Error	t-Statistic	Prob.
Log (Constant)	0.712950	2.77E-10	2.58E+09	0.0000
Log (Land expressed in its objective monetary price)	2.65E-10	3.02E-11	8.781938	0.0000
Log (Water cost)	1.49E-11	1.43E-11	1.040312	0.3004
Log (Fertilizers cost)	-1.15E-10	1.94E-11	-5.916672	0.0000
Log (Capital cost)	1.22E-10	2.12E-11	5.752130	0.0000
Log (Labour cost)	1.000000	2.76E-11	3.62E+10	0.0000
Log (Land expressed in its objective monetary price *Water cost)	-7.33E-12	2.41E-12	-3.046225	0.0029
Log (Land expressed in its objective monetary price *Fertilizers cost)	2.96E-12	2.33E-12	1.270940	0.2063
Log (Land expressed in its objective monetary price * Capital cost)	-1.19E-11	2.53E-12	-4.695510	0.0000
Log (Land expressed in its objective monetary price * Labour cost)	-4.57E-11	5.99E-12	-7.628952	0.0000
Log (Water cost* Fertilizers cost)	5.83E-12	1.92E-12	3.030174	0.0030
Log (Water cost* Capital cost)	-2.40E-12	1.77E-12	-1.356732	0.1775
Log (Water cost*Labor cost)	3.32E-12	2.39E-12	1.389727	0.1673
Log (Fertilizers cost* Capital cost)	4.40E-12	2.01E-12	2.189502	0.0306
Log (Fertilizers cost*Labor cost)	1.36E-11	2.98E-12	4.557848	0.0000
Log (Capital cost*Labour cost)	-1.31E-11	3.56E-12	-3.691098	0.0003

R-squared	1.000000	Mean dependent var	9.696880
Adjusted R-squared	1.000000	S.D. dependent var	0.577947
S.E. of regression	8.37E-12	Akaike info criterion	-48.06023
Sum squared resid	8.06E-21	Schwarz criterion	-47.70906
Log likelihood	3163.945	Durbin-Watson stat	1.650132

Table 2.45. Model 2; Translog production function with big farmers (high output).

Dependent Variable: LOG(Output in €)

Method: Least Squares

Sample(adjusted): 1 131

Included observations: 131 after adjusting endpoints

	Coefficient	Std. Error	t-Statistic	Prob.
Log (Constant)	0.712950	2.77E-10	2.58E+09	0.0000
Log (Land expressed in its objective monetary price)	2.65E-10	3.02E-11	8.781938	0.0000
Log (Water cost)	1.49E-11	1.43E-11	1.040312	0.3004
Log (Fertilizers cost)	-1.15E-10	1.94E-11	-5.916672	0.0000
Log (Capital cost)	1.22E-10	2.12E-11	5.752130	0.0000
Log (Labour cost)	1.000000	2.76E-11	3.62E+10	0.0000
Log (Land expressed in its objective monetary price *Water cost)	-7.33E-12	2.41E-12	-3.046225	0.0029
Log (Land expressed in its objective monetary price *Fertilizers cost)	2.96E-12	2.33E-12	1.270940	0.2063
Log (Land expressed in its objective monetary price * Capital cost)	-1.19E-11	2.53E-12	-4.695510	0.0000
Log (Land expressed in its objective monetary price * Labour cost)	-4.57E-11	5.99E-12	-7.628952	0.0000
Log (Water cost* Fertilizers cost)	5.83E-12	1.92E-12	3.030174	0.0030
Log (Water cost* Capital cost)	-2.40E-12	1.77E-12	-1.356732	0.1775
Log (Water cost*Labor cost)	3.32E-12	2.39E-12	1.389727	0.1673
Log (Fertilizers cost* Capital cost)	4.40E-12	2.01E-12	2.189502	0.0306
Log (Fertilizers cost*Labor cost)	1.36E-11	2.98E-12	4.557848	0.0000
Log (Capital cost*Labour cost)	-1.31E-11	3.56E-12	-3.691098	0.0003

R-squared	1.000000	Mean dependent var	9.696880
Adjusted R-squared	1.000000	S.D. dependent var	0.577947
S.E. of regression	8.37E-12	Akaike info criterion	-48.06023
Sum squared resid	8.06E-21	Schwarz criterion	-47.70906
Log likelihood	3163.945	Durbin-Watson stat	1.650132

Table 2.46. Model 2; Translog production function with irrigated land expressed as percentage of total land.

Dependent Variable: LOG(Output in €)

Method: Least Squares

Sample(adjusted): 1 285

Included observations: 285 after adjusting endpoints

	Coefficient	Std. Error	t-Statistic	Prob.
Log (Constant)	0.712950	2.68E-12	2.66E+11	0.0000
Log (Irrigated land as percentage of total land)	2.90E-12	1.16E-12	2.493024	0.0133
Log (Water cost)	-2.54E-12	3.17E-13	-8.008065	0.0000
Log (Fertilizers cost)	5.05E-12	4.70E-13	10.76409	0.0000
Log (Capital cost)	2.97E-12	5.12E-13	5.800921	0.0000
Log (Labor cost)	1.000000	4.44E-13	2.25E+12	0.0000
Log (Irrigated land as percentage of total land *Water cost)	1.53E-13	1.76E-13	0.866423	0.3870
Log (Irrigated land as percentage of total land *Fertilizers cost)	-1.02E-13	2.59E-13	-0.396346	0.6922
Log (Irrigated land as percentage of total land * Capital cost)	-5.23E-13	2.55E-13	-2.050279	0.0413
Log (Irrigated land as percentage of total land * Labor cost)	-2.19E-13	2.94E-13	-0.745549	0.4566
Log (Water cost* Fertilizers cost)	5.83E-13	8.37E-14	6.961903	0.0000
Log (Water cost* Capital cost)	1.49E-13	9.02E-14	1.649800	0.1002
Log (Water cost*Labor cost)	3.63E-14	9.01E-14	0.403299	0.6870
Log (Fertilizers cost* Capital cost)	-6.39E-13	1.08E-13	-5.945746	0.0000
Log (Fertilizers cost*Labor cost)	-1.02E-12	1.26E-13	-8.113635	0.0000
Log (Capital cost*Labor cost)	-3.51E-13	1.37E-13	-2.566127	0.0108

R-squared	1.000000	Mean dependent var	8.820978
Adjusted R-squared	1.000000	S.D. dependent var	1.057781
S.E. of regression	8.81E-13	Akaike info criterion	-52.62238
Sum squared resid	2.09E-22	Schwarz criterion	-52.41733
Log likelihood	7514.690	Durbin-Watson stat	1.459741

Table 2.47. Wald test for the significance of Model 1.

Wald Test:

Equation: Untitled

Test Statistic	Value	df	Probability
F-statistic	34.09479	(15, 269)	0.0000
Chi-square	511.4219	15	0.0000

Null Hypothesis Summary:

Normalized Restriction (= 0)	Value	Std. Err.
Log (Land)	0.643560	0.412639
Log (Water)	0.048906	0.219434
Log (Labour)	-0.240628	0.337252
Log (Fertilizers)	0.730945	0.243923
Log (Capital)	-0.250483	0.253692
Log (Land*Water)	-0.158819	0.059125
Log (Land*Labour)	0.256352	0.106403
Log (Land*Fertilizers)	0.159743	0.112257
Log (Land*Capital)	-0.238888	0.112828
Log (Water*Labour)	0.090792	0.063085
Log (Water*Fertilizers)	-0.127570	0.068105
Log (Water*Capital)	0.143314	0.064252
Log (Labour*Fertilizers)	-0.238754	0.093163
Log (Labor*Capital)	0.110576	0.095862
Log (Fertilizers*Capital)	0.015489	0.068702

Restrictions are linear in coefficients.

Table 2.48. Production inputs correlation matrix.

	X1	X10	X11	X12	X13	X14	X15	X16	X17	X2	X18	X3	X4	X5	X6	X7	X8	X9
X1	1.00	0.24	0.25	0.20	0.36	0.25	0.25	1.00	0.02	0.02	0.86	0.86	0.16	0.42	-0.07	-0.12	-0.07	0.27
X10	0.24	1.00	0.31	0.44	0.42	0.31	0.31	0.24	0.19	0.19	0.30	0.30	-0.14	0.14	-0.07	-0.05	0.01	0.09
X11	0.25	0.31	1.00	0.17	0.41	1.00	1.00	0.25	0.04	0.04	0.23	0.23	0.00	0.15	-0.16	0.05	-0.01	0.13
X12	0.20	0.44	0.17	1.00	0.32	0.17	0.17	0.20	0.08	0.08	0.21	0.21	-0.03	0.11	-0.10	-0.04	0.03	0.17
X13	0.36	0.42	0.41	0.32	1.00	0.41	0.41	0.36	0.31	0.31	0.46	0.46	-0.10	0.31	-0.18	0.04	0.03	0.28
X14	0.25	0.31	1.00	0.17	0.41	1.00	1.00	0.25	0.04	0.04	0.23	0.23	0.00	0.15	-0.16	0.05	-0.01	0.13
X15	0.25	0.31	1.00	0.17	0.41	1.00	1.00	0.25	0.04	0.04	0.23	0.23	0.00	0.15	-0.16	0.05	-0.01	0.13
X16	1.00	0.24	0.25	0.20	0.36	0.25	0.25	1.00	0.02	0.02	0.86	0.86	0.16	0.42	-0.07	-0.12	-0.07	0.27
X17	0.02	0.19	0.04	0.08	0.31	0.04	0.04	0.02	1.00	1.00	0.53	0.53	-0.55	-0.03	-0.05	-0.14	0.06	0.00
X2	0.02	0.19	0.04	0.08	0.31	0.04	0.04	0.02	1.00	1.00	0.53	0.53	-0.55	-0.03	-0.05	-0.14	0.06	0.00
X18	0.86	0.30	0.23	0.21	0.46	0.23	0.23	0.86	0.53	0.53	1.00	1.00	-0.15	0.34	-0.09	-0.18	-0.03	0.23
X3	0.86	0.30	0.23	0.21	0.46	0.23	0.23	0.86	0.53	0.53	1.00	1.00	-0.15	0.34	-0.09	-0.18	-0.03	0.23
X4	0.16	-0.14	0.00	-0.03	-0.10	0.00	0.00	0.16	-0.55	-0.55	-0.15	-0.15	1.00	0.13	0.06	0.10	-0.18	0.07
X5	0.42	0.14	0.15	0.11	0.31	0.15	0.15	0.42	-0.03	-0.03	0.34	0.34	0.13	1.00	-0.16	-0.06	-0.06	0.88
X6	-0.07	-0.07	-0.16	-0.10	-0.18	-0.16	-0.16	-0.07	-0.05	-0.05	-0.09	-0.09	0.06	-0.16	1.00	-0.12	0.03	-0.15
X7	-0.12	-0.05	0.05	-0.04	0.04	0.05	0.05	-0.12	-0.14	-0.14	-0.18	-0.18	0.10	-0.06	-0.12	1.00	-0.03	-0.02
X8	-0.07	0.01	-0.01	0.03	0.03	-0.01	-0.01	-0.07	0.06	0.06	-0.03	-0.03	-0.18	-0.06	0.03	-0.03	1.00	0.16
X9	0.27	0.09	0.13	0.17	0.28	0.13	0.13	0.27	0.00	0.00	0.23	0.23	0.07	0.88	-0.15	-0.02	0.16	1.00

Table 2.49. Variable terminology in Table 2.48

X1	Irrigated land in 0.1ha
X2	Non irrigated land in 0.1ha
X3	Total land size in 0.1ha
X4	% of irrigated land to total land
X5	Water quantity in m^3
X6	Water sufficiency: 1=Yes, 0=No
X7	Dummy variable on whether a farmer falls in the irrigation category of a public well: 1=Yes, 0=No
X8	Water price in €
X9	Olive oil water cost in €
X10	Fertilizers and pesticides cost in €
X11	Labor (in days)
X12	Capital in €
X13	Output in kg
X14	Labor in €
X15	Output in €
X16	X1*3.000 in €
X17	X2*3.000 in €
X18	X16+X17

7.3.2. Figures appendix

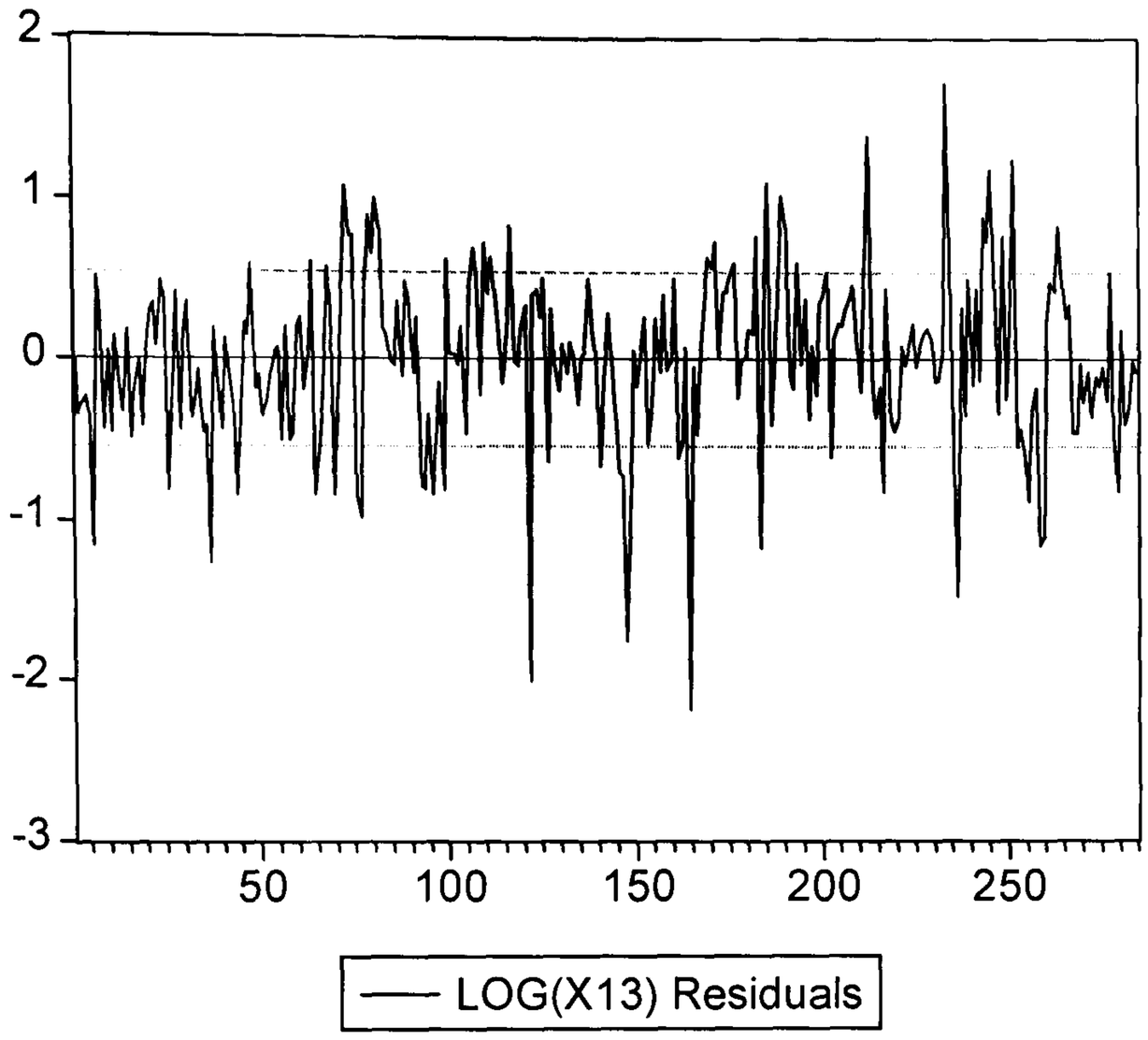


Figure 2.16. Residuals graph for Model 1.

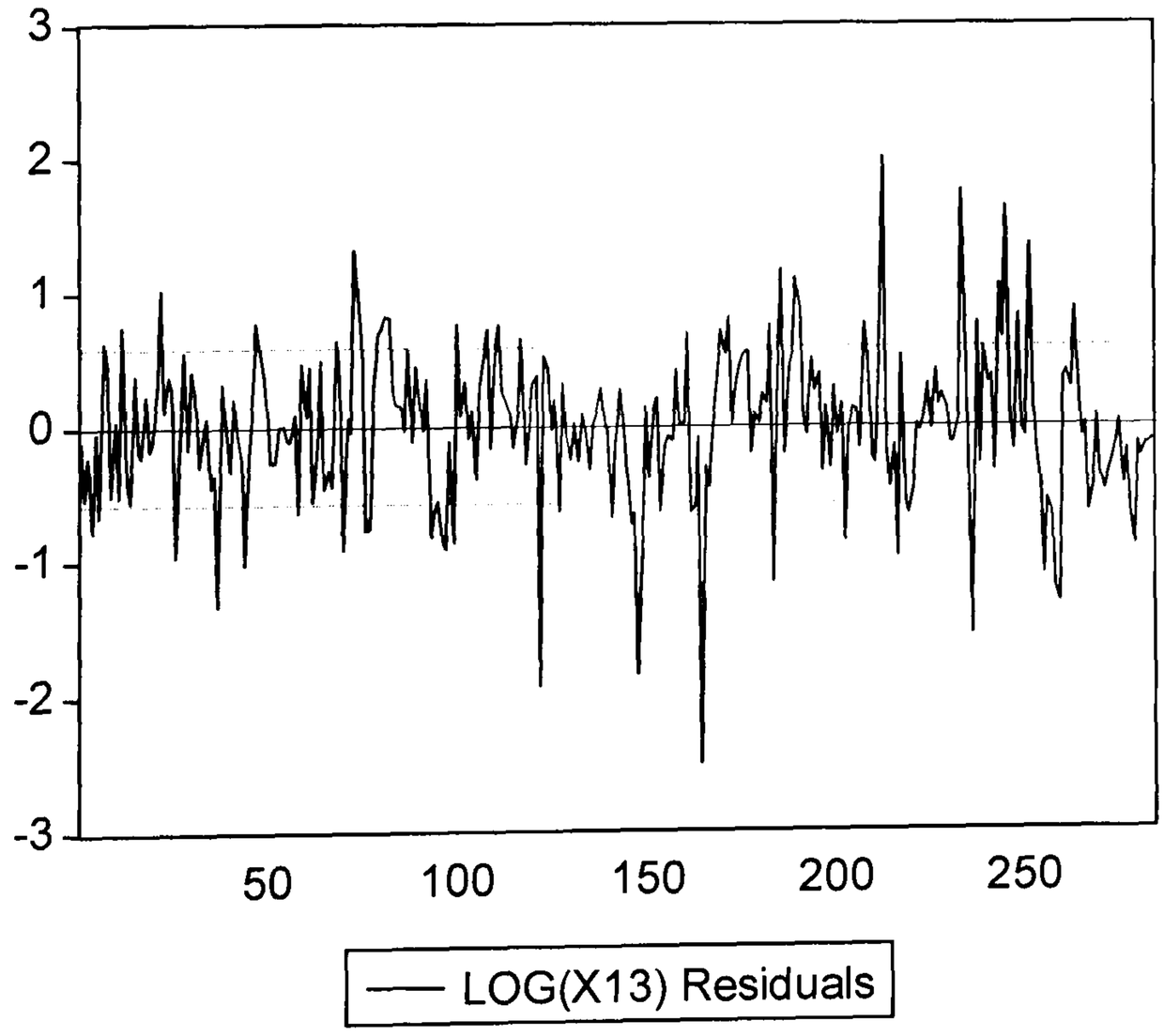


Figure 2.17. Residuals graph for Model 1a.

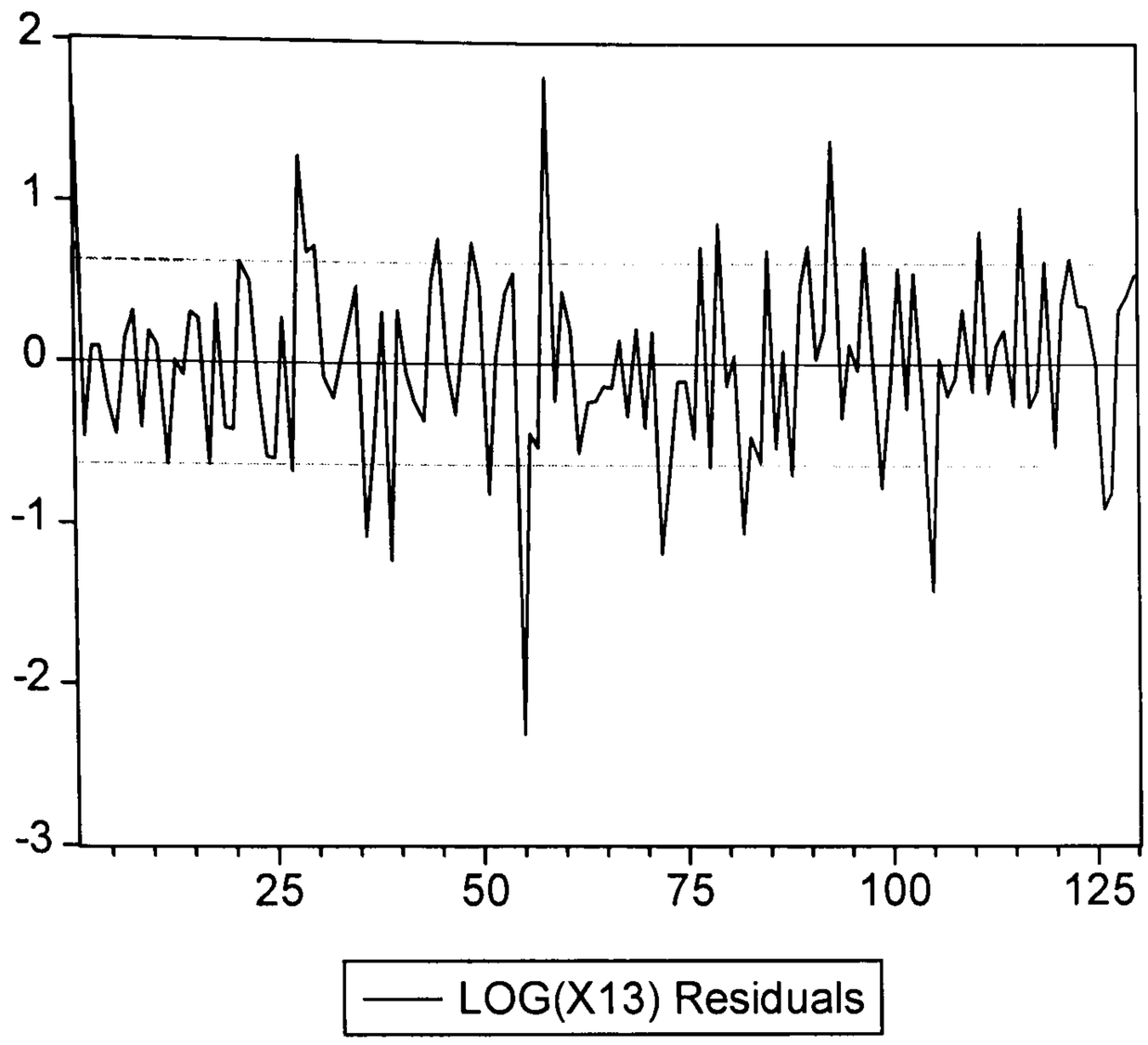


Figure 2.18. Residuals graph for Model 1a with low quantity of water.

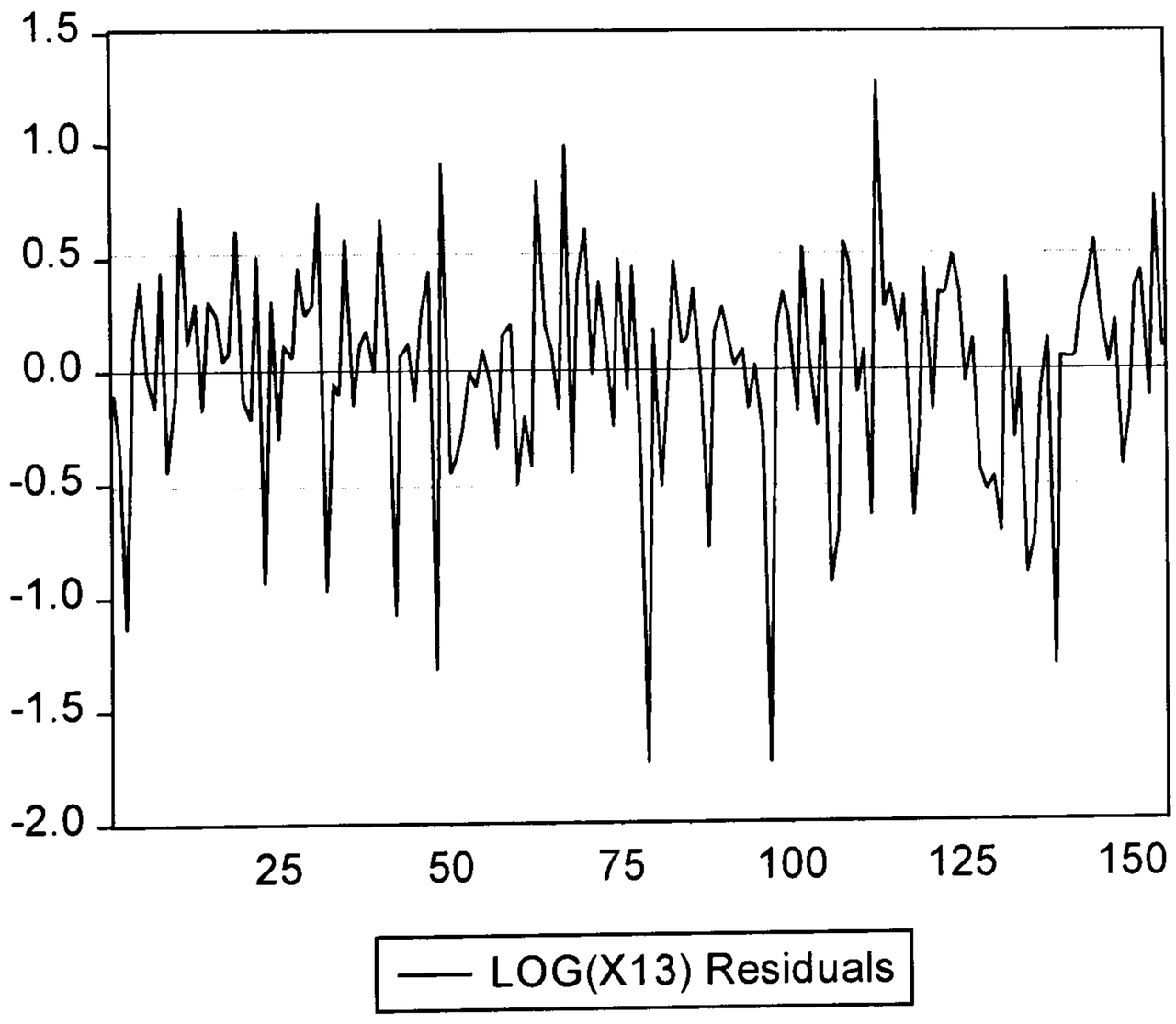


Figure 2.19. Residuals graph for Model 1a with high quantity of water.

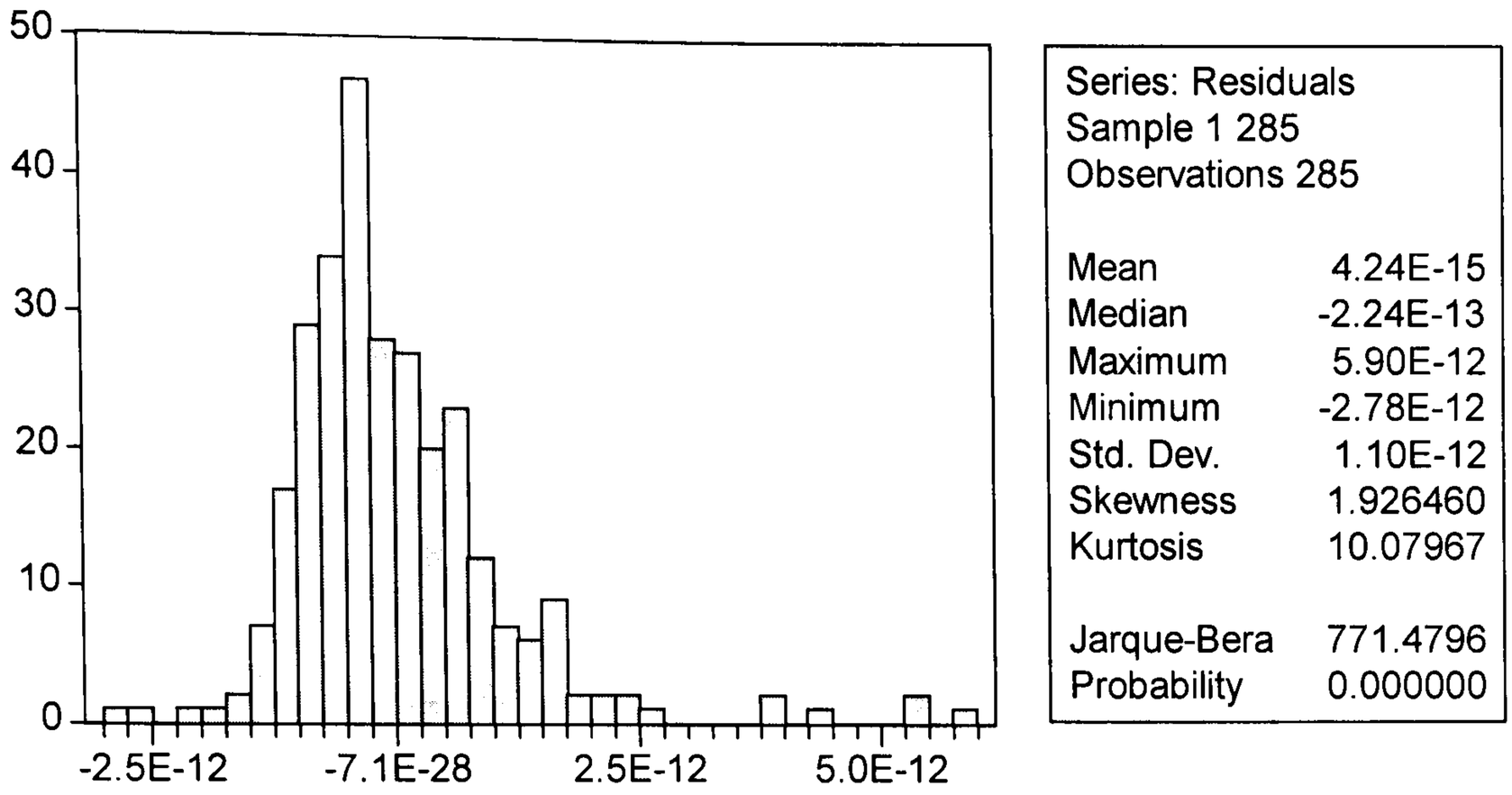


Figure 2.20. Normality test of residuals for Model 2.

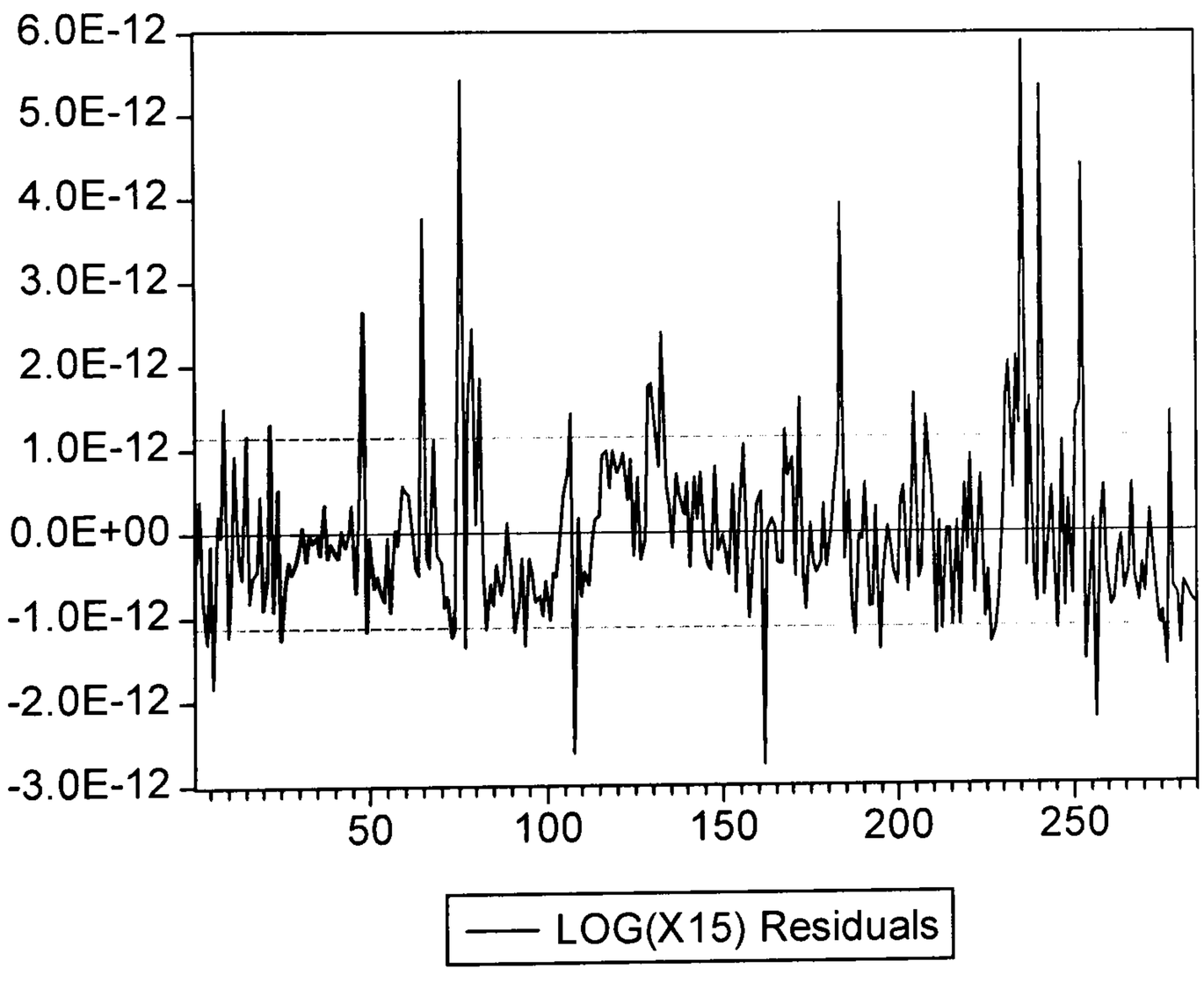


Figure 2.21. Residuals graph for Model 2.

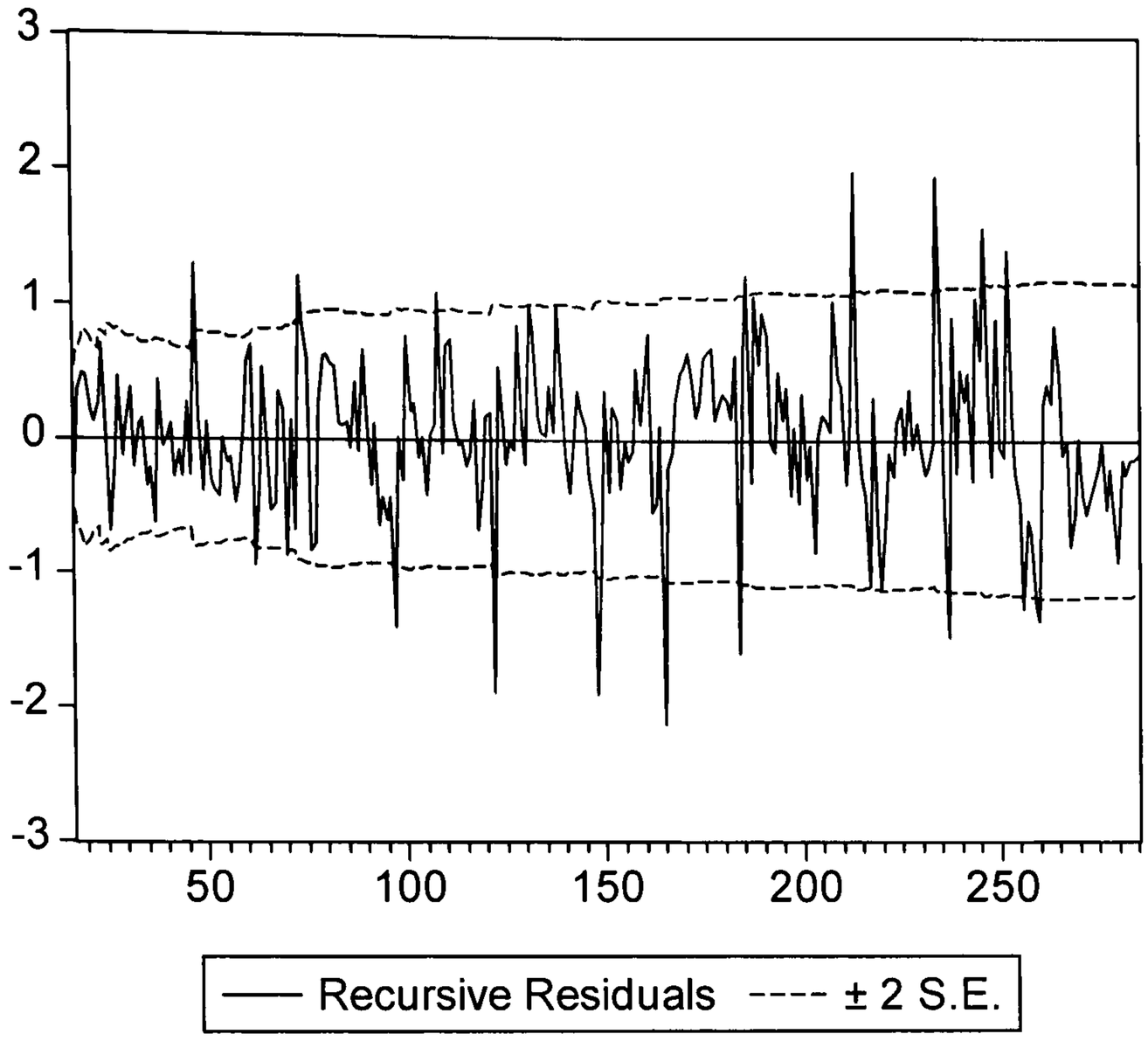


Figure 2.22. Recursive residuals for Model 1a.

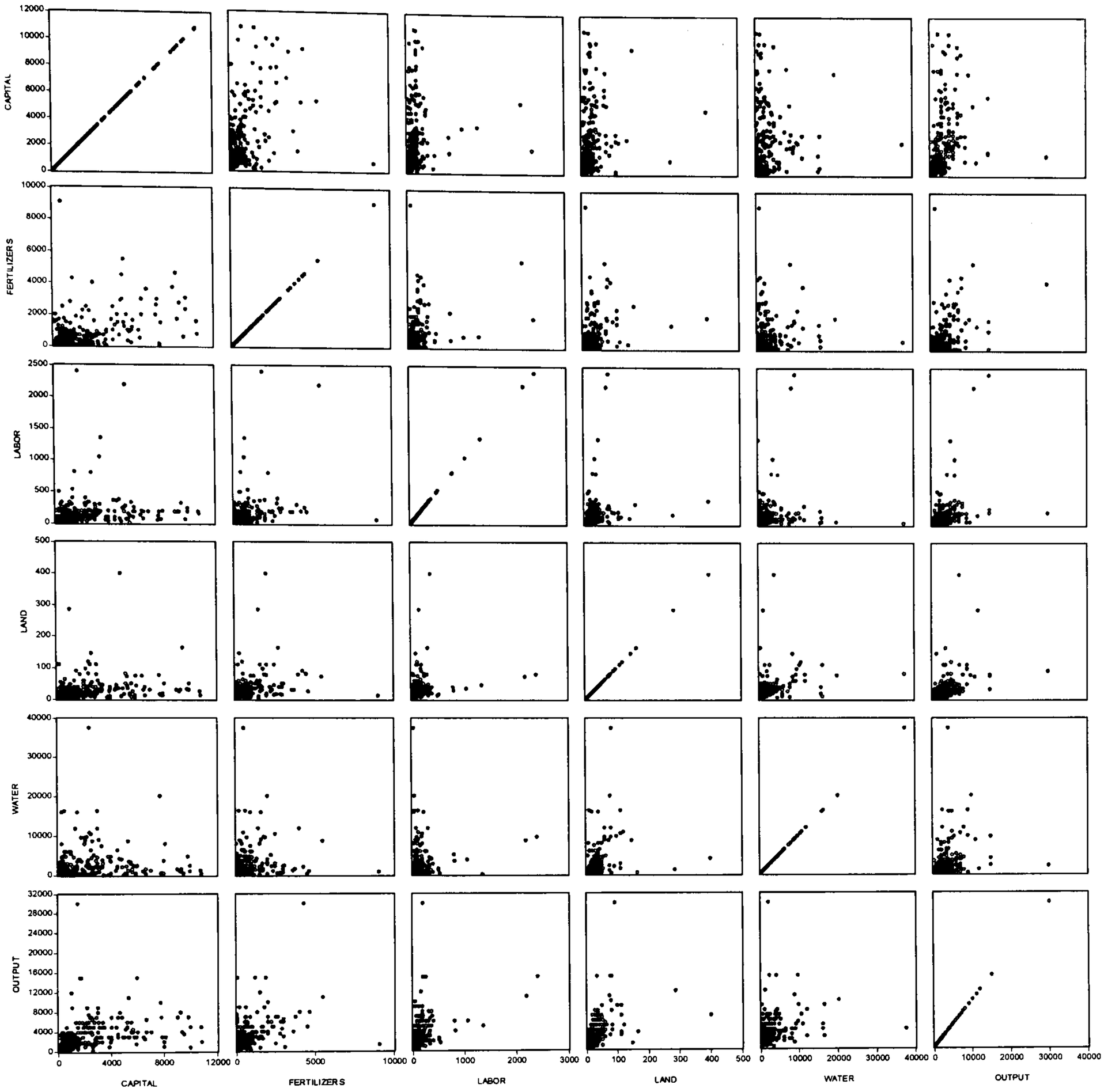


Figure 2.23. Pairwise correlation among all pairs of inputs and output.

7.4. Simlab output

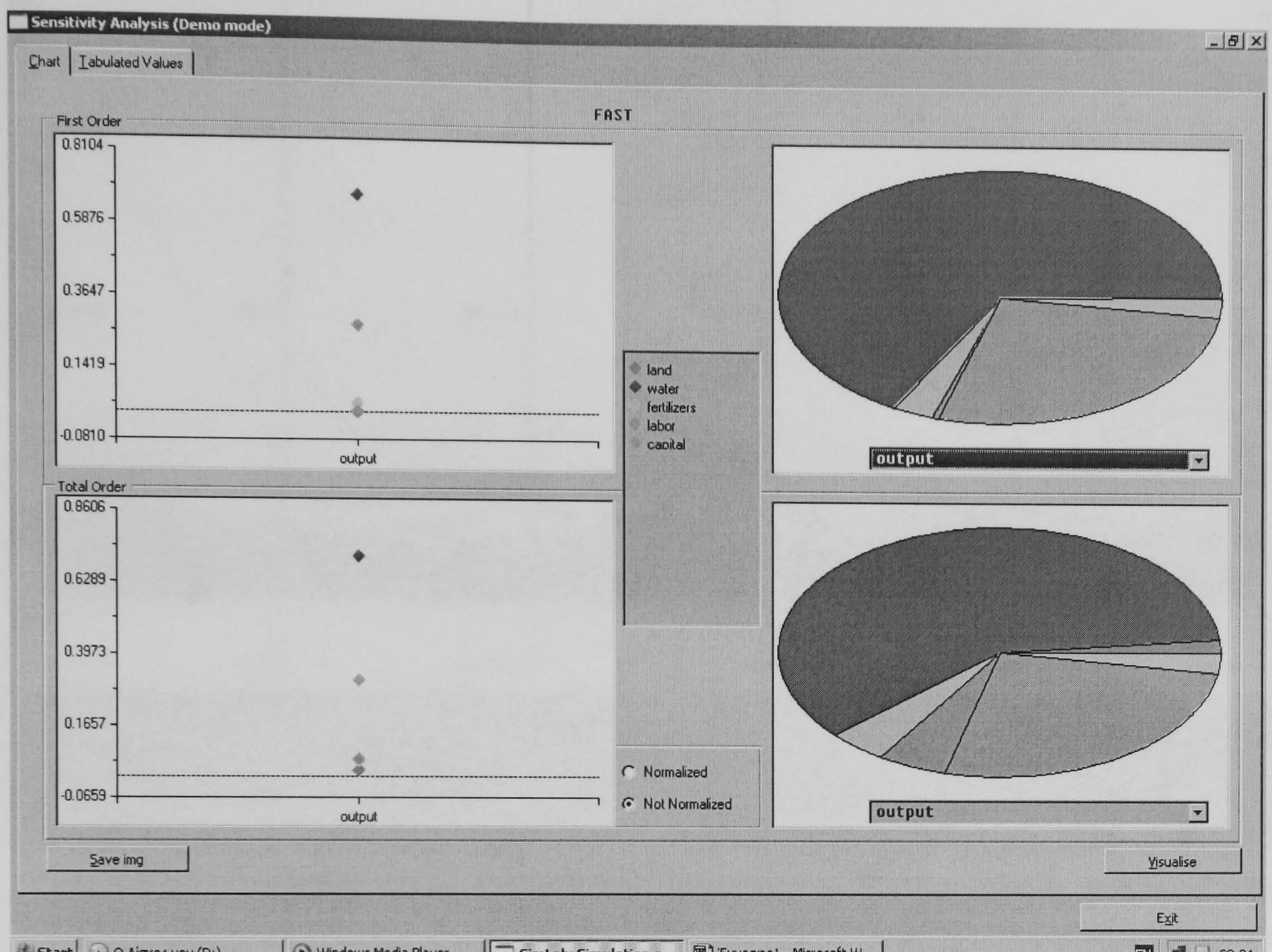


Figure 2.24. Simlab output for sensitivity analysis (part 1).

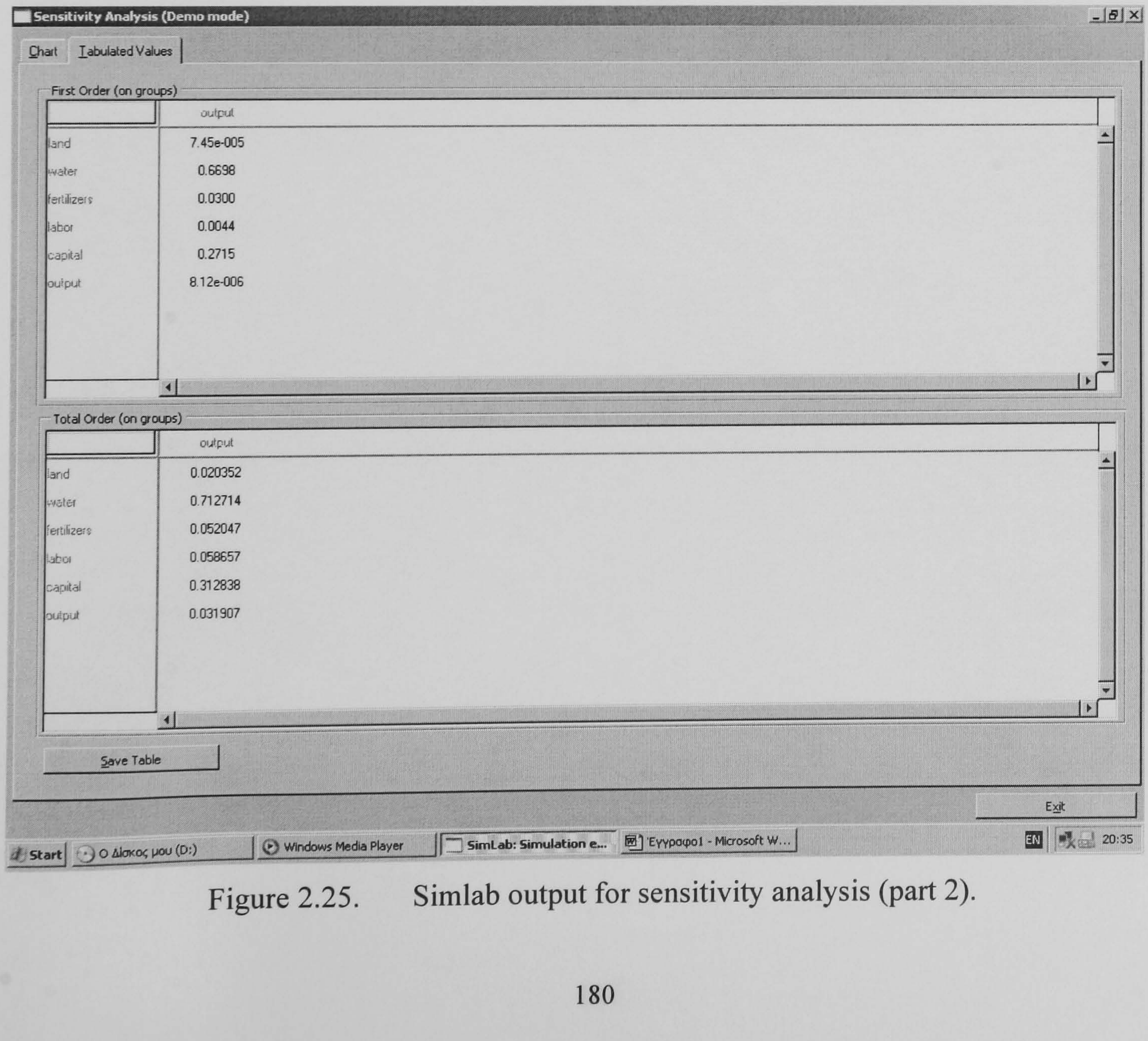


Figure 2.25. Simlab output for sensitivity analysis (part 2).

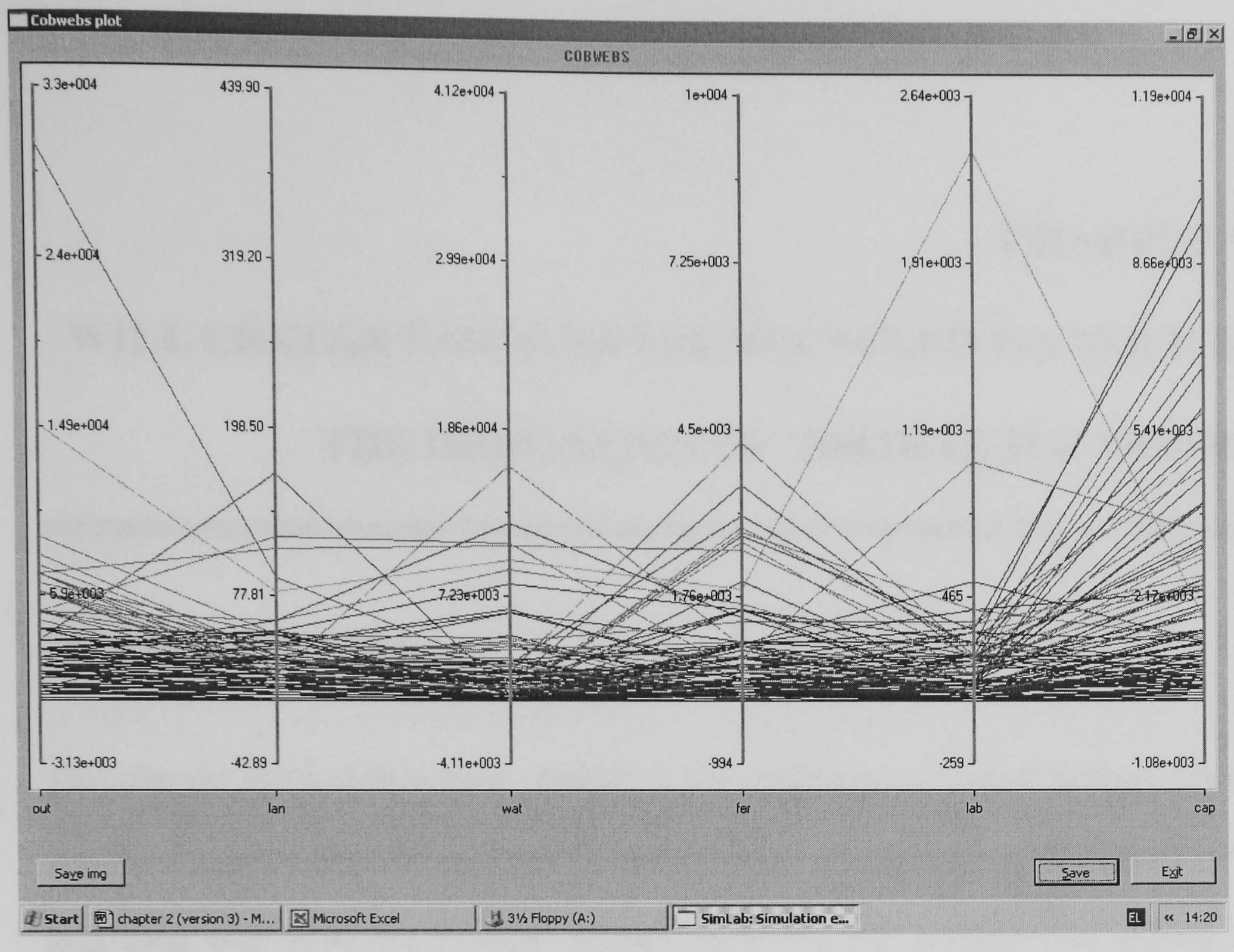


Figure 2.26. Simlab output; Cobweb plot of production function sample generated with Monte Carlo simulation.

CHAPTER 3.

WILL CRETAN FARMERS USE RECYCLED WATER FOR THE IRRIGATION OF THEIR OLIVE TREES?

1. INTRODUCTION

This chapter starts with a short résumé of the contingent valuation method, which was the valuation method we used for recycled water. It continues with analyzing the data from Part B of the farmers' questionnaire that was presented in chapter 2. Chapter 3 investigates willingness to use (WTU) and willingness to pay (WTP) of a sample of Cretan farmers (it is the same sample in chapter 2) for two types of water: Recycled water of quality 2 for the irrigation of the olive tree (for convenience we call it from now on, product 1) and recycled water of quality 3 for the irrigation of the tomato (product 2). Last, a variant of product 1 is also examined (product 1a) which is the irrigation of the olive tree with quality 3 of recycled water (that is higher quality than quality 2).

Logit regressions are used for the WTU models and simple regression models are used for WTP models. Questions 6, 7a and 7b, as enumerated in the questionnaire, investigate WTU. Questions 6.1, 6.2, 6.3, 7.1, 7.2 and 7.3 investigate WTP. The main finding is that farmers are more WTU product 1 than they are for product 2. The superiority of the water quality in product 2 is outweighed by the sensitiveness of the product and the proximity of tomato plant to earth, i.e. there is

the risk of the edible parts being sprinkled with recycled water short before they are consumed.

2. THE CONTINGENT VALUATION; A BRIEF DESCRIPTION OF THE METHOD

In this section we briefly present the Contingent Valuation Method (CVM), which is the method we use for the evaluation of recycled water. We give a definition, a summary of the theory behind it and the most often quoted technical problems for which the method is criticized in literature. We also refer to some empirical studies, which deal with those problems.

2.1.The total value of recycled water for farmers

For sustainable economic development to exist, we need to take into consideration the total economic value of an environmental or public good. The total value of recycled water (see Figure 3.1[1]) consists of a *use value* and a *non-use value*. The use value is derived from using the good. In the case of farmers using recycled water for irrigation, the use value is composed of i) the *direct use value* (farmers use recycled water for irrigation), ii) the *indirect use value* (using recycled water for irrigation saves fresh water resources for drinking and other purposes), iii) *option use value* (farmers save fresh water for the future). The non-use value gives utility from not using the good. This consists of i) the *bequest-value* (the value farmers enjoy from preserving fresh water for future generations) and ii) the *existence value* (value from safeguarding the fresh water systems equilibrium). Fresh water overexploitation leads to desertification caused from saline water intrusion.

[1] This schematic representation has been borrowed from Bateman and Langford (1996).

Total economic value coincides with the *human value*. The *non-human value* concerns the *intrinsic value* of a good. This is e.g. the value of the biological systems that will be damaged or lost with saline water intrusion as an effect of fresh water overexploitation.

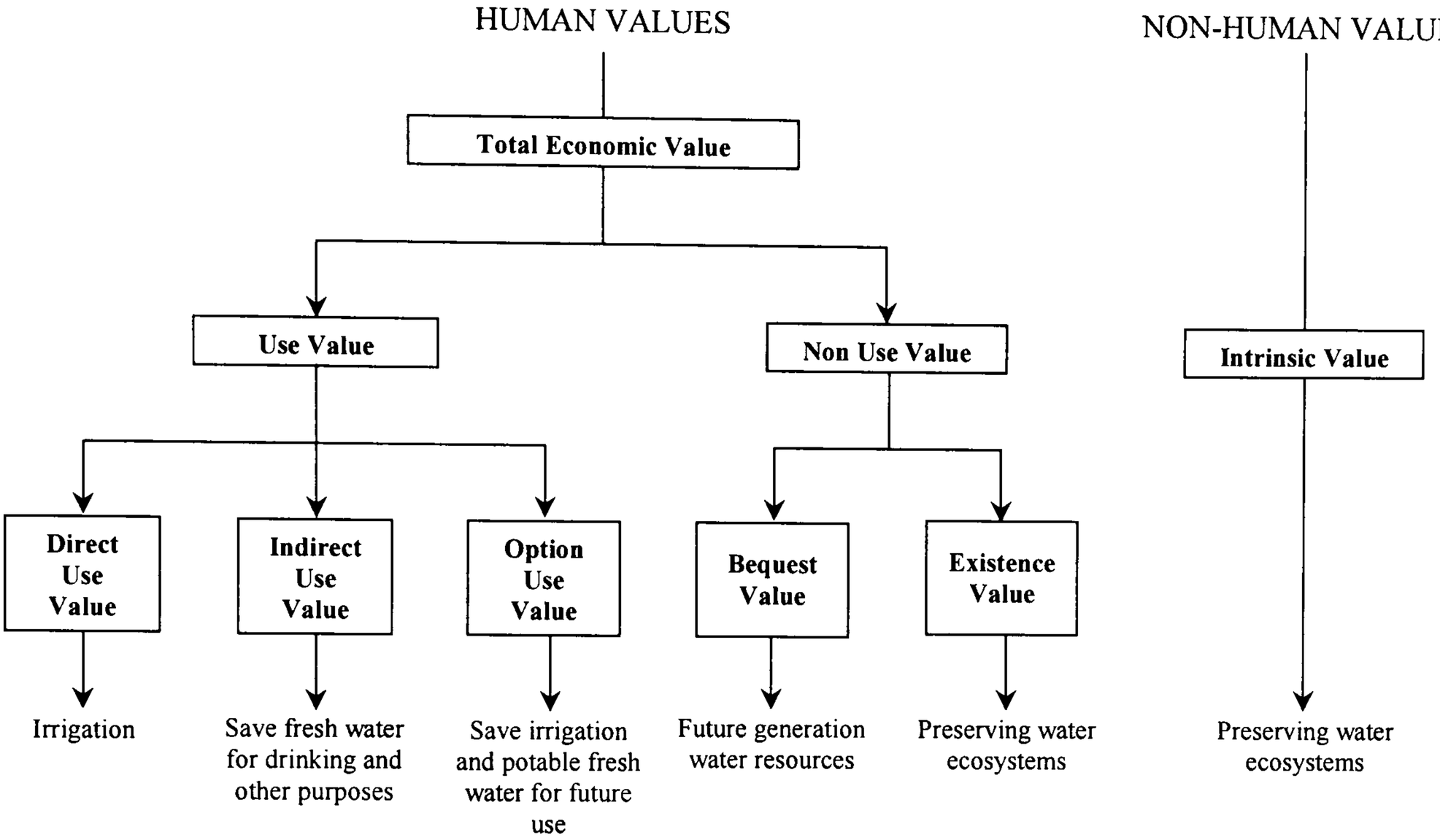


Figure 3.1. Total economic value of recycled water for farmers.

2.2.The total value of recycled water for consumers

A similar analysis could be done for the consumer's value for recycled water. This is presented in Figure 3.2. The only difference will be in the direct use value (consumers eat food products irrigated with recycled water) and in the indirect use value (consumers save fresh water for drinking because their demand for food products irrigated with recycled water will induce farmers to irrigate with it).

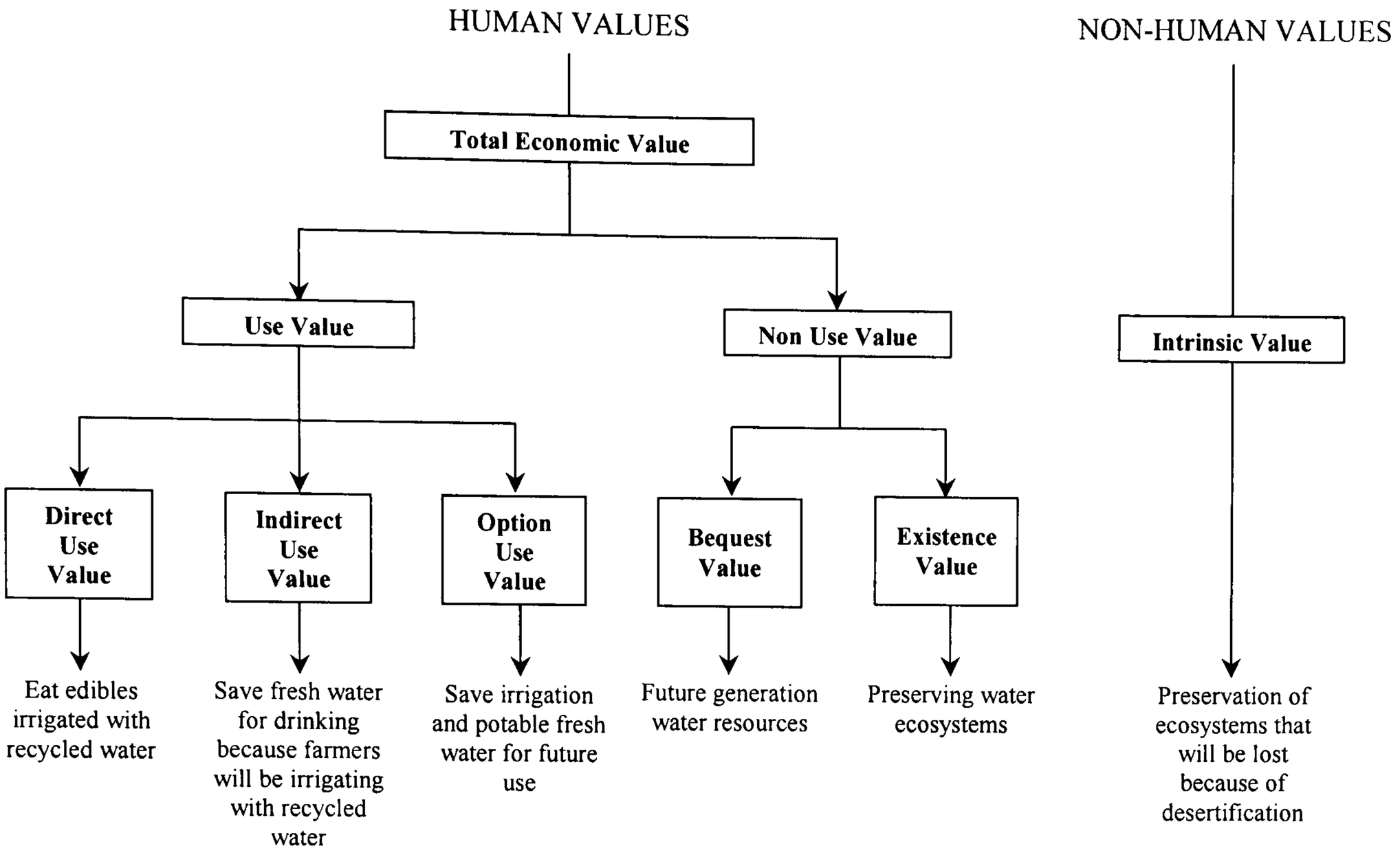


Figure 3.2. Total economic value of recycled water for consumers

What we seek to evaluate with the Contingent Valuation Method is the total economic value of recycled water to these two groups of people: farmers-cultivators of products irrigated with recycled water and consumers who will consume them. Analyzing their preferences will give useful pricing and marketing insights for recycled water.

2.3. The Contingent Valuation Method; Definition and theory

It has increasingly been recognized that environmental cost-benefit analysis is a valuable tool for exercising environmental policy. After the full ratification of the Treaty of European Union on 1st January 1994, the role of environmental considerations within policy-making has been strengthened (Bonnieux and Rainelli, 1991), but according to Pearce (1998a) much European legislation still does not pass a cost-benefit test although it clearly seeks some form of cost-benefit appraisal. He cites from the Article 130r of the Treaty on European Union which requires that: '*in*

preparing its policy on the environment, the Community shall take account of - available scientific and technical data, environmental conditions in the various regions of the Community, the potential benefits and costs of action or lack of action, and the economic and social development of the Community as a whole and the balanced development of its regions'.

Hanley (2001) reports the main weaknesses for the wider acceptance and use of cost-benefit analysis; the acceptability of the ethical framework underlying it, its high cost both from both time and money aspects, cumulative and indirect effects entailed by projects, uncertainty over policy outcomes, the practice of discounting are obstacles in the establishment of cost-benefit analysis as an absolutely impeccable method in environmental appraisal analysis.

The Contingent Valuation Method came to the foreground of economic research after the incidence of the Exxon-Valdez oil spill. It earned its name by the fact that people express their values contingent upon the context of the research. The method has had numerous applications. The variety of valuation subjects is extensive: from natural resources, animal and bird species to cultural assets and projects. Noonan (2003) refers to an innovative study concerning congestion at the British Museum by Maddison and Foster (2001), a study of Mexican Archaeological sites by Beltrán and Rojas (1996).

The CVM seeks to find how much people value the goods for which no markets exist or for non-use values. It sets up a hypothetical market for a good (it tries to make it as realistic as possible) and asks potential consumers how much they would be willing to pay (WTP) to buy that good or how much they would be willing to accept (WTA) in order to forgo the utility earned from the consumption of that good. The debate on Contingent Valuation Method has two major thrusts (Carson,

2000): The first is the philosophical one revolving around whether the passive use values should be included in the economic analysis and the second is about the technical criteria the method should fulfill in order not to bias the results.

The CVM is a stated preference survey method, juxtaposed to the revealed preference methods such as travel cost or hedonic pricing, which estimate the value of a good after the buying action of the consumer has been observed (revealed). Stated preference methods are not based on realized behavior, but on an intended one. The fact that CVM is used for measuring passive values and it relies on what people say rather than what they do, gives a lot of room for various forms of bias to develop for which the method has been criticized. However, this defect is outweighed by the benefit summarized in what Carson *et al.* (2001) claim: *without stated preference methods, economists have to admit that they are not measuring the passive use aspects of environment and other non-market goods, and that these are the aspects about which people care the most. A benefit-cost analysis that omits these considerations will at best be incomplete and at worst completely misleading.* Therefore, in the absence of better alternatives, we have to bear with this method taking into account the criticisms it receives and try to tackle them.

Other stated preference methods are conjoint analysis or choice modeling. The latter does not date back until recently. Both conjoint analysis and choice modeling deal more with the valuation of characteristics and attributes of a good rather than the total value and have been used in marketing and transport research fields. Boxall *et al.* (1996) state that *choice experiments offer considerable enhancements through the incorporation of substitute choices and the possibility of examining a broader range of potential environmental quality changes.* See Stevens *et al.* (2000) for a comparison of the CVM and conjoint analysis.

What we look for from a CVM study is aggregate WTP, not aggregate utility. WTP or WTA measures are aggregated without using explicit welfare weights. But since people's incomes vary, richer people will state higher WTP or lower WTA[2]. This is why the assumption for marginal utility of money to be constant across people or, according to Gowdy and Mayumi (2001) quasi-constant, is a prerequisite. Medin *et al.* (2001) have found that if one assumes equal marginal utility of the public good for everyone, instead of the usual assumption of equal marginal utility of income, aggregate monetary benefit estimates are reduced by a factor of between 2 and 307.

Moreover, CVM has been accused of producing a WTP that does not take individual budget constraints into consideration, i.e. people give a WTP of some amount not necessarily being able to pay it. However, this should not be regarded as a problem, because CVM should focus on the shadow price of an environmental good and not necessarily on WTP. Namely, we are interested to know the true value of a good irrespective of whether people can pay for it. Of course, whether people can pay for it or not, is also very important when we come to the point of implementing policy. Seeing this from another point, Ahlheim (1998) states that *household income is not irrelevant for the valuation of public goods because it enters the shadow price concept indirectly via the household's consumption of market goods*. He also notes that *only if households have to pay for the environmental goods, in that case we may explicitly ask respondents for their WTP because, because WTPs coincide with the respective shadow prices*.

The consumer surplus concept is a key point in the story with WTP. It reveals the "hidden price" that the consumer would be willing to pay, but he does not,

[2] Lower because people with high incomes may demand little compensation for the reduction of their utility.

because the price he is charged is probably lower than that. Consumer surplus is an approximation for WTP/WTA. Given that Willig conditions[3] hold, WTP and WTA equal each one of them, with the consumer surplus, when the income elasticity of demand is zero. Efthimoglou and Xepapadeas (1990) accept that if the income elasticity of demand is very small, then the consumer surplus is a satisfactory[4] approximation of the money equivalent of welfare variation, which is caused by a change in the price of the good, i.e. the consumer surplus is a satisfactory equivalent of WTP.

However, in various empirical studies, WTP does not equal WTA. There are five main explanations in literature: The first is due to reference-dependent preferences (Tversky and Kahneman, 1991). According to this, consumers' preferences are a function of an initial endowment, or a status-quo situation, which affect the marginal rates of substitution between goods. A second explanation (Randall and Stohl, 1980) attributes the above disparity to the transaction costs that one has to incur to replace an item that he has lost. Of course if he never had the item in the first place, again he would have to incur some transaction cost to acquire it. But these two types of transaction cost are different. Third, Kolstad and Guzman (1999) argue that the divergence can be caused by the auction design used in experiments. They show that if the bidder is a buyer unsure of a value and information acquisition is costly, his bid will be shaved downwards relative to his true WTP. Fourth, it is the uncertainty, irreversibility and limited learning opportunities that generate commitment costs (Zhao and Kling, 2001). If a consumer

---

[3] Willig (1976) has showed that if $n>0$, then $E<S<C$, if $n=0$, then $E=S=C$, if $n<0$, then $E>S>C$, where n: income elasticity of demand, E: equivalent variation, C: compensating variation, S: consumer surplus. The estimation of S is feasible, while the estimation of C and E is not an easy matter.

[4] Efthimoglou and Xepapadeas (1990) claim that the basic argument in favor of using the consumer surplus, is that the income elasticity of demand for goods sold by public utilities, is basically small. Most of these goods are essentials and consequently their income elasticity of demand is much smaller than unity.

is unsure of the value of the good and there are non-trivial transaction costs associated with reversing his purchasing or selling decision, he may prefer to delay the decision in order to obtain additional information about the good's value. The fifth is due to the substitution effect between other market goods and the (public) good under study. Hahneman (1999) shows that if there is only a small income effect, there can still be a substantial disparity between WTP and WTA if the aforementioned elasticity of substitution is sufficiently low.

Differences are observed not only between WTP and WTA. They are also observed for the various elicitation formats. We discuss this in section 2.4.

The CVM is not advisable to be used alone. Combining CV information with qualitative information derived from focus groups (various stakeholders, elected representatives etc.) can lead to conclusions of greater relevance to policy makers (Kontogianni *et al.*, 2001). A relevant and quite interesting method, which can work in a complementary way to the contingent valuation method, is the so-called citizen jury[5]. A citizen jury consists of a small group of citizens, representing the general public, which meet to deliberate upon a policy question. Aldred and Jacobs (2000) specify more on the description of the citizen jury: It involves around sixteen ordinary people who represent a cross-section of a defined community. They meet over a period of usually four days to consider an important public policy question. The citizen[6] jury is different from a focus group, because it is used in the latter stages of decision-making, contrary to the focus group, which is used in the early stages.

Kenyon *et al.* (2003) report the advantages of a citizen jury over a contingent valuation. A citizen jury appears to be superior in that researchers can check whether

[5] The term is loosely based on the idea of a criminal jury (Aldred and Jacobs, 2000).
[6] For a detailed description of the role a citizen jury plays, see Kenyon *et al.* (undated).

and what information the respondent understands and also interfere with his understanding. They also have the opportunity to "observe" the way he constructs his values. These points are not easy to be achieved in a contingent valuation experiment. Blamey (1996), Jacobs (1997) and Sagoff (1988) reveal that *economists and others have suggested that a contingent valuation questionnaire asks respondents the wrong question, assuming that consumers think about environmental goods (public goods) in the same way they do about private goods.* Blamey (1996) continues that *respondents should not be treated as consumers of environmental goods, but rather as citizens who think of the welfare of the community when responding to environmental issues*. There is some logic in this statement but the ideal situation would be that the respondent answers both as a utility maximizer and as a citizen. Asking the respondent to act as a citizen would presuppose maturity and knowledge from the average respondent. This is not feasible though and would leave place for free-riding behavior to encroach. The idea of validating CV results through the citizen jury method is very promising.

The use of the CVM is not a panacea and it will not solve problems unless it is combined with strong political will. A field note from the World Bank (1999) entitled "Willing to pay but Unwilling to charge" reveals the uselessness of a CV survey when it cannot influence policy change, because no matter the truth it speaks, politicians are not willing to implement its findings. But even if they are willing to charge, *total social utility will not increase if the fresh water savings generated in the agricultural sector are not put into alternative uses with greater added value for the society as a whole* (Gomez- Limon and Riesgo, 2003).

2.4. Question formats in Contingent Valuation Method and empirical evidence

CVM questionnaires use either open-ended or closed-ended questions (dichotomous and polychotomous choice questions or iterative bidding) or a mix of the two types. Each format bears its pros and cons. Open-ended questions are supposed to provide the respondent with more freedom and independence in his answers while the closed-ended ones boast the help directed to the respondent to formulate his mind through their fully structured questions. For convergent validity to exist, all types of elicitation format must produce the same results. Berrens *et al.* (2002) state that *the effects of the informational treatments should be the same across all elicitation formats and this could be used as a test for convergent validity.* Before discussing the advantages and disadvantages of the two elicitation formats, it is worth noting that the scale tips more towards close-ended questions, but again each CVM experiment is special, with its own needs and problems to be solved.

Open-ended questions have been found to yield consistently lower WTP responses (Markowska and Zylicz, 1999). This can be possibly due to the fact that with this type of questions, the respondent is deprived of a yardstick, with which he could otherwise realize in what terms to answer. He is probably more hesitant in taking the responsibility to give a WTP answer concerning a good, which had never occurred to him before. As regards the deprivation of the answer yardstick, Bateman *et al.* (1995) report that: *respondents experience significant uncertainty in answering open-ended questions and may exhibit free-riding or strategic overbidding tendencies. When answering dichotomous choice questions, respondents seem to experience much less uncertainty although the suggestion that bid levels affect responses cannot be ruled out, and it is clear that respondents behave somewhat*

differently to dichotomous choice as opposed to open-ended formats. Here, Bateman *et al.* imply that the opposite direction of WTP bid magnitude (from the one stated at the beginning of this paragraph) is also possible.

Sugden (1999) notes that there is a good deal of evidence that for CVM when used in surveys, binary choice questions elicit higher valuations than the open-ended ones. It is said[7] that CVM surveys which use binary choice questions correspond to choice tasks, while those that use open-ended questions, correspond with valuation. Namely, in the closed-ended format, it is the choice on which the decision is focused, either a yes or no (This format is also criticized for causing yea-saying). In the open-ended format, the respondent focuses on an amount because he is asked to think by himself and he is not asked to agree or disagree with a readymade bid.

However, Cameron and Quiggin (1994) reveal that, *whereas several varieties of bias may be minimized by dichotomous-choice valuation questions, this elicitation method can be highly statistically inefficient in that vastly larger numbers of observations are required to identify the underlying distribution of resource values with any given degree of accuracy.* According to Bohara *et al.* (1998) research results show that dichotomous choice values are not affected by cost and group-size information, while the open-ended values are negatively affected. Cost information for various public goods was shown to affect WTP in open-ended questions whether it was shown in the form of estimated total cost of the program, implied past expenditures of how the good would be provided.

Another reason why the two formats give different results is, according to the same writer, the scale compatibility hypothesis. This hypothesis recognizes the existence of two main attributes in the options offered in a CVM survey; One is the

---

[7] See chapter 4 for our finding on this.

monetary cost and the other is the non-monetary benefit. If the benefit is viewed as a more important attribute than monetary cost, then binary choice response modes might be expected to elicit responses, which imply relatively high money valuations of non-monetary benefits (because they evoke affirmative answers). Also, if the theory is correct, open-ended CVM questions might be expected to elicit responses, which imply relatively low money valuations of non-monetary benefits (because they will tend to lead respondents' attention on the attribute of monetary cost).

Furthermore, according to the incentive compatibility hypothesis, closed and open- ended questions are affected in a different fashion. An elicitation mechanism is incentive-compatible if, whatever a respondent's true preferences, he has an incentive to respond in a way that correctly reveals the desired information. Binary choices are incentive-compatible if the respondent is made a take-it-or-leave-it offer. Open-ended questions can be made incentive-compatible through a mechanism proposed by Becker DeGroot and Marschak (1964) described in Sugden (1999). This mechanism is a version of take-it-or leave-it offer.

Dichotomous choice questions have been accused of inducing to the manifestation of symbolic demand. Kahneman (1986) attributed this effect to ideological contamination that results in symbolic demand. He noted that: *people seemed to be ready with an answer before the relevant numbers are specified.* He called this symbolic demand because it is true of symbols that quantity is sometimes irrelevant. He also adds that the more controversial, emotional and symbolic the environmental issue, the more the individual feels the need to express her attitudes and values. In dichotomous choice studies, respondents wanting to express their green values must say yes to whatever price they are presented with. This can be remedied with a follow-up question.

As far as the polychotomous[8] choice questions are concerned, Ready *et al.* (1995) argue that *they result in much higher rates of "yes" responses, and therefore much higher estimated WTP than does the dichotomous choice format.* They also found that *their polychotomous choice questions did not provide enough incentive for the respondents to think long and hard when answering the questions. It was too easy for respondents to say, "maybe yes" or "slightly prefer". It takes the discipline forced by a dichotomous choice question to get the respondent to invest the time needed to fully consider the scenario being represented.* On the other hand however, this type of question could be seen as privileged from the point of view that instead of having the respondent to answer between yes/no, it presents the respondent with various degrees of opinion strength.

Closed-ended (or referendum) questions have many versions. The dichotomous choice question, already discussed, is the simplest formulation. The respondent has to decide between yes and no for a certain bid he is asked about. The double bounded dichotomous choice question involves one more stage of choice. After the respondent has chosen between yes and no at the first bid he is offered (stage 1), he also has to decide about a second bid whose height depends on the answer that has been given on the first stage (stage 2). If he answers yes on the bid at stage 1, he is then offered a higher bid, or if he has answered no, he is then offered a lower bid. This type of question produces an interval in which the respondent's bid falls. This elicitation method has been criticized because respondents are suspected to answer inconsistently across the two subsequent questions. According to Cameron and Quiggin (1994) it is possible to determine which effects might dominate by examining the mean and standard deviation of the WTP elicited by the second bid

[8] This is a closed-ended form of question. It is different from the dichotomous choice form in that it presents the respondent with a variety of answers and not only two.

according to whether or not the response to the first offered amount was 'yes' or 'no'. Park (2003) attributes[9] the difference of the two responses to a risk premium respondents demand because of the uncertainty they experience until they actually come to try the suggested good. Furthermore starting points may affect the stated WTP in DB-DC questions. Quoting again from Cameron and Quiggin (1994) *starting point effects can be interpreted as the consequences of suggested values acting as cues for respondents who have no implicit agenda and are motivated only to provide a 'socially correct' answer to a survey question* and they suggest the introduction of dummy variables, one for each starting point in order to find out whether they have a joint significant effect upon the means for either the initial of the follow-up valuation questions.

Analogously to the DB-DC, works the triple-bounded dichotomous choice question. It defines the interval in which the bid falls with more precision, because it has an additional follow-up question with a bid amount that depends on the responses to the first two questions.

Another closed- ended question form is the payment card or ladder. A visual aid lists various amounts and asks respondents to circle the one that comes closest to their own value. Cameron and James (1987) suggest that the response can be interpreted not as an exact statement of the WTP but, rather, as an indication that the WTP lies somewhere between the highest number below the amount circled and the smallest number above it. The biggest advantage of this method is that it avoids the starting point bias from which iterative bidding or bidding games suffer from. Bidding games resemble an auction context. Respondents are faced with several rounds of discrete choice questions with the final question being an open-ended one.

---

[9] He assumes that respondents answer the first bid question truthfully and the second strategically.

2.5. Information and Experience in CVM

The quantity and the quality of information given to respondents in CV experiments, the question of whether and how to give a piece of information and to whom, or whether the information has an effect[10] on WTP are some of the discussion topics CV researchers have dealt with. Below, starting from the pessimistic model of bounded rationality, empirical evidence has shown that prior experience affects WTP positively, that information should be given for certain unknown types of goods but it depends on various factors whether it will affect the magnitude of WTP and last that information should be given only to people concerned on a topic.

According to the model of bounded rationality, it is argued that in complex and unfamiliar situations one would not expect individuals to be able to express their true preferences. Following this, Gans (1999) discusses the possibilities for using experts for valuation as well as providing information for decision making on the preservation of public resources. This is a pessimistic and less democratic point of view according to which only experts are the appropriate people to participate into a CV experiment.

As expected, respondent's experience affects value formation. For example, Boyle *et al.* (1993) in their study of Grand Canyon white-water boating observed question ordering effects for inexperienced boaters, while these did not occur in experienced boaters. Furthermore, as a result of respondents having little or no prior experience with the proposed transaction, they often express "constructive preferences". This means that they shape their preferences while the experiment takes place. Therefore in this context peoples' responses will not be appropriate or

[10] A way of checking about information effects is to ask respondents if they feel like revising their answer at the end of the questionnaire.

reliable to be counted on for a cost-benefit analysis. This can be controlled through the establishment of verbal protocols, which ask the respondent to describe how he came to a specific answer.

In the study that appears in the following chapters, both farmers and consumers were unlikely to have prepared themselves for decision-making, since recycled water is a novelty. Munro and Hanley (1999) say that this is the case that the provision of information is justifiable. If on the contrary the good would be marketed, and the purpose was just to find its value from current users, then there would be no need for further information. They say that: *There is no reason for contaminating the information sets held by individuals.* The questionnaire completion that took part in the present study was preceded by a brief information session.

Munro and Hanley (1999) state that *there is no necessary expectation that the formulated WTP will rise after information is received, even on average*. They also suggest that if we want to test for the effects of information on valuation, messages have to be provided where the effect on beliefs is more clear-cut. As far as the optimal level of information is concerned, they present two approaches: The first treats information like any other economic good, and as such it is provided until marginal benefit equals its marginal cost. The second is that information is not an economic good to be determined from marginal cost or benefit considerations and that it would be wrong to accept uninformed views about the value of the environment. Furthermore, they pose the question of what true and accurate information is, revealing that the interviewer has a lot of room for the respondents' manipulation.

The respondents processing mode affects the degree that information can be understood in a CV experiment. If the research subject is something that concerns the

respondent (as it is in both the farmers and consumers research in chapter 3 and 4) then he adopts a central processing mode. Otherwise they adopt a peripheral processing mode. In the last case they base their judgments on superficial cues in the situation, on implicit moods or motivations, or on simple cognitive heuristics and generally on factors that are unrelated to the message content. Ajzen *et al.* (1996) claim that under conditions of personal relevance, WTP has been found to increase with the quality of the arguments used to describe the good and that subtle contextual cues can seriously bias these estimates. Therefore, we conclude that for the information given in a CV experiment to be absorbed and for the experiment to be successful, the latter should be targeted to concerned groups.

2.6. Hypothetical bias

This form of bias is one of the greatest disadvantages from which CVM is supposed to be suffering. In various studies ((Cummings *et al.* (1995), Neill *et al.* (1994), Blumenschein *et al.* (1997)) the proportion of hypothetical yes responses greatly exceeded the proportion of real yes responses. Murphy *et al.* (2003), in their meta-analysis of hypothetical bias in WTP contingent valuation studies, find that this can occur due to model specification, lack of data variability, the treatment way of extreme values, the nature of a good, namely whether it is public or private etc. Also, they report that student samples suffer more from this.

Hypothetical bias has been found to be correlated with gender. It was three times larger for males than for females (Brown and Taylor, 2000). Gilligan (1982) explains this in that *females pay more attention to the particular context of a problem, while males are more concerned with abstract rights and duties. So females are expected to respond better to the market context in a hypothetical valuation*

exercise than males and state values more similar to their revealed WTP in a corresponding real market.

The hypothetical bias problem could be remedied if every CV experiment could be combined with a revealed preference experiment. For example, if somebody answers "yes, I would be WTP this "x" amount for a specific transaction" and immediately afterwards he is asked to implement his WTP, this would be a nice way to find out how many people really meant what they said. The hypothetical bias can also be minimized by trying to make the experiment as realistic and solemn as possible, e.g. specifying what the WTP answer will be used for. Murphy *et al*. (2004) find that cheap talk script is effective in the elimination of hypothetical bias for respondents facing higher bids, however they claim that its effectiveness may depend on factors such as script length, respondent's experience with the good and the payment amounts.

2.7. Embedding or scope effects

The term is distinguished into two different kinds of effects. Perfect embedding or insensitivity to scope occurs when the WTP is the same between preserving environmental commodities that differ from each other in their quantities or qualities. Regular embedding or part-whole bias refers to a situation when the same good is assigned a lower value if WTP for it is inferred from WTP for a more inclusive good rather than if the particular good is evaluated on its own. Thereby the WTP is determined by how many other (public) goods are included in the contingent valuation scenario and valued simultaneously.

One of the reasons that people might not appear to appreciate a greater quantity or a higher quality of a product is that they may have lexicographic preferences. In

this case respondents appear to have a non-compensating stance. Edwards (1986) suggested that individuals' ethical attitudes could give rise to lexicographic preference orderings of ordinary commodities and environmental attributes, based on a moral commitment in favor of environmental protection. Perman *et al.* (2003) report that lexicographic preferences would imply a lack of price sensitivity and could give rise to high estimates of average WTP for preservation.

2.8. Protest-responses

By protest responses we mean refusals to pay or "do not know" responses. "*A no answer option should be explicitly allowed in addition to the yes and no vote options on the main valuation question"* (Arrow *et al.*, 1993). "Don't know" responses are a category of answers, which need special care in decoding what they mean. Useful messages may be found in them, which a discussion with the respondent can reveal. Wang (1997) picks up four main reasons as to why these answers appear. These are: *indifference between yes or no, inability to make a decision, preference for some other mechanism for making this decision, bored by the survey and anxious to end it as quickly as possible*.

Jorgensen *et al.*, (2001) summarize some more of the meanings that can be attributed to protest responses: *The question of why people will not pay becomes problematic when their responses to the valuation question do not indicate zero consumer surpluses for the proposed change in the public good. For example, respondents who believe that they already pay enough, that the polluters should pay, that there is too much waste in government, or that existing revenue should be used, may still value a certain public good improvement but not the act of paying more money for it*. The same writers add one more reason for protest responses;

respondents who felt that they would not afford to pay, also disliked the valuation question and they did not wish to answer. Last, they warn that protest responses may be more frequently observed when the scope of the good change exceeds an individual's ideal level of service. When one is offered to buy something, which he regards as redundant or excessive, then most probably he will refuse to pay.

In another study by Vossler *et al.* (2002), "Don't knows" had to be treated as refusal to pay. In their external validation experiment, survey and referendum percentage of yes match only if "Don't knows" are treated as no. Groothuis and Whitehead (2002) found that "don't knows" had to be interpreted as no in the WTP framework and as a "middle response" in a WTA framework.

Furthermore, protest bids could depend on the general attitude somebody has in life; whether he falls in the utilitarian or rights-based philosophical set (Spash, 1997). Evidence has been found to support the view that *environmentalists choose to operate on a rights-based approach, which rejects the relative welfare arguments of economics and positively attributes compensation to future generations for environmental damages. These individuals will then be likely to refuse to participate in the WTP or WTA procedure. This rejection could show-up in non-response, zero-bids, or outliers and the data would erroneously be regarded as respondents placing no value on the public good*...Last, protest responses can be detected with initial attitudinal questions or follow-up questions.

2.9. Validity and Reliability

Validity and reliability are two important issues in a CVM study. Bateman *et al.* (2002) give the definitions for the above terms : Reliability refers to the degree of replicability of a measurement, while validity refers to the degree to which a study

measures the intended quantity. The first is studied through test-retest of WTP at two different points in time or comparison of two WTP distributions from two equivalent samples, or comparison of stability of the estimated bid function in repeated samples. The second concept of validity has various facets; Bateman *et al.* (2002) report on the face validity, construct validity, convergent validity and expectation-based validity. Since these definitions are generally known, we will proceed with whether the present study can pass any tests for validity and reliability.

As regards reliability, and given the fact that we cannot repeat the survey, we could only do with testing stability of the estimated bid functions. As regards validity, we believe we have done what we could at the beginning of the survey and gave the utmost attention on this while we were designing the questionnaire. We believe that we have made the questionnaire as simple as possible for people to understand, we have given them as much information as was possible in the context of this research and the method of providing the good was plausible in order to have content validity, but we have not set up a way to check construct or convergent validity in a formal way. Instead we have various bits and pieces, which could be taken as evidence for validity. Let me refer to two examples on this: The first is in Table 4.12, chapter 4, which shows that consumers act as rational agents. As bids get higher, they tend to answer no rather than yes (This is some form of construct validity). The second is in chapter 4 and it concerns the two elicitation formats we have used in the WTP question for product 3. In the non-parametric framework, mean WTP results are not much different. So, this could be some evidence for the existence of convergent validity. Unfortunately, for the farmers' survey, we have no means to check on validity.

2.10.The design of our questionnaires

After all the discussion on how all the above CVM problems can be circumvented, it is useful to see how we have catered for them in our survey designs. A narrative on the rationale behind each question is given in the appendix of chapter 2 (for farmers' questionnaire) and the appendix of chapter 4 (for consumers' questionnaire).

3. DESCRIPTIVE STATISTICS OF WILLINGNESS TO USE AND WILLINGNESS TO PAY

This part presents and interprets the frequency distribution and descriptive statistics of WTU and WTP for products 1 and 2. Product 1 is recycled water of quality 2, which is appropriate for the irrigation of the olive tree. Product 2 is recycled water of quality 3, which is appropriate for vegetable irrigation such as the tomato we use in our example. We also enquire on WTU and WTP of product 1a. This is a variant of product 1. Again it is about the irrigation of the olive tree but with a higher recycled water quality (quality 3).

3.1 Willingness to Use

Table 3.1. provides the frequency distribution of WTU for product 1.

Table 3.1. WTU product 1

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Yes	343	75.7	75.7	75.7
	No	81	17.9	17.9	93.6
	I don't know	29	6.4	6.4	100.0
	Total	453	100.0	100.0	

Apparently the largest part of farmers in Table 3.1 (75.7%) is positively positioned towards using product 1. Although 56% of the farmers admitted they had faced problems with fresh water shortage (in chapter 2), 75.7% were WTU recycled water of quality 2 for irrigation. This means that more farmers than those who were facing water shortage problems saw it good to use recycled water for irrigation. Thus, it is

reasons besides the distress water shortage causes, that drives farmers to use recycled water and it is those reasons we will investigate in sections 5.1 and 5.2.

Table 3.2. WTU product 1a.

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	I don't have to answer this question	372	82.1	82.1	82.1
	Yes	34	7.5	7.5	41.9*	89.6
	No	45	9.9	9.9	55.7*	99.6
	I don't know	2	0.4	0.4	2.4*	100.0
	Total	453	100.0	100.0	100.0	

Note: Asterisks mean that the respective numbers have been calculated with respect to a total of the 81 farmers who had said no in Table 3.1.

The question whose results are shown in Table 3.2 was posed with the purpose to check the existence of scope effects. Roughly 42% of the respondents, who previously had answered that they would not use product 1, now answered that they would use product 1a for this purpose. They understood and appreciated the superior quality of product 1a over product 2 and they changed their initial negative attitude to a positive one.

Table 3.3. WTU product 2.

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Yes	282	62.3	65.3	65.3
	No	101	22.3	23.4	88.7
	I don't know	49	10.8	11.3	100.0
	Total	432	95.4	100.0	
Missing		21	4.6		
Total		453	100.0		

A larger percentage of farmers are WTU product 1 than product 2 (Table 3.3), apparently because the tomato plant is more sensitive than the olive tree and its crops

hang much closer to the ground and run higher the risk of coming in touch with recycled water more easily, if irrigators are not careful.

3.2. "Don't know" responses

In chapter 4 (section 2.1.1), we give a short discussion on the effect of "Don't know" responses and how we are supposed to handle them. The same applies here. "Don't know" responses are 6.4% for product 1 and 11.3% in product 2. Their increase in product 2 could be due to the fact that farmers are more skeptical about a more controversial product such as product 2. "Don't knows" in this case could mean no as well. Nevertheless, "Don't knows" are dropped in our further analysis, because they bear no systematic pattern (i.e. are random) with the regressors we used in Models 1 and 2. "Don't know"s for product 1a, which is the safest product, is only 2.4%. But this percentage cannot be directly compared to the previous one, since the sample where it comes from (n=81) is conditional upon farmers saying no in the total sample (n=453). It would be interesting to see how our results would be affected if "Don't know" responses were taken to mean no. This constitutes a point for further research.

3.3. Willingness to Pay

WTP was first investigated as an intention of paying level. Paying levels were: "less", "as much" and "more". The results of this question are presented in Table 3.4. The largest number of farmers stated themselves as WTP for less than the price they were currently paying for fresh irrigation water. The seven farmers who answered "more" are probably the result of warm-glow effects.

Table 3.4. WTP1 as intention.

Intention to pay	Frequency	Percentage
More	7	2.04
As much as	66	19.24
Less	262	76.38
Missing	8	2.33
Total	343	100%
Question was not addressed	110	
Grand total	453	

Farmers who stated themselves as positive in using product 1 were additionally asked to decide on a bid. The bid had to be formed based on the fresh water price they paid for irrigation at that moment which varied enormously among farmers (these prices are presented in Figure 2.1 and Table 2.4 in chapter 2). Figure 3.3 provides a scatter plot of WTP bids for product 1. We have excluded the two highest bids 2.6 and 3 € for a better representation.

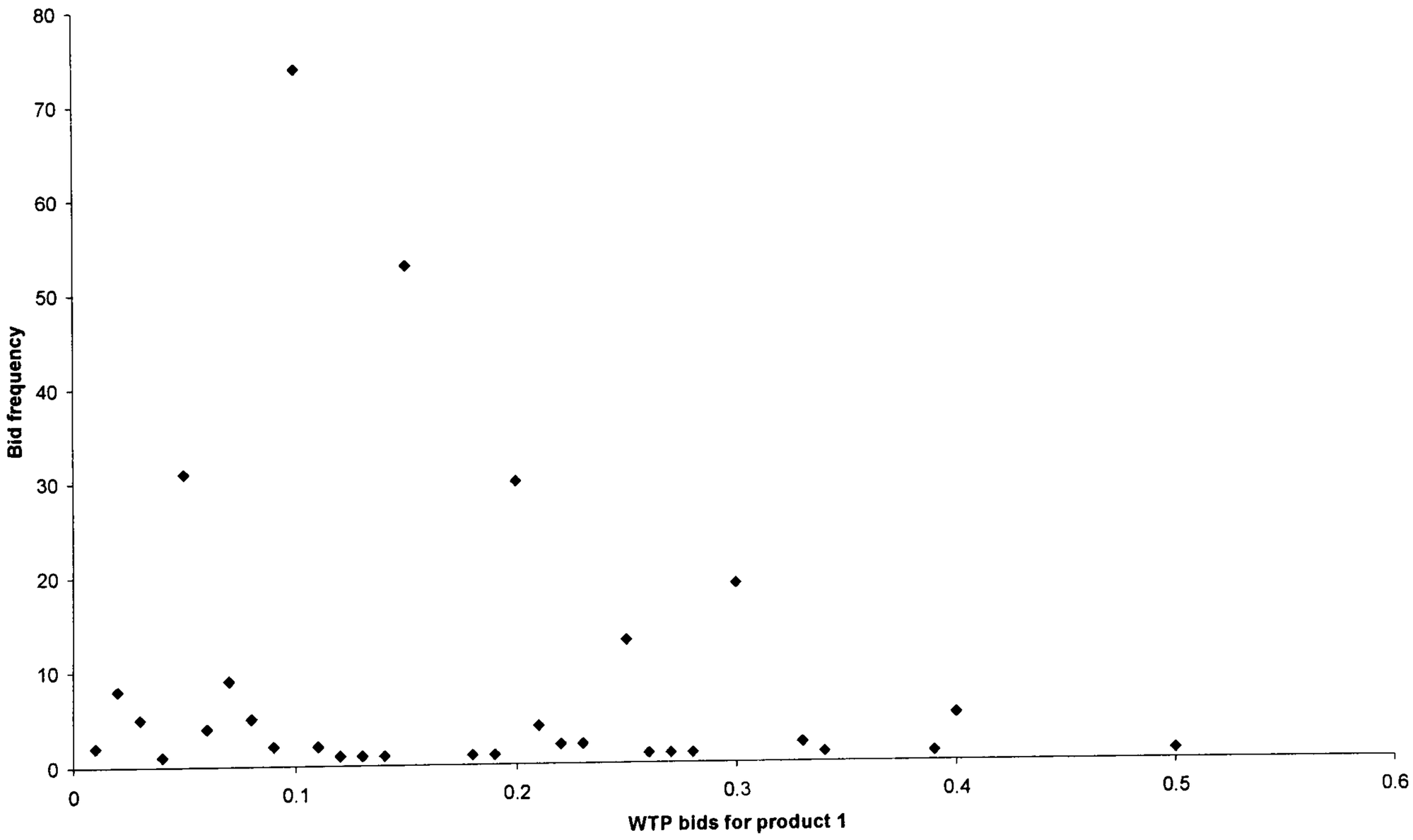


Figure 3.3. WTP for product 1 (pecuniary amount).

Table 3.5. Descriptive statistics of WTP for product 1 (non-irrigators excluded)

	N	Minimum	Maximum	Mean	Std. Deviation
WTP1 (pecuniary amount)	288	0.01	3.00	0.1640	0.23808
Valid N (listwise)	288				

Note: According to Table 3.1, bids should be 343. Fifty-five bids are missing due to non-respondents and non-irrigators.

Mean WTP for product 1 is 0.16 euros. The 95% confidence interval of the mean is found by

$\mu \pm 1.96 * \frac{\sigma}{\sqrt{n}}$. This is (0.13-0.19) for WTP1.

A 95% confidence interval means that if all possible samples of the same size were taken, 95% of them would include the true population mean somewhere within the interval around their sample means and only 5% would not.

Table 3.6 concerns WTP for product 2 and is read in an analogous way Table 3.4 was read. 69.14% of farmers appear as WTP for less. "As much as" respondents represent roughly the same percentage for both products 1 and 2. The percentage for "less" decreases in product 2 while the missing responses percentage increases significantly. Actually it stands for 10.99% of respondents. This could mean that these farmers were so skeptical about this product that they could not decide which payment level to opt for. Maybe they did not want to pay at all and thus we should take them to mean zero WTP. In that case, they would have to be included under the "less" payment level. No farmers voted for the "more" payment level. This makes us wonder whether "more" bids for product 1 have been due to warm glow effect after all, because if they had, they would have continued their existence in product 2 as well. However we cannot be sure of this, since the WTP samples are derived only from farmers who stated a positive WTU. This is a different sample for products 1 and 2.

Table 3.6. WTP2 (as intention).

Intention to pay	Frequency	Percentage
More	0	0
As much as	56	19.85
Less	195	69.14
Missing	31	10.99
Total	282	100%
Question was not addressed	171	
Grand total	453	

Table 3.7. Descriptive statistics of WTP for product 2 (non-irrigators excluded).

	N	Minimum	Maximum	Mean	Std. Deviation
WTP2 (pecuniary amount)	239	0.02	4.03	0.1704	0.26689
Valid N (listwise)	239				

Note: According to Table 3.3 bids should be 282. The 43 bids missing are non-respondents and non-irrigators.

The 95% confidence interval for the mean is (0.13-0.20). The distribution of WTP bids for product 2 is shown in Figure 3.4. Moreover, we must note here that 0.17€ for product 2 is insignificantly different from 0.16 € for product 1.

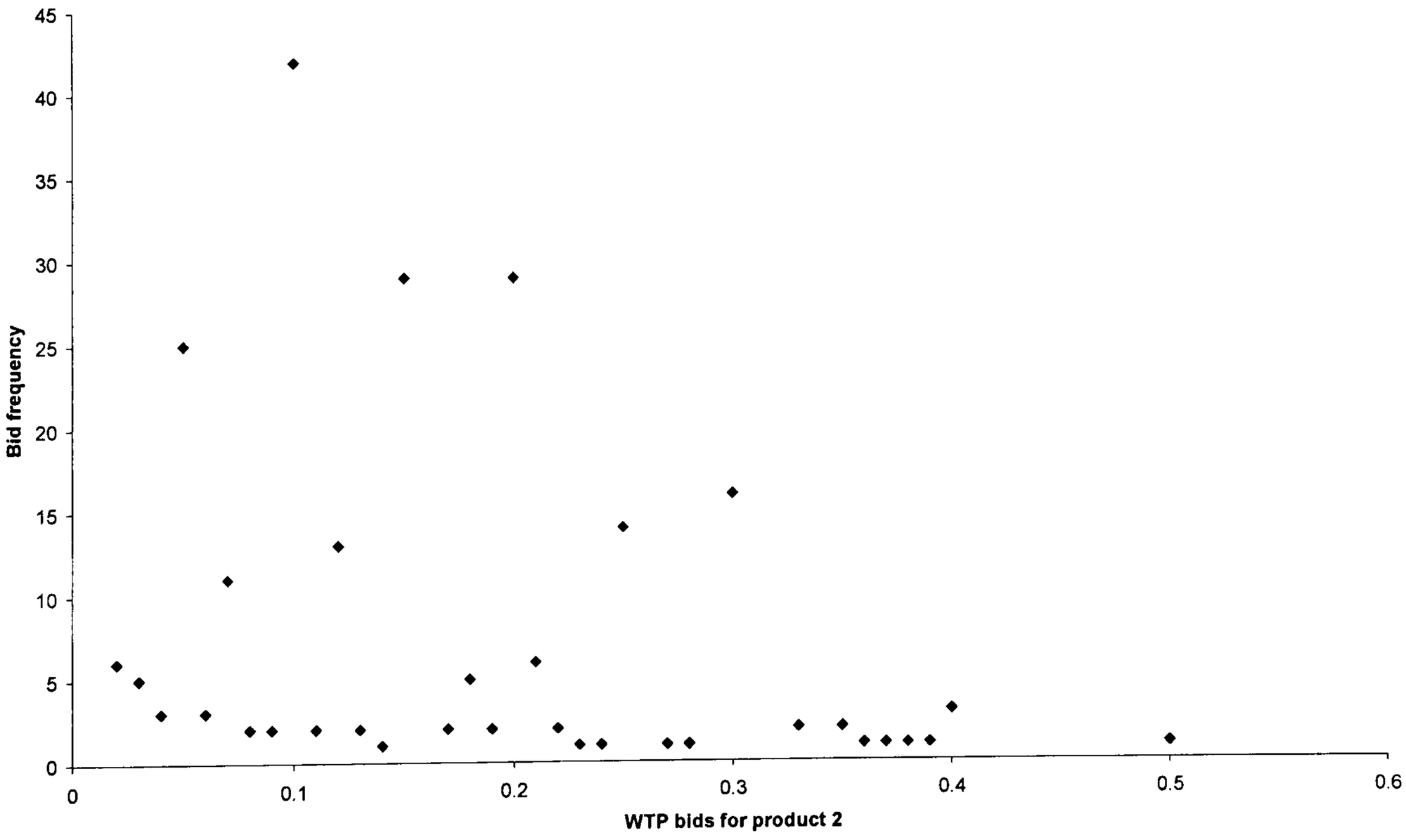


Figure 3.4. WTP for product 2 (pecuniary amount).

Comparing the results of Tables 3.5 with 3.7, we see that mean WTP for product 2 (0.17 €) is higher than WTP for product 1 (0.16 €), which means that more farmers gave higher bids for this product, obviously acknowledging its better quality. On the other hand though, standard deviation of WTP for product 2, is also higher (0.26) than the one of WTP for product 1 (0.23). Therefore, there is a higher dispersion of bids in the WTP for product 2 around its mean. This reveals that although on average, bids were higher for the WTP of product 2, this product is regarded as more controversial, because farmers appear to be less in unison for its WTP as compared to the WTP of product 1.

Next (Table 3.8), we are presenting the variable names we are going to use in in the models of section 4 and section 5.

Table 3.8. List of variables.

Variable name	Description
WTU1	Willingness to Use product 1: Binary variable with D=1 if the respondent is WTU product 1 and D=0 otherwise.
WTU2	Willingness to Use product 2: Binary variable with D=1 if the respondent is WTU product 2 and D=0 otherwise.
WTP1	Willingness to Pay for product 1.
WTP2	Willingness to Pay for product 2.
INFO	It describes how informed the farmer thinks he is about environmental problems. It is a categorical variable taking values from 0 to 5, with zero being the farmer who is not informed at all.
LACKW	It describes the degree of seriousness consumers assign to the problem of water shortage. It takes values from 1 to 5. Seriousness of degree 5, signifies a very serious problem.
ACTIONS	It answers how many of the four mentioned (in the questionnaire) environmentally friendly actions the farmer is involved in. This is a count variable taking values from 0 to 4.
HERA	Binary variable with D=1 if the respondent is a Herakliot and D=0 if he is not.
AGE1	Binary variable with D=1 if the respondent falls in age groups 18-24 or 25-34 and D=0 if he is not.
AGE2	Binary variable with D=1 if the respondent falls in age groups 35-44 or

Variable name	Description
	45-54 and D=0 if he is not.
AGE3	Binary variable with D=1 if the respondent falls in age groups 55-64 or 65-and above and D=0 if he is not (this is the excluded11 age variable).
EDU1	Binary variable with D=1 if the respondent is illiterate and D=0 if otherwise.
EDU2	Binary variable with D=1 if the respondent is primary school graduate and D=0 if otherwise.
EDU3	Binary variable with D=1 if the respondent is secondary school graduate and D=0 if otherwise.
EDU4	Binary variable with D=1 if the respondent is tertiary education graduate and D=0 if otherwise (this is the excluded education variable).
INCOME	Monthly family income; This is a categorical variable with ten age categories, which stand for the mid value12 of the interval that described the income group.
SEX	Binary variable with D=1 if the respondent is a man and D=0 if the respondent is a woman.
CHID	Binary variable with D=1 if the respondent has children and D=0 if he does not.

[11] Exclusion took place to avoid the dummy variable trap.
[12] The first income group, which ranged from 0-300 € was represented by its mid value which is 150 €.

4. CORRELATION AMONG REGRESSORS

Prior to undertaking bid curve analysis, correlation analysis should be performed with the purpose of detecting any possible high correlation between any pair of variables and take measures against multicollinearity. Studying correlation will also and foremost help us explain better the results received from the models in the rest of the chapter. Kendall's tau measure was used for the construction of Table 3.9, because most variables are categorical.

Table 3.9. Correlation matrix of regressors.

	INFO	LACKW	ACTIONS	WPRICE	INCOME	AGE1	AGE2	EDU1	EDU2	EDU3	SEX	CHID	HERA
INFO	1	0.059	0.154	-0.031	0.135	0.117	0.036	-0.116	-0.188	0.162	-0.052	-0.098	0.052
LACKW	0.59	1	0.091	-0.044	0.125	0.008	0.203	-0.101	-0.009	0.054	-0.069	-0.006	0.161
ACTIONS	0.154	0.091	1	-0.011	0.117	-0.048	0.021	-0.011	-0.074	0.024	0.089	-0.018	-0.126
WPRICE	-0.031	-0.044	-0.011	1	-0.049	-0.051	0.078	0.025	0.041	-0.013	0.014	0.026	0.063
INCOME	0.135	0.125	0.117	-0.049	1	0.068	0.252	-0.203	-0.236	0.207	-0.046	-0.052	-0.007
AGE1	0.117	0.008	-0.048	-0.051	0.068	1	-0.336	-0.066	-0.217	0.193	0.003	-0.623	0.025
AGE2	0.036	0.203	0.021	0.078	0.252	-0.336	1	-0.139	-0.141	0.282	-0.135	0.195	0.115
EDU1	-0.116	-0.101	-0.011	0.025	-0.203	-0.066	-0.139	1	-0.081	-0.092	0.004	0.133	0.065
EDU2	-0.188	-0.009	-0.074	0.041	-0.236	-0.217	-0.141	-0.081	1	-0.664	0.030	0.196	-0.011
EDU3	0.162	0.054	0.024	-0.013	0.207	0.193	0.282	-0.092	-0.664	1	-0.058	-0.099	0.009
SEX	-0.052	-0.069	0.089	0.014	-0.046	0.003	-0.135	0.004	0.030	-0.058	1	-0.034	0.001
CHID	-0.098	-0.006	-0.018	0.026	-0.052	-0.623	0.195	0.133	0.196	-0.099	-0.034	1	0.005
HERA	0.052	0.161	-0.126	0.063	-0.007	0.025	0.115	0.065	-0.011	0.009	0.001	0.005	1

4.1. Correlation among "awareness variables"

As "Awareness variables" we call the variables that come from the introduction part of the questionnaire, which aimed at grasping the environmental profile of the consumer and in particular to show how "aware" he was of environmental problems.

Their correlations are in the bordered part of Table 3.9. No high correlation exists among them and hence we can include all of them simultaneously in the models to follow.

4.2. Correlation among all regressors

It is useful to study correlations among all possible couples of regressors in order to see if we should include any interaction variables in the models that follow. However, we see from Table 3.9 that correlations are not high between any of the variable pairs.

5. WHAT DETERMINES FARMERS WILLINGNESS TO USE RECYCLED WATER FOR IRRIGATION

This part studies the factors that determine farmers' WTU of recycled water for the irrigation of olive trees (section 5.1) and tomato plants (section 5.2). We employ simple binary logit analysis in the following two models.

5.1. Willingness to Use Product 1 (Model 1)

Model 1 is given by Equation 3.1. Numbers in parenthesis are p-values. Stars indicate significance at 5%. For a full output see also Table 3.14 in Appendix 8.1.

$$\begin{aligned} P(WTU1=1) = {} & \underset{(0.47)}{0.81} - \underset{(0.61)}{0.056}\,INFO + \underset{(0.01^{*})}{0.26}\,WLACK + \underset{(0.51)}{0.09}\,ACTIONS \\ & + \underset{(0.37)}{0.85}\,WPRICE + \underset{(0.08^{*})}{0.00}\,INCOME - \underset{(0.77)}{0.17}\,AGE1 - \underset{(0.12)}{0.53}\,AGE2 - \\ & \underset{(0.25)}{0.98}\,EDU1 - \underset{(0.35)}{0.63}\,EDU2 - \underset{(0.21)}{0.80}\,EDU3 - \underset{(0.45)}{0.36}\,SEX - \underset{(0.43)}{0.41}\,CHID \\ & + \underset{(0.05)}{0.62}\,HERA \end{aligned} \tag{3.1}$$

5.1.1. Robustness of Model 1

Robustness (goodness of fit) of model 1, and of the others to follow, will be assessed as a combination of the following three things:

i) Pseudo R^2: For this model it is very low.

$$Pseudo - R^2 = 1 - \frac{\ln L}{\ln L_0} = 1 - \frac{-174.97}{-186.55} = 0.07$$

ii) Significance of the total model: The χ^2 value rejects (significance level 0.039<0.05) the null hypothesis that the model did not have greater explanatory power than the "intercept only" model. Therefore, model 1 is significant as a whole.

iii) The predicted ability of the model: The model predicts 312/383=81% of the observations correctly. The naïve model which always predicts y=1, because P>0.5 predicts 379/383=99% of the observations correctly. Therefore the naïve model overpredicts the "yes" choice by 18% (see section 4.1.3.1 in chapter 4 for a discussion on the naïve predictor).

5.1.2. Model 1 expectations and verification

We expected that the probability of being WTU product 1 would be higher (i.e. a positive coefficient sign) for those who:

- Declared themselves as informed about environmental problems (since this would mean that they would understand the necessity of replacing irrigation fresh water with recycled water).
- Admitted that water shortage is a significant water problem (for same reasons as previously).

- Admitted having engaged themselves to environmental friendly actions (irrigating with recycled water is an environmental friendly action).
- Fell in the age groups 18-24, 25-34, 35-44, 45-54 (because younger farmers are more willing to experiment on new farming methods).
- Had gone to high school (because they would understand better the information given to them during the information session and would be less afraid of using recycled water).
- Belonged to Heraklion prefecture (because this prefecture has larger cultivations and more water shortage problems).
- Paid larger fresh water prices (since the higher these prices are, the more willing a farmer is to find resource to other cheaper water resources).

We expected a negative sign for those who:

- Are illiterate (since they would not understand easily the information given to them during the info session).
- Are primary school graduates (for same reasons as above).

We had doubtful expectations as to what the situation would be for the following variables: i) INCOME: We could expect that richer farmers are rational maximizers and consequently more WTU product 1 because they are richer as a result of their having taken wiser actions in their agricultural businesses. On the other hand we expect that poorer farmers will be more WTU product 1 (and at a cheaper price) since they cannot afford high prices. ii) SEX: Only several of the farmers questioned were female, because the leader of the agricultural business is usually a man. Thus, we cannot really decide if being a male farmer really affects the probability of being

WTU product 1. iii) CHILDREN: We would normally expect farmers with children to be more sensitive and hesitant about using product 1.

5.1.3. Model 1 Results

As appears in Equation 3.1 and Table 3.14 (in appendix 8.1 of this chapter), WLACK was significant at 5%. Farmers who regarded water luck as a problem, were more WTU recycled water for the irrigation of their olive trees. Heraklion farmers also appeared most likely to use recycled water for irrigation because Heraklion prefecture gathers the largest part of systematic olive oil cultivations and faces the problem of water shortage in a more intensive way. INCOME is significant at 10% with a positive sign, which means that richer farmers are more WTU product 1 than the poorer ones. This might be due to the fact that they are rich because they have taken wiser actions in their agricultural businesses. The use of recycled water for irrigation is claimed to be a wiser thing to do since (under normal conditions) it is a perfect substitute for fertilizers and as it appears from the experience of other countries, it will be a cheaper way of irrigation.

5.1.4. Model 1 marginal probabilities

Marginal probabilities answer the question of how the various outcomes would change when the value of one of the variables influencing the outcomes changes.

For continuous variables: Income is the only continuous variable we have (Table 3.14). How would a farmer's probability of being WTU recycled water would change if he was "a 300 €" richer?

For dummy variables: They have been calculated as the probabilities that result when each variable takes its two different values across all the farmers in the sample,

with the values of the other variables held at their sample means. Estimates of the probabilities of being WTU product 1 and being unwilling to use product 1 have been calculated, in which first a farmer has the characteristic the dummy variable encompasses (D=1) and then he does not (D=0). The difference of these two propabilities measures the effect of the characteristic the dummy variable stands for, on the willingness to use recycled water. However, the significance of marginal probabilities is as appears in the binary logit model in Table 3.14 under the heading *partial derivatives*. For example WLACK marginal probability was significant. This means that if the problem of water luck significance increases by 1 grade (we have acknowledged 5 grades of significance) in the questionnaire, then the probability that farmers will say yes to using recycled water, will increase by 0.037.

5.2. Willingness to Use Product 2 (Model 2)

Model 2 is given by Equation 3.2. Numbers in parenthesis are p-values. Stars indicate significance at 5%. For a full output see also Table 3.15 in Appendix 8.1.

$$\begin{aligned} P(WTU2=1) = &\underset{(0.02^*)}{-2.29} + \underset{(0.16)}{0.15}\,INFO + \underset{(0.69)}{0.05}\,WLACK - \underset{(0.02^*)}{0.33}\,ACTIONS \\ &+ \underset{(0.95)}{0.01}\,WPRICE + \underset{(0.68)}{0.00}\,INCOME + \underset{(0.40)}{0.47}\,AGE1 + \underset{(0.84)}{0.06}\,AGE2 \\ &+ \underset{(0.97)}{0.02}\,EDU1 + \underset{(0.02^*)}{1.12}\,EDU2 + \underset{(0.01^*)}{1.07}\,EDU3 + \underset{(0.03^*)}{0.78}\,SEX + \underset{(0.46)}{0.35}\,CHID \\ &+ \underset{(0.00^*)}{1.58}\,HERA \end{aligned} \tag{3.2}$$

5.2.1. Robustness of Model 2

i) Pseudo R^2: For this model it is very low.

$$Pseudo - R^2 = 1 - \frac{\ln L}{\ln L_0} = 1 - \frac{-176.93}{-199.35} = 0.11$$

ii) Significance of the total model: The χ^2 value rejects (significance level 0.00002<0.05) the null hypothesis that the model did not have greater explanatory power than the "intercept only" model. Therefore, model 2 is significant as a whole.

iii) The predicted ability of the model: The model predicts 262/346=75.7% of the observations correctly. The naïve model which always predicts y=1, because P>0.5 predicts 307/346=88.7% of the observations correctly.

5.2.2. Model 2 expectations and verification

As far as the WTU product 2 is concerned (Table 3.15), we have the same sign expectations as the ones for the case of product 1. In this case we could additionally expect to see farmers with children to be more hesitant in using this type of water, which is obviously not confirmed.

5.2.3. Model 2 results

ACTION, EDU2, EDU3, SEX and HERA are significant at 5%. HERA significance is attributed to the same reasons as in Model 1. The significance of ACTION shows that farmers who are engaged to environmental friendly actions are more likely to use recycled water for tomato cultivation. This signals something for product 2. One needs to have a developed environmental conscience in order to use this product. Education variables were significant with a positive sign showing that the more educated farmers were the more WTU the more supposedly dangerous product 2. This is probably due to the fact that educated farmers realized that there were not real risks if this irrigation method is applied correctly and safely. Male farmers were the most likely to use recycled water of quality 2, because actually the vast majority of farmers were male.

6. WHAT DETERMINES FARMERS WILLINGNESS TO PAY FOR RECYCLED WATER FOR IRRIGATION

This part studies the factors that determine farmers' WTP for recycled water for the irrigation of olive trees and tomato plants (product 1 and product 2). We employ simple regression analysis in the following two models (Model 3 and 4). The independent variable is *log*WTP so that we are "legalized" in working under the log-normal distribution framework. More about the log-normal assumption is said in chapter 4.

6.1. Willingness to Pay for Product 1 (Model 3)

The willingness to pay question for product 1 was addressed only to farmers who had stated a positive WTU in this product. Farmers were invited first to state whether they would be WTP "more", "as much as" or "less" than the price paid for fresh water (Results of this question are presented in Table 3.4). Then they were invited to state the percentage of exactly how much more, or how much less. We run a simple linear regression (Equation 3.3). The sample size has been reduced here because we left out non-responses (farmers who did not give a bid) and the zeros with which non-irrigators had been codified and could not be included in the regression because of the log formulation (for a full output see Table 3.16, appendix 8.2 of this chapter). Numbers in parenthesis are p-values. Stars indicate significance at 5%.

$$\log(WTP1) = \underset{(0.00^{*})}{-0.91} + \underset{(0.63)}{0.00}\,ACTION + \underset{(0.56)}{0.00}\,INFO - \underset{(0.77)}{0.00}\,WLACK + \underset{(0.77)}{0.02}\,AGE1$$
$$+ \underset{(0.15)}{0.06}\,AGE2 + \underset{(0.03^{*})}{0.12}\,EDU1 - \underset{(0.46)}{0.02}\,EDU2 - \underset{(0.01^{*})}{0.09}\,EDU3 + \underset{(0.15)}{0.00}\,WPRICE \qquad (3.3)$$
$$+ \underset{(0.00^{*})}{0.0003}\log INCOME + \underset{(0.48)}{0.04}\,SEX + \underset{(0.90)}{0.007}\,CHID - \underset{(0.78)}{0.01}\,HERA$$

Adj-R^2= 0.038, F (13,287) = 1.82 (p-value = 0.03)

6.1.1. Model 3 expectations and verification

We expected that the following categories of farmers would be WTP higher prices for product 1:

- Those who are more informed about environmental problems
- Experience water shortage as a problem
- Engage themselves to environmental friendly actions
- Pay high fresh water prices
- Have higher incomes
- Are secondary school graduates
- Are Herakliots

We expected lower bids from farmers who:

- Are low-income farmers or illiterate (EDU1) or primary school-graduates (EDU2) or belong to younger ages (AGE1 and AGE2)

We did not have any specific expectations about the sign for SEX and CHID.

6.1.2. Model 3 results

According to our findings, the following variables were significant: EDU1 (with a plus), EDU3 (with a minus) and logINCOME (with a plus). The first means that illiterate farmers appeared as more likely to give higher bids than farmers who had received some education (although the educated farmers have been more WTU product 1) Furthermore, the significance of EDU3 means that farmers who were secondary school graduates appeared to be less likely to pay higher bids for product 1 which somehow strengthens the first finding. Both these findings tell us that the

less time farmers spend in education, the more favorably they see product 1 and the higher the bids they are going to give for it. Less educated farmers are obviously more experienced with agricultural problems such as water shortage.

Last, higher income farmers are also WTP higher prices for reasons we have explained in Model 1. Having taken the logarithm of income gives the elasticity of WTP with respect to income. This means that a 1 euro increase in income will cause a 0.0003 € WTP increase.

Table 3.10. Model 3 OLS estimation results

Variable	Coefficient	Std. Error	t-Statistic	Prob.
Constant	-0.914141	0.101000	-9.050936	0.0000
INFO	0.000136	0.000234	0.580241	0.5622
WLACK	-9.07E-05	0.000315	-0.287509	0.7739
ACTION	0.000114	0.000242	0.473159	0.6365
WPRICE	0.000314	0.000222	1.413724	0.1586
AGE1	0.020956	0.074480	0.281369	0.7786
AGE2	0.065624	0.045506	1.442091	0.1504
EDU1	0.125328	0.060263	2.079691	0.0385
EDU2	-0.027330	0.037497	-0.728856	0.4667
EDU3	-0.098107	0.038840	-2.525909	0.0121
LOGINCOME	0.000331	9.74E-05	3.395040	0.0008
CHID	0.007505	0.060877	0.123281	0.9020
SEX	0.041800	0.059992	0.696755	0.4865
HERA	-0.014264	0.052963	-0.269328	0.7879
R-squared	0.081795	F-statistic		1.870717
Adjusted R-squared	0.038071	Prob(F-statistic)		0.033408

Note: For a full output, see Table 3.16 in Appendix 8.2.

6.1.3. Significance of Model 3

Model 3 is significant as a whole at 5%, but the explanatory power of the model is small (the adj-R^2 is small).

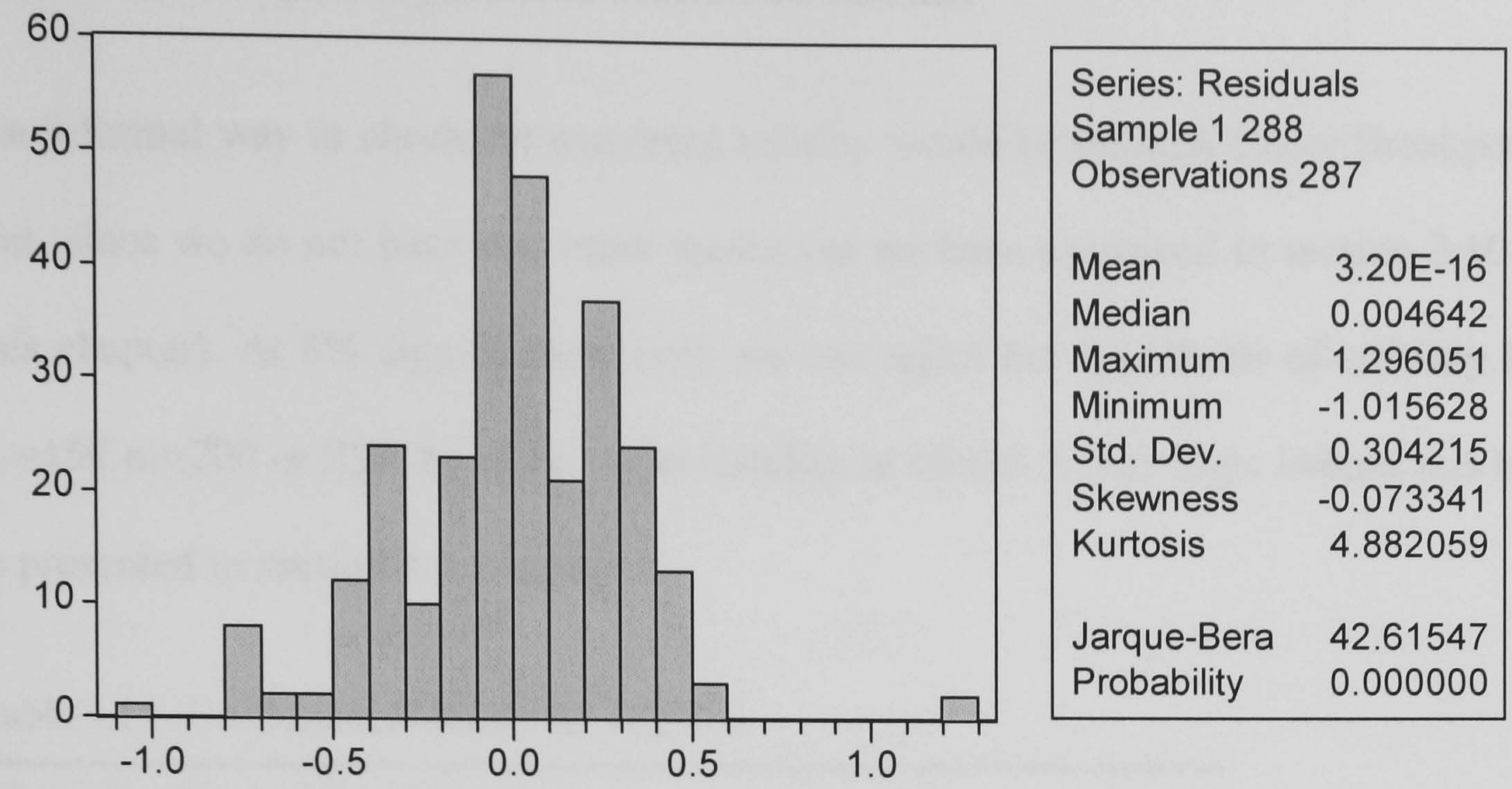


Figure 3.5. Jarque-Bera residual normality test of Model 3.

The normality test for residuals gave a significant Jarque-Bera test (Figure 3.5), which means that residuals do not follow the normal distribution. Also the White test could not reject the zero hypothesis for the existence of heteroskedasticity. This means that there are sub-categories of data, which might correspond to distinctively different WTP answers and that different WTP models should be formed for each such data category.

A good idea would be to see which variables are significant in model 3 (Equation 3.3) and split the data according to one of them. Of course we cannot split the data to more than two sub-categories because this would produce too small sub-samples with too many regressors. We found convenient to split data according to EDU3 because this separation gave two almost equally numbered samples. Therefore, we have run one regression with secondary school graduates and another with all the other educational groups. Results were not any better. We believe that poor results of both Model 3 and 4 (that follows below) are due to small samples, which were inevitable to have, since we had to leave out non-irrigators.

6.1.4. Model 3 specification and coefficient stability

An informal way to check for construct validity would be through Chow Breakpoint test, since we do not have any other means (as we have explained in section 2.10 in this chapter). At 5% significance level, we can reject the hypothesis of stability for n_1=150 n_1=200 or 250. So, there is no stability in Model 1. The logic behind this test is presented in section 4.6, chapter 2.

Table 3.11. Coefficient Stability for Model 3.

Chow Breakpoint Test: 150			
F-statistic	5.645001	Probability	0.000000
Log likelihood ratio	76.43002	Probability	0.000000
Chow Breakpoint Test: 200			
F-statistic	7.274865	Probability	0.000000
Log likelihood ratio	95.17756	Probability	0.000000
Chow Breakpoint Test: 250			
F-statistic	3.418229	Probability	0.000042
Log likelihood ratio	48.66028	Probability	0.000010

Besides, we saw appropriate to apply Ramsey RESET test for model specification (omitted variables, incorrect functional form and/or correlation between the explanatory variables and the error term). According to the test results (Table 3.18 in Appendix 8.2), model misspecification is not confirmed.

6.2. Willingness to Pay for Product 2 (Model 4)

The willingness to pay question for product 2 was posed only to those farmers who had answered that they were WTU this product. As with model 3, we estimated a simple regression for model 4. Numbers in parenthesis are p-values. Stars indicate significance at 5%.

$$\log(WTP2) = \underset{(0.00^*)}{-1.04} + \underset{(0.13)}{0.0005}ACTIONS + \underset{(0.51)}{0.0001}INFO - \underset{(0.26)}{0.0004}WLACK$$
$$+ \underset{(0.08)}{0.0001}LOGINCOME + \underset{(0.50)}{0.05}AGE1 + \underset{(0.72)}{0.01}AGE2 + \underset{(0.42)}{0.06}EDU1 - \underset{(0.96)}{0.00}EDU2 \quad (3.4)$$
$$- \underset{(0.18^*)}{0.06}EDU3 + \underset{(0.02^*)}{0.0006}WPRICE + \underset{(0.10)}{0.104}SEX + \underset{(0.15)}{0.108}CHID - \underset{(0.82)}{0.014}HERA$$

Adj-R^2= 0.02, F(13.239) = 1.36 (p-value = 0.17)

6.2.1. Model 4 expectations and verification

Expectations are the same as in Model 3. In addition to them, we also expected that the elasticity of WTP with respect to income would be higher for product 2 than product 1, since it concerned a better and more expensive to produce, water quality.

6.2.2. Model 4 results

Table 3.12 offers a full output of Model 4.

Table 3.12. Model 4 OLS estimation results

Variable	Coefficient	Std. Error	t-Statistic	Prob.
Constant	-1.041817	0.121245	-8.592681	0.0000
INFO	0.000162	0.000252	0.644652	0.5198
WLACK	-0.000445	0.000395	-1.125963	0.2614
ACTION	0.000590	0.000396	1.491089	0.1373
WPRICE	0.000691	0.000309	2.233859	0.0265
AGE1	0.056288	0.084633	0.665083	0.5067
AGE2	0.018038	0.050401	0.357885	0.7208
EDU1	0.064677	0.080880	0.799671	0.4247
EDU2	-0.002299	0.046637	-0.049292	0.9607
EDU3	-0.062550	0.047546	-1.315555	0.1897
LOGINCOME	0.000181	0.000107	1.703386	0.0899
CHID	0.108439	0.075243	1.441182	0.1509
SEX	0.104604	0.063956	1.635550	0.1033
HERA	-0.014547	0.064445	-0.225722	0.8216
R-squared	0.073191	F-statistic		1.366804
Adjusted R-squared	0.019642	Prob(F-statistic)		0.176823

Note: Full EViews output is in Table 3.17, Appendix 8.2.

WPRICE is significant at 5% with a positive sign and LOGINCOME is significant at 10% with a positive sign. The elasticity of income with respect to WTP for product 2 is one third of what was for product 1. Also, if fresh water price increases by 1 euro, WTP will increase by 0.0006 euros. The fact that WPRICE is significant only in model 4 and not in model 3 could be due to the fact that since farmers perceive product 2 to be more dangerous, they will end up buying it only if fresh water becomes expensive. This belief is also strengthened by the fact that no other variable is significant at 5% in this model except for fresh water price.

6.2.3. Significance of Model 4

It is significant as a whole, at 5%, but the explanatory power of the model is small (the adj-R^2 is very low). The p-value for the F statistic is bigger than 5%. The latter combined with residual non-normality (Figure 3.6) produces a model, which is unreliable for predictions.

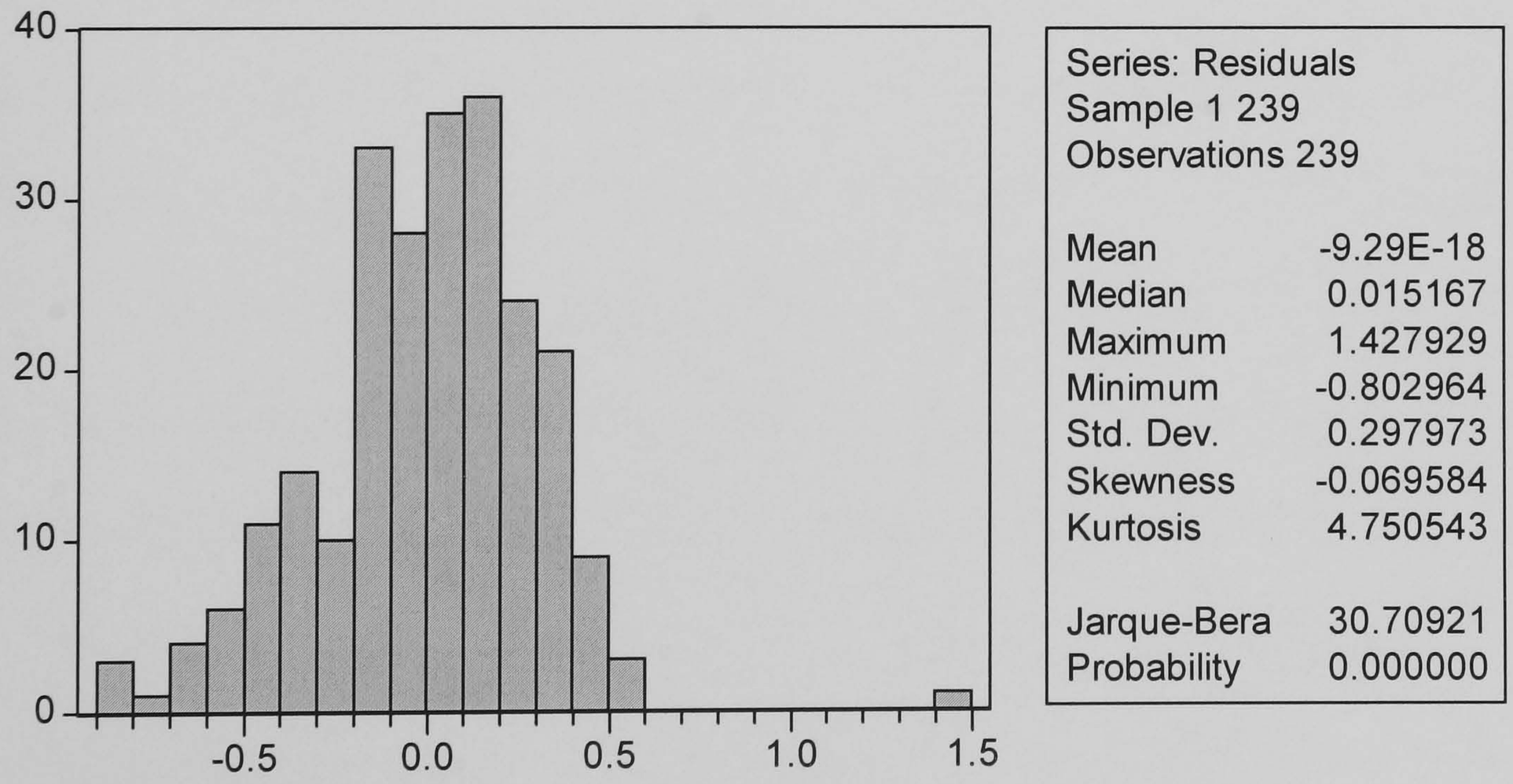


Figure 3.6. Jarque-Bera residual normality test of Model 4.

6.2.4. Model 4 specification and coefficient stability

At 5% significance level we can reject the hypothesis of stability for n_1=100 n_1=150. At n_1=200 this is not confirmed (Table 3.13).

Table 3.13. Coefficient Stability for Model 4

Chow Breakpoint Test: 100			
F-statistic	9.556265	Probability	0.000000
Log likelihood ratio	117.3659	Probability	0.000000
Chow Breakpoint Test: 150			
F-statistic	3.993262	Probability	0.000004
Log likelihood ratio	56.17390	Probability	0.000001
Chow Breakpoint Test: 200			
F-statistic	1.365664	Probability	0.172117
Log likelihood ratio	20.73082	Probability	0.108732

According to Ramsey RESET test for model specification (omitted variables, incorrect functional form and/or correlation between X and the error term) there is no model misspecification (Table 3.19 in Appendix 8.2).

7. CONCLUSIONS

7.1. Farmers' Willingness to Use and Willingness to Pay for Recycled Water

75.7% of respondents were WTU recycled water of quality 2 for the irrigation of the olive tree (product 1). 17.9% were unwilling to do so. From those who were unwilling, 41.9% were WTU a better quality (recycled water of quality 3) for the irrigation of their olive trees, thus assuring for scope effects. Therefore on total 83.2% of respondents would be WTU recycled water at least of quality 3 for the irrigation of the olive tree.

Fewer respondents (62.3%) were WTU recycled water of quality 3 for the irrigation of the tomato (product 2), showing that recycled water of this quality is on one hand, water of a better quality, but on the other hand it is considered to be a more dangerous product when it is destined for the irrigation of the tomato. This is reflected in the basic descriptive statistics (mean and standard deviation) of WTP. The WTP for product 2 is higher than WTP for product 1 indicating that farmers realize its better quality. However, the standard deviation of WTP for product 2 is also higher suggesting that there is a larger dispersion of bids, stemming from the fact that farmers are not in unison for this product as much as they are for product 1.

Most farmers (76.38%) vote the quality 2 recycled water price to be less than the fresh water price. This percentage falls to 69.14% when quality improves (quality 3) but is applied to a more sensitive plant. At the same time though, the number of missing values increases from 2.33% to 10.99% showing the indecision of farmers in front of this product. The latter is further explained by the fact that few farmers were

systematic tomato cultivators. Most of the enquired farmers were systematic olive-tree cultivators but not tomato cultivators. They cultivated tomatoes mostly for self-consumption. This fact may have made them extra careful and unable to decide and thus ending up not giving a WTP value (missing value).

Mean WTP1 is 0.16 euros and mean WTP2 is 0.17 euros. Mean fresh water price is 0.27 euros. This means that for farmers to buy products 1 and 2, their prices must be 60% and 63% of the fresh water. Although the treatment cost of product 2 is higher than that of product 1, we do not observe a significant difference between mean WTP1 and WTP2.

7.2. Factors that determine farmers' Willingness to Use and Willingness to Pay for Recycled Water

7.2.1. Willingness to Use

The only environmental awareness variables being significant in farmers WTU models were WLACK for product 1 and ACTION for product 2. This shows that it is water shortage that drives farmers to use recycled water of quality 2 for the irrigation of the olive tree, but it is environmental conscience that drives them to use recycled water of quality 3. Education variables became significant only in product 2, showing that the more educated farmers were more WTU product 2. Heraklion origin (HERA) was significant in both models, because Heraklion origin has more systematic cultivations and more water problems. Income has not been significant in any of the two models.

7.2.2.Willingness to Pay

Regarding the factors that determine WTP, income was significant at 5% with a positive sign, i.e. richer farmers are expected to give higher WTP bids for product 1. Moreover, two of the education variables were significant. EDU1 with a positive sign and EDU3 with a negative one. According to the first, illiterate farmers are more likely to pay higher bids, while according to the second, secondary school graduates (they constitute the largest education group in our sample) are the most likely to pay lower bids. The first finding complements the second. In a few words, long education does not make farmers pay higher prices for recycled water. On the contrary, the more educated farmers are, the more likely they are to pay for less. This can be explained either with the reason already given in section 6.1, namely that farmers' education does not necessarily signal farmers' experience in agriculture. So, uneducated farmers have spent less time at school and more time in work or better phrased, they have spent more time in practice rather than in theory. Another perspective from which we can see this result, is that the more educated farmers such as secondary school graduates realize recycled water is a lower quality by-product of fresh water and they act strategically in bidding it for a low price. They try to hide their consumer surplus from policy makers (this can be strengthened by our finding in part 5 that the more educated farmers are more WTU recycled water). This is of course a more extreme explanation, which if confirmed would not flatter the quality of the research done in the present project, because the questionnaire design should have been clever enough to prevent this thing from happening.

As far as WTP2 is concerned, the only 5% significant variable found was fresh water price. Since the tomato plant is not very water consuming, fresh water price was not expected to affect WTP2. But it is probably the hypothetical nature of the

question, which as it turned out to be, it was posed to farmers who were not tomato cultivators and probably thought that tomato would be as water consuming as the olive tree. Or it is the fact of how repellent farmers found the idea of tomato irrigation with this type of water that leads them to act this way; i.e. accept this type of recycled water for irrigation only if fresh water becomes too expensive, as a last resort.

References

Ahlheim M. (1998). Contingent valuation and the budget constraint. *Ecological Economics*, **27,** 205-211.

Ajzen I., Brown T.C., and Rosenthal L.H. (1996). Information bias in contingent valuation: effects of personal relevance, quality of information and motivational orientation. *Journal of Environmental Economics and Management*, **30,** 43-57.

Aldred J. and Jacobs M. (2000). Citizens and wetlands: evaluating the Ely citizen's jury. *Ecological Economics,* **34,** 217-232.

Arrow K.J., Solow R., Leamer E., Portney P., Radner R. and Schuman H. (1993). *Report of the NOAA Panel on Contingent Valuation*. Fed, Regist., 58, 4601-4614. In: Wang, H. (1997). Treatment of "Don't Know" responses in contingent valuation surveys: A random valuation model. *Journal of Environmental Economics and Management,* **32,** 219-232.

Bateman I.J., Carson R.T., Brett D., Hanemann M., Hanley N., Hett T., Jones-Lee M., Loomes G., Mourato S., Özdemiroğlou E., Pearce D., Sugden R. and

Swanson J. (2002). *Economic Valuation with Stated Preference Techniques. A Manual*, Edward Elgar, pp 458.

Bateman I.J. and Langford I.H. (1996). Non-users' Willingness to pay for a national Park: An application and critique of the contingent valuation method. *Regional Studies*, **31(6),** 571-582.

Bateman I.J., Langford I.H., Turner R.K., Willis K.G. and Garrod G.D. (1995). Elicitation and truncation effects in contingent valuation studies. *Ecological Economics*, **12,** 161-179.

Becker G.M., DeGroot M.H., and Marschak J. (1964). Measuring Utility by a Single-Response Sequential Method. *Behavioral Science*, **9,** 226-32. In: Sugden R. (1999). Alternatives to the Neo-classical Theory of Choice, In: Bateman I.J. and Kenneth G.W. (eds). (1999). *Valuing Environmental Preferences, Theory and Practice of the Contingent Valuation Method in the US, EU and Developing Countries*, Oxford University Press, pp 645.

Beltrán E. and Rojas M. (1996). Diversified Funding Methods in Mexican Archaeology". *Annals of Tourism Research,* **23(2),** 463- 478, In: Noonan, D.S. (2003). Contingent Valuation and Cultural Resources: A Meta-Analytic Review of the Literature. *Journal of Cultural Economics,* **27,** 159-176.

Berrens R.P., Hank J.S., Bohara A.K. and Silva C.L. (2002). Further investigation of voluntary contribution contingent valuation: fair share, time of contribution and respondent uncertainty. *Journal of Environmental Economics and Management*, **44,**144-168.

Bjornstad D.I. and Kahn J.R. (eds). (1996). *The Contingent Valuation of Environmental Resources*, Edward Elgar, pp 305.

Blamey R.K. (1996). Citizens, Consumers and Contingent Valuation: Clarification and the Expression of Citizen Values and Issue-Options. In: Adamowicz, W.L., Boxhall, P.C., Luckert, W.C., Philips, W.A., and White (Eds), Forestry Economics and the Environment. Oxon: CAB International. [In: Kenyon, *et al.* (2003), referenced here].

Blamey R.K. (1998). Decisiveness, attitude expression and symbolic responses in contingent valuation surveys. *Journal of Economic Behavior and Organization*, **34,** 577-601.

Blumenschein K., Johannesson M., Blomquist G.C., Liljas B. and O'Conor R.M. (1997). Hypothetical versus real payments in Vickrey auctions. *Economics Letters*, **56,** 177-180.

Bohara A.K., McKee M., and Berrens R.P. (1998). Effects of total cost and group-size information on willingness to pay responses: open-ended vs. dichotomous choice.*Journal of Environmental Economics and Management*, **35,**142-163.

Bonnieux F. and Rainelli, P. (1991). Contingent Valuation Methodology and the EU Institutional Framework, In: Bateman, I. and Willis, K.G. (eds). *Valuing Environmental Preferences*, 1991, Oxford University Press, pp 645.

Boxall P.C., Adamowicz W.L., Swait J., Williams M. and Louviere J. (1996). A comparison of stated preference methods for environmental valuation. *Ecological Economics*, **18,** 243-253.

Boyle K.J., Welsh M.P. and Bishop R.C. (1993). The role of question order and respondent experience in contingent-valuation studies. *Journal of Environmental Economics and Management*, **25,** S-80-S-99

Brown K.M. and Taylor L.O. (2000). Do as you say, say as you do: evidence on gender differences in actual and stated contributions to public goods. *Journal of Economic Behavior and Organization*, **43,** 127-139.

Cameron T.A. and James M.D. (1987). Efficient estimation methods for closed-ended contingent valuation surveys. *Review of Economics and Statistics*, **69(2),** 269-76, In: Bateman *et al.* (2002) referenced here.

Cameron T.A. and Quiggin J. (1994). Estimation using contingent valuation data from a dichotomous choice with follow-up questionnaire. *Journal of Environmental Economics and Management*, **27,** 218-234.

Carson R.T. (2000). Contingent Valuation: A User's guide. *Environ. Sci. Technol.*, **34,**1413-1418.

Carson R.T., Flores N.E., and Meade N.F. (2001). Contingent valuation: controversies and evidence. *Environmental and Resource Economics,* **19**, 173-210.

Cummings R.G., Harrison G.W., Rutström E.E. (1995). Homegrown values and hypothetical surveys: Is the dichotomous choice approach incentive-compatible? *American Economic Review*, **85,** 260-266. In: Blumenschein, K., Johannesson, M., Blomquist, G.C., Liljas, B. and O'Conor, R.M. (1997). Hypothetical versus real payments in Vickrey auctions. *Economics Letters*, **56,**177-180.

Edwards S.F. (1986). Ethical preferences and the assessment of existence values: does the neoclassical model fit? *Northeastern Journal of Agricultural Economics*, **15,** 145-159. [In: Perman *et al.* (2003), referenced here]

Efthymoglou P. and Xepapadeas A. (1990). *Public Utilities*. Peireas: Stamoulis Press (in Greek).

Gans S.G. (1999). Limited information, the possibility of rational choice and the contingent valuation method. *International Journal of Social Economics*, 26, 402- 414.

Gilligan C. (1982). In a different voice: *Psychological Theory and Women's Development*. Harvard University Press, Cambridge, MA [In: Brown and Taylor (2000), referenced here].

Gowdy J.M. and Mayumi K. (2001). Reformulating the foundations of consumer choice theory and environmental valuation. *Ecological Economics*, **39,** 223-237.

Groothuis P.A. and Whitehead J.C. (2002). Does don't know mean no? Analysis of "don't know" responses in dichotomous choice contingent valuation questions. *Applied Economics*, **34,** 1935-1940.

Haneman M. (1999). The Economic Theory of WTP and WTA, In: Bateman, I. and Willis, K.G. (eds). *Valuing Environmental Preferences*, Theory and Practice of the Contingent Valuation Method in the US, EU and Developing Countries, pp 645.

Hanley N. (2001). Cost-benefit analysis and environmental policymaking. Environment and Planning C, **19,** 103-118.

Jacobs M. (1997). Environmental Valuation, Deliberative Democracy and Public Decision Making Institutions. In Foster J. (Ed), Valuing Nature? *Economics Ethics and Environment*. London: Routledge. [In: Kenyon *et al*. (2003), referenced here].

Jorgensen B.S., Wilson M.A. and Heberlein T.A. (2001). Fairness in the contingent valuation of environmental public goods: attitude paying for environmental improvements at two levels of scope. *Ecological Economics*, **36,** 133-148.

Kahneman D. (1986). Comments. In: Cummings, R.G. Brookshire, D.S., Schulze, W.D. (Eds), *Valuing environmental goods: A state of the art assessment of the contingent valuation method.* Rowman and Allanheld, Totowa, 185-194. [In Blamey (1998), referenced here].

Kenyon W., Nevin C., and Hanley N. (2003). Enhancing environmental decision-making using citizen juries. *Local Environment*, **8(2)**, 221-232

Kolstad C.D., Guzman R.M. (1999). Information and the divergence between willingness-to-accept and willingness-to-accept and willingness-to-pay. *Journal of Environmental Economics and Management*, **38,** 66-80.

Kontogianni A., Skourtos M.S., Langford I.H., Bateman I.J. and Georgiou S. (2001). Integrating stakeholder analysis in non-market valuation of environmental assets. *Ecological Economics,* **37,** 123-138.

Limon-Gomez J.A. and Riesgo L. (2003). Irrigation water pricing: Differential impacts on irrigated farms, Paper prepared for the *International Conference-Irrigation Water Policies: Micro and Macro Considerations*, Agadir, 15-17 June 2002.

Maddison D. and Foster T. (2001). Valuing Congestion Costs in the British Museum, Paper presented to the *Economic Valuation of Cultural Heritage Conference* in the Department of Economics of University College London, In: Noonan, D.S. (2003). Contingent Valuation and Cultural Resources: A Meta-Analytic Review of the Literature. *Journal of Cultural Economics*, **27,** 159-176

Markowska A. and Zylicz T. (1999). Costing an international public good: the case of the Baltic Sea. *Ecological Economics*, **30,** 301-316.

Medin H., Nyborg K. and Bateman, I. (2001). The assumption of equal marginal utility of income: how much does it matter? *Ecological Economics*, **36,** 397-411.

Munro A. and Hanley N.D. (1999). Information, Uncertainty and Contingent Valuation, In: Bateman, I. and Willis, K.G. (eds) *Valuing Environmental Preferences*, 1991, Oxford University Press, pp 645.

Murphy J.J., Stevens T. and Weatherhead D. (2004). Is Cheap Talk Effective at Eliminating Hypothetical Bias in a Provision Point Mechanism? *Environmental and Resource Economics*, **30,** 327-343.

Murphy J.J., Allen P.G., Stevens T. and Weatherhead D.A. (2003). "A Meta-Analysis of Hypothetical Bias in Stated Preference Valuation". *Environmental and Resource Economics*, **30,** 313-325.

Neill H.R., Cummings R.G., Ganderton P.T., Harrison G.W., McGuckin T. (1994). Hypothetical surveys and real economic commitments, *Land Economics,* **70,**145-154. In: Blumenschein, K., Johannesson, M., Blomquist, G.C., Liljas, B. and O'Conor, R.M. (1997). Hypothetical versus real payments in Vickrey auctions.*Economics Letters*, **56,** 177-180.

Noonan D.S. (2003). Contingent Valuation and Cultural Resources: A Meta-Analytic Review of the Literature.*Journal of Cultural Economics*, **27,**159-176.

O'Connor M. and Spash C. (eds) (1999). *Valuation and the Environment*, Edward Elgar, pp 339.

Park J.H. (2003). A test of the answering mechanisms of the double-bounded contingent valuation method. *Applied Economics Letters*, **10,** 975-984.

Pearce D. (1998a). Does European Union environmental policy pass a cost-benefit test? *World Economics*, **5(3),** 115-118.

Pearce D. (1998b). Environmental Appraisal and Environmental Policy in the European Union. *Environmental and Resource Economics,* **11(3-4)**, 489-501.

Perman R., Ma Y., McGilvray J., and Common M. (2003). *Natural Resource and Environmental Economics*, 3rd ed., Pearson Education Limited, Essex.

Randall A., Stoll J.R. (1980). Consumer's surplus in commodity space. *American Economic Review*,**70,** 449- 455.

Ready R.C., Whitehead J.C. and Blomquist G.C. (1995). Contingent valuation when respondents are ambivalent. *Journal of Environmental Economics and Management*, **29,** 181-196.

Sagoff M. (1988). *The Economy of the Earth.* Cambridge: Cambridge University Press, [In: Kenyon *et al*. (2003) referenced here].

Spash C.L. (1997). Ethics and environmental attitudes with implications for economic valuation. *Journal of Environmental Management*, **50,** 403- 416.

Stevens T.H., Belkner R., Dennis D., Kittredge D. and Willis C. (2000). Comparison of contingent valuation and conjoint analysis in ecosystem management. *Ecological Economics,* **32,** 63-74.

Sugden R. (1999). Alternatives to the Neo-classical Theory of Choice, In: Bateman, I.J. and Willis, K.G. (eds) (1999). *Valuing Environmental Preferences*, Oxford University Press, pp 645.

Tversky A. and Kahneman D. (1991). Loss aversion in riskless choice: a reference-dependent model. *Quarterly Journal of Economics,* **106,** 1039-1061.

Vossler C.A., Kerkvliet J., Polasky S. and Gainutdinova O. (2002). Externally validating contingent valuation: an open-space survey and referendum in Corvallis, Oregon. *Journal of Economic Behavior and Organization*, **1485,** 1-17.

Wang H. (1997). Treatment of "Don't Know" responses in contingent valuation surveys: A random valuation model. *Journal of Environmental Economics and Management,* **32,** 219-232.

Willig R. (1976). Consumer surplus without apology. *American Economic Review,* [In: Efthymoglou and Xepapadeas (1990), referenced here].

World Bank (1999). Willing to Pay but Unwilling to Charge, Field Note, Department for International Development (DFID).

Zhao J. and Kling C.L. (2001). A new explanation for the WTP/WTA disparity. *Economics Letters*, **73,** 293-300.

8. APPENDICES

8.1. Limdep outputs

Table 3.14. Limdep output for Model 1

```
--> RESET
--> READ;file="C:\MENEGAKI\PhD CHAPTERS\chapter 3\WTU1S.xls";format=xls;names$
 this is record 512. expect len=10, found  10
--> LOGIT;Lhs=WTU1;Rhs=ONE,INFO,WLACK,ACTION,WPRICE,AGE1,AGE2,EDU1,EDU2,EDU3
    ,INCOME1,SEX,CHID,HERA;Margin$

            +--------------------------------------------+
            | Logit model                                |
            | There are  2 outcomes for LH variable WTU1 |
            | These are the OLS start values based on the|
            | binary variables for each outcome Y(i) = j.|
            | Coefficients for LHS=0 outcome are set to 0.0 |
            +--------------------------------------------+
+---------+--------------+----------------+--------+---------+----------+
|Variable | Coefficient  | Standard Error |b/St.Er.|P[|Z|>z] | Mean of X|
+---------+--------------+----------------+--------+---------+----------+
         Characteristics in numerator of Prob[Y = 1]
 Constant  .6322271584      .15634793        4.044   .0001
 INFO     -.9454989215E-02  .16491685E-01    -.573   .5664  2.3733681
 WLACK     .4774432443E-01  .18163822E-01    2.629   .0086  4.5456919
 ACTION    .1299564692E-01  .21724152E-01     .598   .5497  1.6919060
 WPRICE    .3291541042E-01  .53476066E-01     .616   .5382  .24048564
 AGE1     -.2609772007E-01  .82838497E-01    -.315   .7527  .14099217
 AGE2     -.7412845387E-01  .49841818E-01   -1.487   .1369  .48302872
 EDU1     -.1170938152      .11914129        -.983   .3257  .54830287E-01
 EDU2     -.5418460878E-01  .79144540E-01    -.685   .4936  .39947781
 EDU3     -.7708061638E-01  .72461902E-01   -1.064   .2874  .44647520
 INCOME1   .5661370361E-04  .34800316E-04    1.627   .1038  980.28721
 SEX      -.4611401240E-01  .65778945E-01    -.701   .4833  .89295039
 CHID     -.5175996160E-01  .70633453E-01    -.733   .4637  .83550914
 HERA      .1039202440      .51595732E-01    2.014   .0440  .80417755

Normal exit from iterations. Exit status=0.

            +--------------------------------------------+
            | Logit Model                                |
            | Maximum Likelihood Estimates               |
            | Dependent variable                WTU1     |
            | Weighting variable                ONE      |
            | Number of observations            383      |
            | Iterations completed              6        |
            | Log likelihood function       -174.9762    |
            | Restricted log likelihood     -186.5564    |
            | Chi-squared                    23.16059    |
            | Degrees of freedom                13       |
            | Significance level             .3978900E-01|
            +--------------------------------------------+
+---------+--------------+----------------+--------+---------+----------+
|Variable | Coefficient  | Standard Error |b/St.Er.|P[|Z|>z] | Mean of X|
+---------+--------------+----------------+--------+---------+----------+
         Characteristics in numerator of Prob[Y = 1]
 Constant  .8188152793      1.1450865         .715   .4746
 INFO     -.5605991135E-01  .11286595        -.497   .6194  2.3733681
 WLACK     .2647816330      .10398408       2.546   .0109  4.5456919
 ACTION    .9652237857E-01  .14884673        .648   .5167  1.6919060
 WPRICE    .8515960533      .95969940        .887   .3749  .24048564
 AGE1     -.1750840666      .61418404        -.285   .7756  .14099217
 AGE2     -.5331491531      .34377003       -1.551   .1209  .48302872
 EDU1     -.9818151507      .86833326       -1.131   .2582  .54830287E-01
 EDU2     -.6374919994      .68428933        -.932   .3515  .39947781
 EDU3     -.8056214510      .65640512       -1.227   .2197  .44647520
 INCOME1   .4503869166E-03  .26358685E-03    1.709   .0875  980.28721
 SEX      -.3625987546      .48390308        -.749   .4537  .89295039
 CHID     -.4113613268      .52669702        -.781   .4348  .83550914
 HERA      .6265182143      .31950322        1.961   .0499  .80417755


+-----------------------------------------+
| Partial derivatives of probabilities with |
```

```
| respect to the vector of characteristics. |
| They are computed at the means of the Xs. |
| Observations used for means are All Obs.  |
+-------------------------------------------+
```

Variable	Coefficient	Standard Error	b/St.Er.	P[|Z|>z]	Mean of X
	Marginal effects on Prob[Y = 1]				
Constant	.1155867707	.16064611	.720	.4718	
INFO	-.7913609187E-02	.15931308E-01	-.497	.6194	2.3733681
WLACK	.3737748265E-01	.14610242E-01	2.558	.0105	4.5456919
ACTION	.1362542971E-01	.20977955E-01	.650	.5160	1.6919060
WPRICE	.1202142171	.13356300	.900	.3681	.24048564
AGE1	-.2471546680E-01	.86689186E-01	-.285	.7756	.14099217
AGE2	-.7526116140E-01	.48095244E-01	-1.565	.1176	.48302872
EDU1	-.1385963911	.12146375	-1.141	.2538	.54830287E-01
EDU2	-.8999055514E-01	.95645491E-01	-.941	.3468	.39947781
EDU3	-.1137242847	.91308677E-01	-1.245	.2130	.44647520
INCOME1	.6357816049E-04	.36673887E-04	1.734	.0830	980.28721
SEX	-.5118568272E-01	.68125970E-01	-.751	.4524	.89295039
CHID	-.5806917451E-01	.74156197E-01	-.783	.4336	.83550914
HERA	.8844145802E-01	.44933277E-01	1.968	.0490	.80417755

Frequencies of actual & predicted outcomes
Predicted outcome has maximum probability.

	Predicted		
Actual	0	1	Total
0	3	70	73
1	1	309	310
Total	4	379	383

Table 3.15. Limdep full output for Model 2

```
--> RESET
--> READ;file="C:\MENEGAKI\PhD CHAPTERS\chapter 3\WTU2S.xls";format=xls;names$
 this is record 512. expect len=10, found  10
--> LOGIT;Lhs=WTU2;Rhs=ONE,INFO,WLACK,ACTION,WPRICE,AGE1,AGE2,EDU1,EDU2,EDU3
    ,INCOME1,SEX,CHID,HERA;Margin$

           +--------------------------------------------+
           | Logit model                                |
           | There are  2 outcomes for LH variable WTU2 |
           | These are the OLS start values based on the|
           | binary variables for each outcome Y(i) = j.|
           | Coefficients for LHS=0 outcome are set to 0.0 |
           +--------------------------------------------+
+---------+-------------+----------------+-------+--------+----------+
|Variable | Coefficient | Standard Error |b/St.Er.|P[|Z|>z] | Mean of X|
+---------+-------------+----------------+-------+--------+----------+
         Characteristics in numerator of Prob[Y = 1]
 Constant  .7890716155E-01  .18501067          .427   .6697
 INFO      .2564488231E-01  .19188528E-01     1.336   .1814  2.4046243
 WLACK     .1077035574E-01  .23612404E-01      .456   .6483  4.6098266
 ACTION   -.5711402762E-01  .25049633E-01    -2.280   .0226  1.6878613
 WPRICE    .4988714042E-02  .58043353E-01      .086   .9315  .23900578
 AGE1      .7680135687E-01  .97742264E-01      .786   .4320  .15028902
 AGE2      .1199729787E-01  .57867844E-01      .207   .8358  .50000000
 EDU1     -.1384076901E-01  .13944052         -.099   .9209  .46242775E-01
 EDU2      .2084805993      .89180066E-01     2.338   .0194  .39306358
 EDU3      .2037447983      .80657883E-01     2.526   .0115  .45664740
 INCOME1   .1386395116E-04  .38999685E-04      .355   .7222  1001.4451
 SEX       .1425534036      .66207180E-01     2.153   .0313  .86127168
 CHID      .5760613153E-01  .85208711E-01      .676   .4990  .83526012
 HERA      .3243787005      .59441597E-01     5.457   .0000  .81791908

Normal exit from iterations. Exit status=0.

           +--------------------------------------------+
           | Logit Model                                |
           | Maximum Likelihood Estimates               |
           | Dependent variable                    WTU2 |
           | Weighting variable                    ONE  |
           | Number of observations                346  |
           | Iterations completed                    5  |
           | Log likelihood function          -176.9357 |
           | Restricted log likelihood        -199.3574 |
           | Chi-squared                       44.84338 |
           | Degrees of freedom                      13 |
           | Significance level             .2222359E-04 |
           +--------------------------------------------+
+---------+-------------+----------------+-------+--------+----------+
|Variable | Coefficient | Standard Error |b/St.Er.|P[|Z|>z] | Mean of X|
+---------+-------------+----------------+-------+--------+----------+
         Characteristics in numerator of Prob[Y = 1]
 Constant -2.299353043      1.0533460       -2.183   .0290
 INFO      .1550888326      .11158049        1.390   .1646  2.4046243
 WLACK     .5303426605E-01  .13501616         .393   .6945  4.6098266
 ACTION   -.3322480320      .14641662       -2.269   .0233  1.6878613
 WPRICE    .1739234065E-01  .34013434         .051   .9592  .23900578
 AGE1      .4755880223      .57429947         .828   .4076  .15028902
 AGE2      .6665318032E-01  .33788863         .197   .8436  .50000000
 EDU1      .2009250015E-01  .72468619         .028   .9779  .46242775E-01
 EDU2      1.121573624      .48821688        2.297   .0216  .39306358
 EDU3      1.077937027      .43756907        2.463   .0138  .45664740
 INCOME1   .9181555039E-04  .22764770E-03     .403   .6867  1001.4451
 SEX       .7862956604      .36442832        2.158   .0310  .86127168
 CHID      .3564724020      .48274387         .738   .4603  .83526012
 HERA      1.586119153      .31320090        5.064   .0000  .81791908

Matrix: Las
[14,4]
+----------------------------------------+
```

```
| Partial derivatives of probabilities with |
| respect to the vector of characteristics. |
| They are computed at the means of the Xs. |
| Observations used for means are All Obs.  |
+-------------------------------------------+
+---------+-------------+----------------+--------+---------+----------+
|Variable | Coefficient | Standard Error |b/St.Er.|P[|Z|>z] | Mean of X|
+---------+-------------+----------------+--------+---------+----------+
         Marginal effects on Prob[Y = 1]
 Constant -.4168280786      .19270480      -2.163   .0305
 INFO      .2811459523E-01  .20153056E-01   1.395   .1630  2.4046243
 WLACK     .9614083091E-02  .24482675E-01    .393   .6945  4.6098266
 ACTION   -.6023011960E-01  .26309940E-01  -2.289   .0221  1.6878613
 WPRICE    .3152893792E-02  .61660512E-01    .051   .9592  .23900578
 AGE1      .8621487773E-01  .10398589        .829   .4070  .15028902
 AGE2      .1208292792E-01  .61254338E-01    .197   .8436  .50000000
 EDU1      .3642380300E-02  .13136578        .028   .9779  .46242775E-01
 EDU2      .2033195294      .87972391E-01   2.311   .0208  .39306358
 EDU3      .1954090612      .78826548E-01   2.479   .0132  .45664740
 INCOME1   .1664437723E-04  .41243961E-04    .404   .6865  1001.4451
 SEX       .1425401420      .65732003E-01   2.169   .0301  .86127168
 CHID      .6462152771E-01  .87410723E-01    .739   .4597  .83526012
 HERA      .2875326174      .56531176E-01   5.086   .0000  .81791908

Frequencies of actual & predicted outcomes
Predicted outcome has maximum probability.

              Predicted
------  ----------  +  -----
Actual         0     1  |  Total
------  ----------  +  -----
  0           23    68  |     91
  1           16   239  |    255
------  ----------  +  -----
Total         39   307  |    346
```

8.2. EViews outputs

Table 3.16. EVIEWS full output for Model 3.

Dependent Variable: LOGWTP1
Method: Least Squares
Sample(adjusted): 1 288
Included observations: 287
Excluded observations: 1 after adjusting endpoints

Variable	Coefficient	Std. Error	t-Statistic	Prob.
Constant	-0.914141	0.101000	-9.050936	0.0000
INFO	0.000136	0.000234	0.580241	0.5622
WLACK	-9.07E-05	0.000315	-0.287509	0.7739
ACTION	0.000114	0.000242	0.473159	0.6365
WPRICE	0.000314	0.000222	1.413724	0.1586
AGE1	0.020956	0.074480	0.281369	0.7786
AGE2	0.065624	0.045506	1.442091	0.1504
EDU1	0.125328	0.060263	2.079691	0.0385
EDU2	-0.027330	0.037497	-0.728856	0.4667
EDU3	-0.098107	0.038840	-2.525909	0.0121
LOGINCOME	0.000331	9.74E-05	3.395040	0.0008
CHID	0.007505	0.060877	0.123281	0.9020
SEX	0.041800	0.059992	0.696755	0.4865
HERA	-0.014264	0.052963	-0.269328	0.7879

R-squared	0.081795	Mean dependent var	-0.914324
Adjusted R-squared	0.038071	S.D. dependent var	0.317476
S.E. of regression	0.311374	Akaike info criterion	0.551908
Sum squared resid	26.46842	Schwarz criterion	0.730419
Log likelihood	-65.19880	F-statistic	1.870717
Durbin-Watson stat	1.502289	Prob(F-statistic)	0.033408

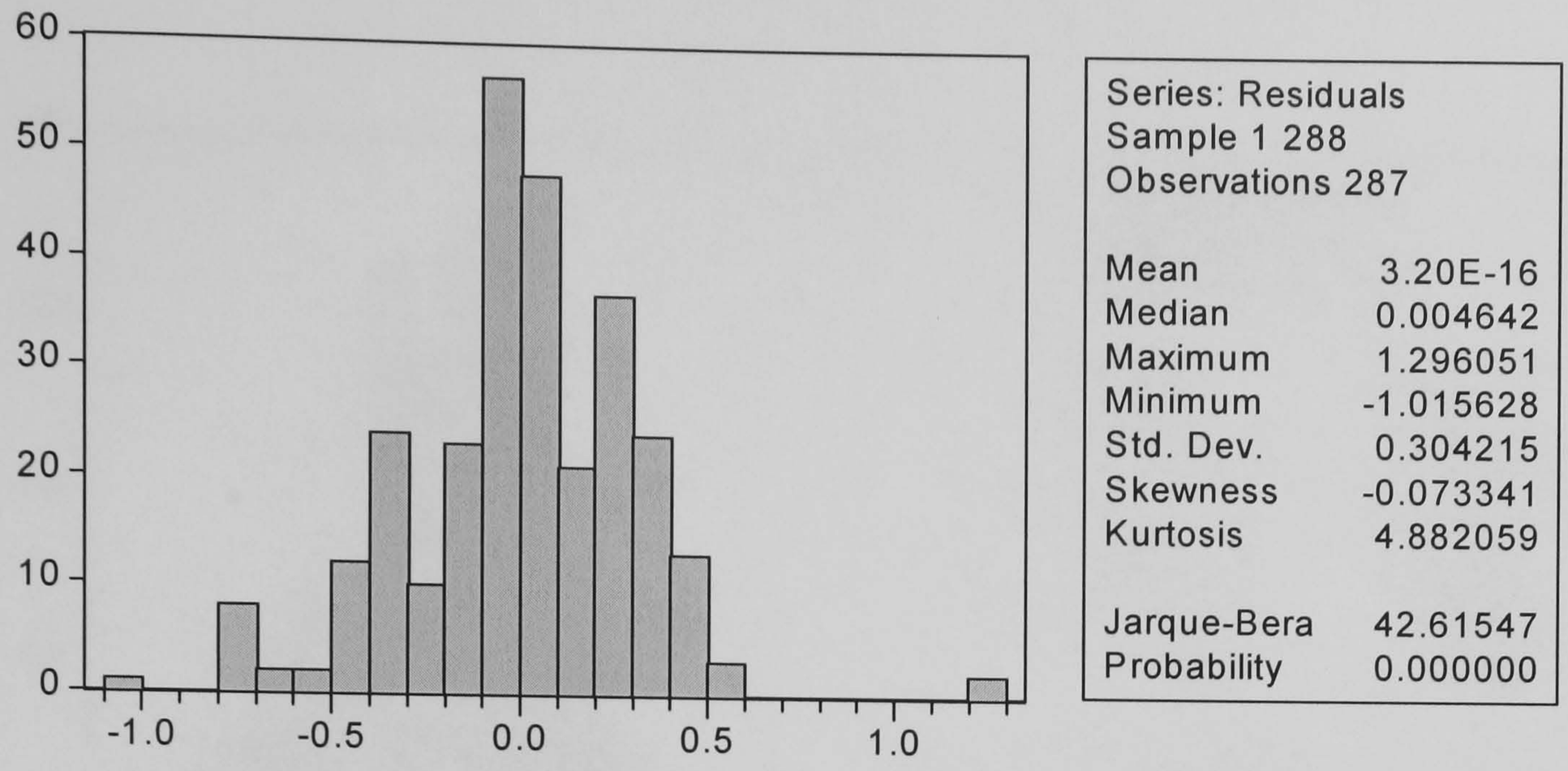


Figure 3.7. Jarque-Bera residual normality test of Model 3.

Table 3.17. EVIEWS full output for Model 4.

Dependent Variable: LOGWTP2

Method: Least Squares

Sample(adjusted): 1 239

Included observations: 239 after adjusting endpoints

Variable	Coefficient	Std. Error	t-Statistic	Prob.
Constant	-1.041817	0.121245	-8.592681	0.0000
INFO	0.000162	0.000252	0.644652	0.5198
WLACK	-0.000445	0.000395	-1.125963	0.2614
ACTION	0.000590	0.000396	1.491089	0.1373
WPRICE	0.000691	0.000309	2.233859	0.0265
AGE1	0.056288	0.084633	0.665083	0.5067
AGE2	0.018038	0.050401	0.357885	0.7208
EDU1	0.064677	0.080880	0.799671	0.4247
EDU2	-0.002299	0.046637	-0.049292	0.9607
EDU3	-0.062550	0.047546	-1.315555	0.1897
LOGINCOME	0.000181	0.000107	1.703386	0.0899
CHID	0.108439	0.075243	1.441182	0.1509
SEX	0.104604	0.063956	1.635550	0.1033
HERA	-0.014547	0.064445	-0.225722	0.8216

R-squared	0.073191	Mean dependent var	-0.892485
Adjusted R-squared	0.019642	S.D. dependent var	0.309516
S.E. of regression	0.306461	Akaike info criterion	0.529337
Sum squared resid	21.13159	Schwarz criterion	0.732979
Log likelihood	-49.25580	F-statistic	1.366804
Durbin-Watson stat	1.713662	Prob(F-statistic)	0.176823

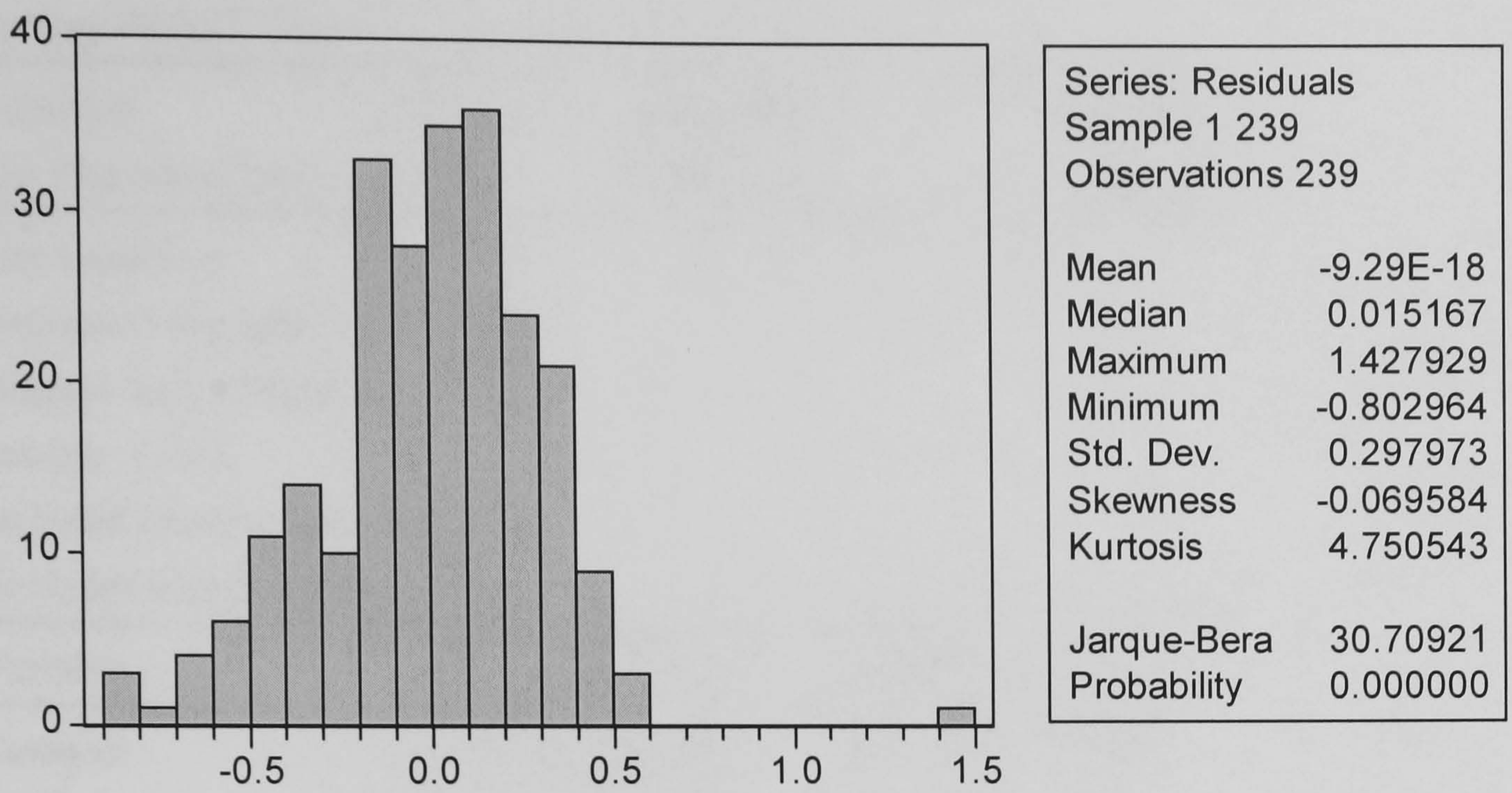


Figure 3.8. Jarque-Bera residual normality test of Model 4.

Table 3.18. Ramsey RESET test for Model 3.

Ramsey RESET Test:

F-statistic	0.026655	Probability	0.870433
Log likelihood ratio	0.028123	Probability	0.866820

Test Equation:

Dependent Variable: LOGWTP1

Method: Least Squares

Sample: 1 288

Included observations: 287

Excluded observations: 1

Variable	Coefficient	Std. Error	t-Statistic	Prob.
Constant	-1.214902	1.844973	-0.658493	0.5108
INFO	0.000228	0.000611	0.373318	0.7092
WLACK	-0.000149	0.000476	-0.312517	0.7549
ACTION	0.000186	0.000500	0.371335	0.7107
WPRICE	0.000551	0.001468	0.374957	0.7080
AGE1	0.035662	0.116963	0.304900	0.7607
AGE2	0.108858	0.268710	0.405114	0.6857
EDU1	0.202564	0.476917	0.424736	0.6714
EDU2	-0.042579	0.100672	-0.422947	0.6727
EDU3	-0.160157	0.382052	-0.419203	0.6754
LOGINCOME	0.000584	0.001556	0.375537	0.7076
CHID	0.012804	0.069086	0.185340	0.8531
SEX	0.068799	0.175954	0.391006	0.6961
HERA	-0.023550	0.077782	-0.302772	0.7623
FITTED^2	0.355820	2.179437	0.163262	0.8704

R-squared	0.081885	Mean dependent var	-0.914324
Adjusted R-squared	0.034629	S.D. dependent var	0.317476
S.E. of regression	0.311931	Akaike info criterion	0.558779
Sum squared resid	26.46582	Schwarz criterion	0.750041
Log likelihood	-65.18474	F-statistic	1.732805
Durbin-Watson stat	1.503494	Prob(F-statistic)	0.049187

Table 3.19. Ramsey RESET test for Model 4.

Ramsey RESET Test:

F-statistic	0.072028	Probability	0.788654
Log likelihood ratio	0.076839	Probability	0.781628

Test Equation:

Dependent Variable: LOGWTP2

Method: Least Squares

Sample: 1 239

Included observations: 239

Variable	Coefficient	Std. Error	t-Statistic	Prob.
Constant	-2.327774	4.793094	-0.485652	0.6277
INFO	0.000540	0.001429	0.377757	0.7060
WLACK	-0.001298	0.003202	-0.405333	0.6856
ACTION	0.001780	0.004450	0.400004	0.6895
WPRICE	0.002656	0.007327	0.362447	0.7174
AGE1	0.177206	0.458461	0.386525	0.6995
AGE2	0.056883	0.153300	0.371060	0.7109
EDU1	0.196514	0.497873	0.394707	0.6934
EDU2	-0.004387	0.047377	-0.092595	0.9263
EDU3	-0.192632	0.487031	-0.395524	0.6928
LOGINCOME	0.000591	0.001529	0.386428	0.6995
CHID	0.342881	0.876797	0.391062	0.6961
SEX	0.335711	0.863501	0.388779	0.6978
HERA	-0.046209	0.134493	-0.343577	0.7315
FITTED^2	1.193578	4.447344	0.268380	0.7887

R-squared	0.073489	Mean dependent var	-0.892485
Adjusted R-squared	0.015582	S.D. dependent var	0.309516
S.E. of regression	0.307095	Akaike info criterion	0.537384
Sum squared resid	21.12479	Schwarz criterion	0.755572
Log likelihood	-49.21738	F-statistic	1.269086
Durbin-Watson stat	1.712554	Prob(F-statistic)	0.228043

CHAPTER 4.

CONSUMERS' ATTITUDE TOWARDS RECYCLED WATER

1. INTRODUCTION

This chapter is going to study Cretan consumers' attitude towards recycled water. This will be achieved through studying the willingness to use (WTU) of a sample of Cretan consumers for three specific products: The first is olive oil produced by olive trees irrigated with recycled water of quality 2 (for convenience we refer to it from now on, as *product 3*). The second is tomatoes irrigated with recycled water of quality 3 (*product 4*). The third object of our research is a park irrigated with recycled water of quality 2 (*product 5*). Although the term product is not proper for product 5, we still have to use this term for the sake of convenience and brevity. Product 3a is a variant of product 3; It is olive oil produced by olive trees irrigated with a higher quality of recycled water (quality 3).

Furthermore, we will examine WTP for product 3. The reason we concentrated only on WTP of product 3 is first, because we wanted to keep the questionnaire as short as possible, and second, because product 3, both objectively and from the point of view of consumers, is a product of middle risk, compared to the other two. Irrigation for product 3 stops at least a month before reaping the olive crops. The latter starts in the end of November. Tomato reaping, on the other hand, takes place

round the year, even a day after the last irrigation session. Consumers perceive product 4 to be the most dangerous, while product 5 is the least dangerous.

WTU for the three products will be modeled with ordered logit models. WTP data have been split and will be modeled with two ways: a part of the data will be modeled with a least squares linear regression model and another part with a maximum likelihood estimation method, which is imposed from the double-bounded dichotomous (DB-DC) nature of this data. We used two elicitation formats because we wanted to see whether this would play any role in the estimation of WTP.

We believe that consumers' study is an indispensable part of the farmers' study that was presented in the previous chapter, since the opinion of the former is vital in this whole venture of irrigation with recycled water. If consumers will not consume these products, then there is no point for the farmers producing them. Studying consumers' attitude (through WTU) will give information as to the way we should formulate education, information and marketing policies, which will persuade consumers to use these products. Studying WTP will reveal the size of consumer's surplus and thus contribute to the formulation of pricing policies that will induce people to consume these products.

1.1. The variables

Table 4.1 provides a brief description of the variables that will be used in the models of this chapter.

Table 4.1. List of variables.

Variable	Description
INFO	It describes how informed the consumer thinks he is about environmental problems. It is a categorical variable taking values from 0 to 5, with zero being the consumer who is not informed at all.
LACKW	It describes the degree of seriousness consumers assign to the problem of water shortage. It takes values from 1 to 5. Seriousness of degree 5, signifies a very serious problem.
ACTIONS	It answers how many of the four mentioned (in the questionnaire) environmentally friendly actions the consumer is involved in. This is a count variable taking values from 0 to 4.
WTU3	Willingness to consume product 3. This is an ordered variable. Respondents choose among: Definitely no, Maybe no, Maybe yes, Definitely yes and I don't know.
WTU3a	Willingness to consume olive oil irrigated with recycled water of quality 3 (for convenience we call it product 3a). This is an ordered variable. Respondents choose among: Definitely no, Maybe no, Maybe yes, Definitely yes and I don't know.
WTU4	Willingness to consume product 4. This is an ordered variable. Respondents choose among: Definitely no, Maybe no, Maybe yes, Definitely yes and I don't know.
WTU5	Willingness to use (visit) product 5. This is an ordered variable. Respondents choose among: Definitely no, Maybe no, Maybe yes, Definitely yes and I don't know.
WTP3O	Willingness to pay for 1 kg of product 3 (open ended question).
WTP3D	Willingness to pay for 1 kg of product 3 (DB-DC question).
AGE1	Binary variable with D=1 if the respondent falls in age groups 18-24 or 25-34 and D=0 if he is not.
AGE2	Binary variable with D=1 if the respondent falls in age groups 35-44 or 45-54 and D=0 if he is not.
AGE3	Binary variable with D=1 if the respondent falls in age groups 55-64 or 65-and above and D=0 if he is not (this is the excluded[1] age variable).
EDU1	Binary variable with D=1 if the respondent is illiterate and D=0 if otherwise.
EDU2	Binary variable with D=1 if the respondent is primary school graduate and D=0 if otherwise.
EDU3	Binary variable with D=1 if the respondent is secondary school graduate and D=0 if otherwise.
EDU4	Binary variable with D=1 if the respondent is tertiary education graduate and D=0 if otherwise (this is the excluded education variable).
INCOME	Monthly family income. This is a categorical variable with ten age categories, which stand for the mid value of the interval that described the income group, e.g. the first income group, which ranged from 0-300 € was represented by its mid value which is 150 €.
GENDER	Binary variable with D=1 if the respondent is a man and D=0 if the respondent is a woman.
CHID	Binary variable with D=1 if the respondent has children and D=0 if he does not.

1.2.The research sample

Three hundred forty two consumers participated in the research. Twelve researchers (they were the same who implemented the farmers' survey) stood in some of the

[1] Exclusion took place to avoid dummy variable trap.

busiest points in the center of Heraklion city from July 2003- October 2003 and randomly picked pedestrians in different hours of the day both in the morning and in the afternoon. The interview together with an information session lasted on average thirty minutes. Consumers were stopped on the street, were told a few things about the research and if they felt like participating, they answered the questionnaire. An information session preceded the completion of the questionnaire (the technical primer in chapter 1 is the content of the booklet). The sample size was satisfactory based on the formula described in section 2.1 in chapter 2. A copy of the consumers' questionnaire is in appendix 6.1 of this chapter.

2. DESCRIPTIVE STATISTICS OF WILLINGNESS TO USE AND WILLINGNESS TO PAY

This part consists of two sections. Section 2.1 discusses the findings from the WTU descriptive statistics while section 2.2 discusses the corresponding findings from WTP as well as the non-parametric estimation of the mean WTP.

2.1. Willingness to use

This section explains the findings of Tables 4.2-4.5. Table 4.2 provides the frequency distribution for WTU3.

Table 4.2. WTU olive oil irrigated with recycled water of quality 2.

		Frequency	Percent	Valid percent	Cumulative percent
Valid	Definitely no	32	9.4	9.4	9.4
	Maybe no	18	5.3	5.3	14.6
	Maybe yes	166	48.5	48.5	63.2
	Definitely yes	110	32.2	32.2	95.3
	I don't know	16	4.7	4.7	100.0
	Total	342	100.0	100.0	

Apparently, the largest part of consumers, namely 80.70% (this is the sum of "maybe yes" and "definitely yes" responses) in Table 4.2 is positively positioned towards consuming product 3. From them, more than half (48.5%) said "maybe yes" rather than "definitely yes", meaning that they were not very confident with their positive attitude.

According to some consumers, the general reason for all positive responses is that *irrigation fresh water is already dirty enough and that recycled water would not be any dirtier*. It is common knowledge that water sources in some areas of Crete have been contaminated by uncontrolled rubbish pits, pesticides application and seawater intrusion.

Those who were negative (14.7%) were also asked the reason for this. The most commonly mentioned reason for not wanting to consume product 3 or product 4 was the fear that farmers would not use the right type of water for the right plant, or that they would not follow the irrigation safety guidelines. Actually, this fear was justifiably expressed more intensively for product 4, because tomatoes can be irrigated one day before reaped. Consumers' fears go back to whether the responsible authorities will do their job well in supervising farmers in their application of recycled water to agriculture.

Afterwards, the negative answering farmers were further asked whether they would consume olive oil irrigated with recycled water of quality 3. The latter is safe for irrigating all types of plants, since it is one level less clean than potable water. Results are shown in Table 4.3.

Table 4.3. WTU olive oil irrigated with recycled water of quality 3.

		Frequency	Percent	Valid percent		Cumulative percent
Valid	The respondent was not addressed this question	289	84.5	85.25		85.25
	Definitely no	1	0.29	0.29	*2.00*	85.54
	Maybe no	4	1.17	1.18	*8.00*	86.72
	Maybe yes	19	5.56	5.60	*38.00*	92.33
	Definitely yes	22	6.43	6.49	*44.00*	98.82
	I don't know	4	1.17	1.18	*8.00*	100.0
	Total	339	99.12	100.0	*100.0*	
Missing		3	0.88			
Total		342	100.0			

Note: Italics represent percentages with the category "the respondent was not addressed this question" excluded

As we see 77.3% (this percentage is the sum of "maybe yes" and "definitely yes" responses in Table 4.3) of the consumers who were not WTU product 3, said that they would be WTU it after all, on the condition that it would have been irrigated with quality 3 of recycled water. This is some proof for the existence of scope effects. Consumers were not indifferent to a better quality of recycled water. If we take into consideration the results from both Tables 4.2 and 4.3, we get that on total, 92.7% (this is the sum of "maybe yes" and "definitely yes" responses from both Tables 4.2 and 4.3) of the respondents would be WTU olive oil irrigated at least with type 3 of recycled water.

Table 4.4. WTU tomatoes irrigated with recycled water of quality 3.

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Definitely no	53	15.5	15.6	15.6
	Maybe no	53	15.5	15.6	31.2
	Maybe yes	134	39.2	39.4	70.6
	Definitely yes	81	23.7	23.8	94.4
	I don't know	19	5.6	5.6	100.0
	Total	340	99.4	100.0	
Missing		2	0.6		
Total		342	100.0		

A smaller number of consumers (63.2%) were WTU product 4 in Table 4.4, compared to those who were WTU product 3, indicating the apprehension with which some consumers face this product. It is understood that for product 4, the better quality of recycled water is outweighed by the greater sensitiveness of tomato and the directness it has in consumption. Olive oil is processed before it reaches consumption. Tomato usually is not and quite often it is consumed raw. However, despite the skepticism manifested by a small number of consumers, the majority of them have made up their minds to consume product 4, which is still very optimistic. In addition to this, product 4 has gathered the most middle responses (55%), namely "maybe no" or "maybe yes" showing how less confident people were with this product.

Table 4.5. WTU a park irrigated with recycled water of quality 4.

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Definitely no	8	2.3	2.4	2.4
	Maybe no	24	7.0	7.1	9.4
	Maybe yes	108	31.6	31.9	41.3
	Definitely yes	191	55.8	56.3	97.6
	I don't know	8	2.3	2.4	100.0
	Total	339	99.1	100.0	
Missing		3	0.9		
Total		342	100.0		

A larger number (88.2%) of consumers were WTU a park irrigated with recycled water of quality 2, in Table 4.5. More than half of people participating in the research said "definitely yes" to visiting such a park. Consumers obviously regarded the idea of park irrigation with this type of water as innocuous. At this point we need to stress a fact which has to do with Cretan or generally Greek peoples' habits in using a park. Greek people will never be seen lying on the grass of the park, as lots of people do during sunny days in other Western European countries. Probably this is one of the reasons they see product 5 as less dangerous.

2.2. "Don't know" responses

It is important to know whether "Don't know" responses mean anything or they are just random, before we drop them from our sample. Strazzera *et al.* (2000) showed that their results on WTP in an application of forest resources for recreational use, would have lead to overestimation of WTP if protest responses had been censored.

Trying to decipher what "Don't know" responses mean in our data, we thought of applying the Heckman sample selection model to eliminate any possible selectivity bias. In the Heckman sample selection model, the outcome (i.e. WTU) depends upon a prior choice made on a selection stage. For example, we believed that people who had given "Don't know" answers probably needed more information in order to make up their minds.

In order to implement the Heckman model we would assume that before the WTU question, we had placed an imaginary question to the respondents which said: "*After all the information we gave you in this questionnaire, can you make up your mind as to whether you would use products irrigated with recycled water"?* Respondents who had given an answer other than "Don't know" would be considered as people who had enough information to decide, while people who had answered with "Don't know" would be considered as not having enough information.

However, this model did not make sense because if a person admits in a prior question that he has no sufficient information to make up his mind, then definitionally he cannot answer the WTU question and there is no point going on asking him right after about his WTU. Therefore this approach and model were abandoned.

"Don't know" responses are 4.7% in product 3, 5.6% in product 4 and only 2.4% in product 5 (Figure 4.1). They seem to mean one of the middle categories, namely "maybe yes" or "maybe no" or something in the middle of these two categories, namely indifference between "maybe yes" or "maybe no". The reason we say so, is supported by the fact that the number of "Don't know" responses increases as the risk of the product rises. It is the highest for the most dangerous product (product 4) and the smallest for the least dangerous product (product 5). The number of maybe responses follows the same pattern. Therefore, people express their opinion with more determination in products 3 and 5 (the sum of definitely yes or no responses outnumbers the sum of maybe yes or no responses) and appear as more unconfident in product 4.

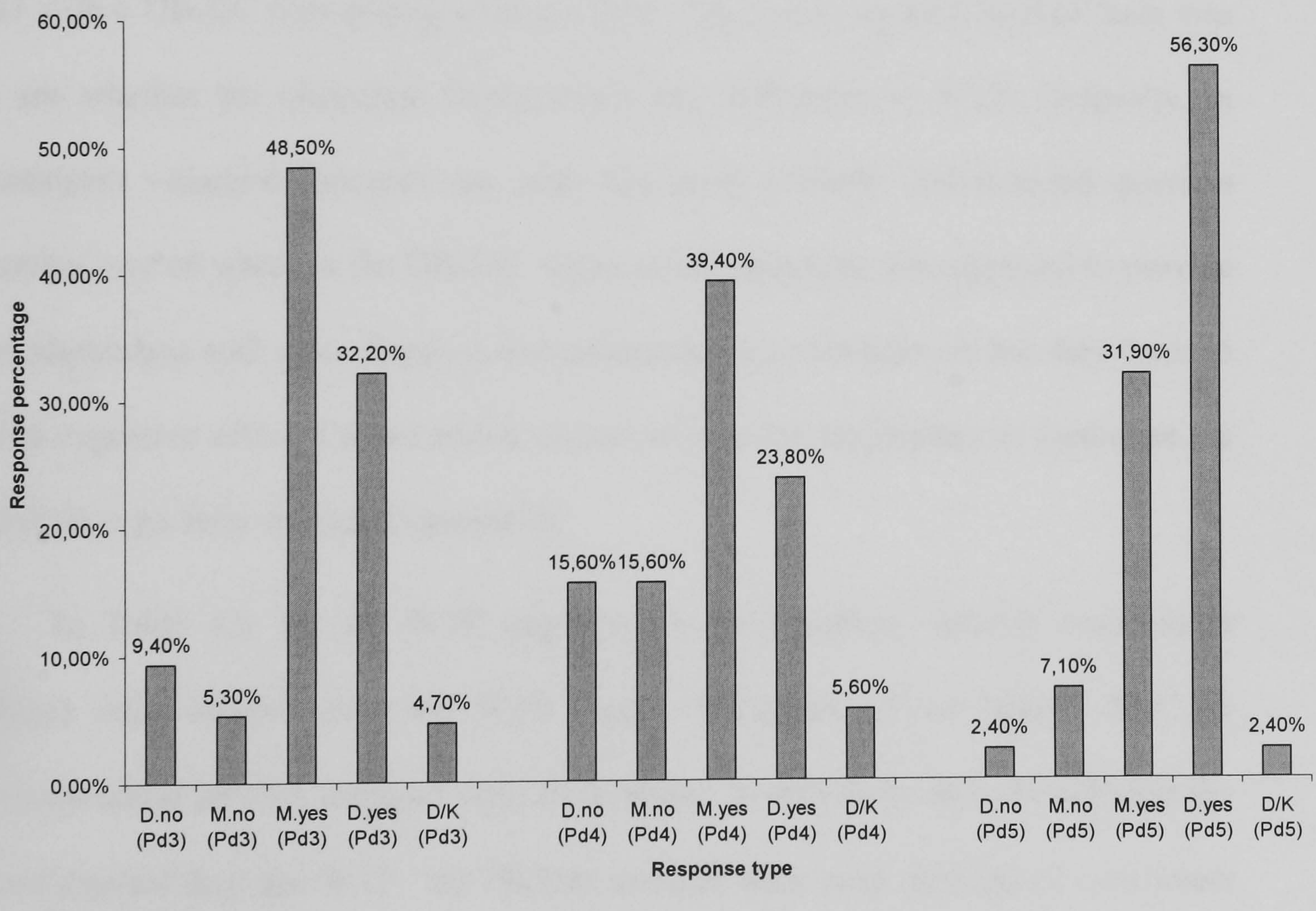


Figure 4.1. All products percentage WTU answers (Note that: D.no=Definitely no, M.no= Maybe no, M.yes= Maybe yes, D/K="Don't know", Pd3= Product 3, Pd4= Product 4, Pd5= Product 5)

In the analysis that follows in this chapter, we have left out "Don't know" responses, first because they were a trivial part of our sample and second because they were random. Namely, there is no systematic pattern in the regressors we are using in our models, i.e. consumers who answer, "Don't know" come from all ages, all education levels, all incomes etc.

2.3. Willingness to pay

WTP has been investigated as regards product 3. The question wording was: *"Suppose that 1kg of olive oil is sold for 3 € in the supermarket. How much would you be WTP for it if you knew it had been irrigated with recycled water of quality 2?"* We got 128 observations with the open question format (see section 2.3.1) and 147 with a DB-DC format (see section 2.3.2). The reason we used both of them was to see whether the elicitation format made any difference in WTP. Generally, in contingent valuation literature the scale tips more towards closed-ended question formats, one of which is the DB-DC. Open-ended questions are supposed to provide the respondent with more freedom and independence in his answers but they demand more cognitive effort. Closed ended questions help the respondent to formulate his mind through fully structured questions.

In Table 4.6 we see WTP expressed as an intention, namely respondents declare only whether they are WTP "less", "as much as" or "more" than the corresponding product irrigated with fresh water. At this stage they do not state the exact amount they are WTP. 69.7% (see column with valid percent) of consumers are bidding for "less", 28.1% for "as much" and 2.2% for "more".

Table 4.6. WTP (as intention) for product 3.

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Less	191	55.8	69.7	69.7
	As much as	77	22.5	28.1	97.8
	More	6	1.8	2.2	100.0
	Total	274	80.1	100.0	
Missing		2	0.6		
	Respondent was not addressed this question	66	19.3		
	Total (missing)	68	19.9		
Total		342	100.0		

Note: "As much as" answers have been included in the open bid data and have been quoted with the current hypothetical market price of 3 €.

Six consumers bid "more". A couple of them mistook product 3 for organic oil. Of course there is an ecological approach[2] in the cultivation of product 3, but by no means is it an organic product. Nevertheless consumers thought it was of superior quality and gave higher bids for it. At this point we need to repeat something, which we have already mentioned; the prejudice some people suffer from and which will not let them hear the information the researcher was giving them at the interview. The other consumers gave higher bids either because of commitments to an ecological way of life or due to warm-glow effects.

2.3.1. Open-question data

This section will give the non-parametric estimation of mean WTP from the open-ended data set. Bateman *et al.* (2003) write that non-parametric estimation is an indispensable step in the analysis of contingent valuation data when the objective is to estimate the mean and median WTP of a sample. By non-parametric estimation we refer to a purely empirical approach under no distribution assumption. The reason we opt for the non-parametric estimation of the mean WTP is the fact that WTP models

[2] Ideally recycled water will completely substitute fertilizers. Technical characteristics on this are given in chapters 1 and 2.

in Tables 4.14, 4.16 and 4.17 were of poor fit with few significant variables. So, it is not felt that the parametric mean WTP is not to be trusted more than the non-parametric one.

For the continuous data we have in the open-ended WTP question, the non-parametric estimation of WTP means estimating the survivor function through the Kaplan-Meier product limit estimator. This is done with arranging the sample's WTP values in ascending order. Then we derive the survivor function by calculating the proportion of the sample that have a WTP greater than each WTP value (Bateman *et al*. (2003), pages 226-229). However, the mean WTP that stems from this procedure is the same as the one that would be returned from the more familiar calculation of summing the reported WTP values in the sample and dividing by the sample size (Bateman *et al*. 2003) with 95% confidence intervals being constructed as follows: meanWTP±1.96 standard errors either side of the mean.

Open-question data include bids from all three categories: "less", "as much as" and "more". The mean is 2.67€ (Table 4.7) which is 89% of the hypothetical current market price. The 95% confidence interval of the mean is given in Equation 4.1.

$$2.67 \pm 1.96 \frac{0.58}{\sqrt{130}} \text{ i.e. } (2.57\text{-}2.77) \qquad (4.1)$$

A 95% confidence interval means that if all possible samples of the same size were taken, 95% of them would include the true population mean somewhere within the interval around their sample means and only 5% would not.

Table 4.7. Descriptive statistics of WTP (open-ended data) for product 3.

	N	Minimum	Maximum	Mean	Median	Std. Deviation
WTP (open-ended question) in €	128	€ 1.00	€ 4.00	€ 2.674	€ 3.00	€ 0.58326
Valid N (listwise)	128					

2.3.2. DB-DC data

We have used six questionnaire versions in the DB-DC data as a result of having six different starting points. Table 4.8 shows the upper and lower bids related to the starting points. The consumer is asked first whether he would pay the amount stated by the starting point and according to the answer he gives, the bid is adapted to a higher or a lower level, so that we have an interval on which the bid falls. We must note that we do not know the impact of the introduction of recycled water in the irrigation cost of the olive tree. Therefore, we do not know how realistic the offered bids in Table 4.8 are. We constructed them randomly by subtracting or adding 20-25 cents from the initial bid.

Table 4.8. Bid design for DB-DC data.

Questionnaire version	Lower bid level BL	Initial bid B	Upper bid level BH
1	1.75	2.00	2.25
2	2.20	2.40	2.60
3	2.25	2.50	2.75
4	2.45	2.65	2.85
5	2.45	2.70	2.95
6	2.65	2.80	2.95

Non-parametric estimation of mean WTP with interval data requires the use of a technique known as Turnbull's self-consistency algorithm (TSCA). We have estimated TSCA in two ways. The first was a way that imitates TSCA and is based on its general philosophy but it uses down-to-earth arithmetics (from now on we will call it "imitated TSCA"). The second way was the "true" TSCA algorithm as written by Olvar Bergland (Agricultural University of Norway) and adapted by Brett Day, in University of East Anglia (2001) from whom the thesis writer borrowed it. The reason both ways are reported is that the thesis writer had proceeded with the first way and afterwards she borrowed the TSCA code. So, she thought it might be

interesting to report the results of the first way too just too to see how the two ways differ.

First we explain how we calculated the "imitated TSCA". Overlapping intervals lead to a larger number of interval combinations compared to what we would have got from mutually exclusive intervals. The problem with them though, is that we must disentangle their frequencies if we want to get the mean WTP.

Table 4.9. Bid interval frequency with DB-DC data (overlapping intervals).

Interval code	Interval		Number of respondents in interval	
A	0	1.75	0	0.00%
B	1.75	2.00	1	0.68%
C	2.00	2.25	2	1.36%
D	2.25	∞	5	3.40%
E	0	2.20	1	0.68%
F	2.20	2.40	2	1.36%
G	2.40	2.60	2	1.36%
H	2.60	∞	1	0.68%
I	0	2.25	6	4.08%
J	2.25	2.50	3	2.04%
K	2.50	2.75	7	4.76%
L	2.75	∞	2	1.36%
M	0	2.45	36	24.49%
N	2.45	2.65	31	21.09%
O	2.65	2.85	24	16.33%
P	2.85	∞	12	8.16%
Q	2.45	2.70	3	2.04%
R	2.70	2.95	2	1.36%
S	2.95	∞	1	0.68%
T	0	2.65	0	0.00%
U	2.65	2.80	4	2.72%
V	2.80	2.95	1	0.68%
W	2.95	∞	1	0.68%
Sum			147	100.00%

The boundary values of the 23 intervals (in an increasing order) are: € 0, 1.75, 2.00, 2.20, 2.25, 2.40, 2.45, 2.50, 2.60, 2.65, 2.70, 2.75, 2.80, 2.85, 2.95, ∞. Taking each

one with the one next, we get non-overlapping intervals, which we called basic intervals in order to distinguish them from the consumers' overlapping WTP intervals. Then we break all the overlapping interval observations with the trick looking like what Bateman *et al.* describe[3] in their book (page 234-235) as TSCA and the new frequency distribution based on non-overlapping intervals is the one presented in Table 4.10. Figure 4.4 in appendix 6.3 shows how observations were split.

Table 4.10. Bid interval frequency with DB-DC data (mutually-exclusive intervals).

Basic intervals		Number of observations	Frequency
0	1.75	31.26	21.22
1.75	2.00	5.47	3.79
2.00	2.20	6.07	4.20
2.20	2.25	1.51	1.12
2.25	2.40	5.75	3.99
2.40	2.45	2.16	1.46
2.45	2.50	9.78	6.71
2.50	2.60	21.17	14.30
2.60	2.65	10.21	6.90
2.65	2.70	9.79	6.71
2.70	2.75	9.59	6.48
2.75	2.80	8.59	5.80
2.80	2.85	7.59	5.13
2.85	2.95	11.19	7.56
2.95	∞	6.87	4.63
		147	100%

Afterwards we calculate the mean WTP from DB-DC data by multiplying each interval mid with its frequency and then divide by the total number of observations.

[3] Bateman *et al.* (2003) describe the calculation of TSCA as follows: *Split each observation into a number of fractions summing to one. A fraction is allotted to each of the basic intervals spanned by the consumer's WTP interval. Breaking all the overlapping interval observations in this manner and then adding up all the fractions each basic interval receives, we will get a new data set, which contains only non-overlapping interval observations.*

Mean WTP with DB-DC data is 2.23 € which is 74.3% of the hypothetical current market price. Its 95% confidence interval is

$$2.23 \pm 1.96 * \frac{0.76}{\sqrt{147}} \text{ or } (2.10\text{-}2.35) \qquad (4.2)$$

which is wider than the one in the open question data (Table 4.7), because standard deviation is bigger. Although the last interval in Table 4.10 is supposed to be open to infinity, we have bounded it with 3 (which is the hypothetical olive oil current market price). We did this for convenience of basic interval frequencies calculation. If however we bounded this with 4 or 5, then results would slightly differ. As we have reported in section 2.2, respondents who gave bids higher than the current price of 3 €, were exaggerating. We do not really expect bids higher than 3 €, so in this sense, we do not feel very uncomfortably with the above estimation way (the imitated TSCA).

As far as the "true" TSCA result is concerned, this gave a mean WTP of 2.55 €. The GAUSS output for this, is presented in appendix 6.3, sections 6.3.2.1 and 6.3.3.2. Results with the imitated TSCA differ by 3.2 cents. This is the linear interpolation of mean WTP, which assumes that the survivor function falls linearly across each equivalence class (basic interval). The term equivalence class signifies the intervals in which the survivor function fall. The GAUSS output for the 95% confidence interval of the "true" TSCA is presented in the appendix 6.3.2.2.

2.3.3. Comparison of the mean WTP from the open and DB-DC data

There is contradictive evidence in literature as to which mean should be higher, i.e. the one generated from the open or the DB-DC data. Mean open-ended WTP, calculated in a non-parametric way, is 2.67 € while the corresponding mean for DB-

DC data equals 2.23 €. Markowska and Zylicz (1999) state that the open-ended version gives lower bids because the respondent is deprived of a yardstick, with which he could otherwise realize in what terms to answer. The respondent is probably more hesitant in taking the responsibility giving a WTP answer concerning a good, which had never occurred to him before. However Bateman *et al.* (1995) state that the opposite is possible, which is our finding too (Table 4.11), and attribute it to the uncertainty respondents experience when answering open-ended questions, which may exhibit strategic overbidding tendencies.

Table 4.11. Comparison of mean WTP from the open and DB-DC data.

	Mean WTP in €
Open data	2.67 (2.57, 2.77)*
DB-DC data ("imitated" TSCA)	2.23 (2.10, 2.35)*
DB-DC data ("true" TSCA)	2.55 (2.50, 2.57)*

*Asterisks indicate 95% confidence intervals

Assuming that consumers in the DB-DC question consult the same preferences in both bid questions, Table 4.12 shows that the interviewed sample, act as rational agents. As bid increases, answers tend to fall more often on the lower bid interval (bold and underlined numbers show where the largest observation concentration lies). The shaded areas in Table 4.12 make more obvious the point we want to stress; that respondents act rationally and adopt an averting behavior as starting bids increase, i.e. they opt for intervals 3 and 4 which stand for the lower bid intervals. More specifically, we observe that for the first three bids, more responses tend to fall in intervals 1 and 2. For the last three bids, more responses tend to fall in intervals 3 and 4.

Table 4.12. Consumers' averting behavior to bid increase.

Starting point	2.00 €	2.40 €	2.50 €	2.65 €	2.70 €	2.80 €
Interval 1	62.5	16.7	11.1	11.9	12.5	14.3
Interval 2	25.0	33.3	38.9	23.8	25.0	14.3
Interval 3	12.5	33.3	16.6	30.7	37.5	71.4
Interval 4	0	16.7	33.4	33.6	25.0	0
Total	100%	100%	100%	100%	100%	100%

Note: Interval 1 stands for yes-yes. Interval 2, for yes-no. Interval 3, for no-no. Interval 4, for no-yes.

3. CORRELATION AMONG REGRESSOR VARIABLES

Correlation analysis is performed with the purpose of detecting any possible high correlation between any pair of variables and take measures against multicollinearity. Studying correlation will also and foremost help us explain better the results received from the models in the rest of the chapter. Kendall's tau measure was used for the construction of Table 4.13, because most variables are categorical.

Table 4.13. Correlation matrix of chapter 4 models regressors.

	INFO	**ACTIONS**	**LACKW**	**AGE1**	**AGE2**	**EDU1**	**EDU2**	**EDU3**	**INCOME**	**SEX**	**CHID**
INFO	1	0.251	0.141	0.096	-0.035	-0.094	-0.254	-0.064	0.036	0.026	-0.134
ACTIONS	0.251	1	0.083	-0.121	0.122	-0.028	-0.120	-0.068	0.058	0.037	0.107
LACKW	0.141	0.083	1	0.033	-0.024	-0.003	-0.091	0.074	-0.021	0.041	-0.002
AGE1	0.096	-0.121	0.033	1	-0.859	-0.150	-0.371	0.004	-0.190	-0.008	-0.737
AGE2	-0.035	0.122	-0.024	-0.859	1	0.018	0.198	0.075	0.206	0.073	***0.621***
EDU1	-0.094	-0.028	-0.003	-0.150	0.018	1	-0.043	-0.115	-0.066	-0.125	0.141
EDU2	-0.254	-0.120	-0.091	-0.371	0.198	-0.043	1	-0.330	-0.053	-0.034	0.327
EDU3	-0.064	-0.068	0.074	0.004	0.075	-0.115	-0.330	1	0.020	0.081	0.060
INCOME	0.036	0.058	-0.021	-0.190	0.206	-0.066	-0.053	0.020	1	-0.055	0.215
SEX	0.026	0.037	0.041	-0.008	0.073	-0.125	-0.034	0.081	-0.055	1	0.008
CHID	-0.134	0.107	-0.002	-0.737	0.621	0.141	0.327	0.060	0.215	0.008	1

3.1. Correlation among "awareness variables"

As "Awareness variables" we call the variables that come from the introduction part of the questionnaire, which aimed at grasping the environmental profile of the consumer and in particular to show how "aware" he was of environmental problems. Their correlations are in the bordered part of Table 4.13. No high correlation exists among them and hence we can include all of them simultaneously in the models to follow.

3.2. Correlation among all regressor variables

We observe that high correlation exists only between CHID and AGE2 (significant at 10%). It makes sense because it is AGE2 when people usually have children. We tried tackling this in section 4.2.1 by trying an interaction variable on these two variables. There was no improvement for the model though and we dropped it.

4. WHAT DETERMINES CONSUMERS' WTU AND WTP FOR PRODUCTS IRRIGATED WITH RECYCLED WATER

This part is going to study the factors that determine consumers' WTU of products 3, 4 and 5 and WTP for product 3. Sections 4.1, 4.2 and 4.3 handle WTU. Section 4.4 handles WTP for product 3.

Although our WTP model does not have a good fit, because of the small sample size, we nevertheless attempt to use the WTP model of the DB-DC data for the estimation of a parametric mean WTP.

As regards the ordered models we use for WTU, after observing their frequency distributions, we initially thought it would be interesting to collapse adjacent WTU categories, e.g. collapse "definitely yes" with "maybe yes", and "definitely no" with "maybe no" in order to improve the asymptotic approximations used in the analysis. However, Murad *et al.* (2003) claim that collapsing categories can lead to loss of information and reduces the power of Wald test. Besides, since it was feasible to estimate an ordered regression with our data and software, it would be a pity to collapse categories and work under the binary logistic framework, something we did in chapter 3, and not exploit the analysis opportunities for a more subtle analysis the ordered regression offers.

4.1. Willingness to Use Product 3

WTU3 is a ranked variable, i.e. the answers-options provided (for respondents) in the questionnaire are inherently ordered, mutually exclusive and collectively exhaustive. This is why we have formulated an ordered logit model. Model 1 in section 4.1.3

describes what determines the willingness to consume olive oil irrigated with recycled water of quality 2.

4.1.1.The methodology

Before proceeding with the results of model 1, we briefly present the methodology behind it. The same methodology is applied for models 2 and 3. The interested reader could consult Borooah (2001) and Train (2003) for a more technical presentation of the methodology behind ordered models.

What we really sought to measure in this application was consumer's utility from recycled water, which is assumed to be a linear function of K determining variables, whose values for consumer *i*, are X_{ik}. Consumers are supposed to derive utility from indirect recycled water consumption, which is a function of their health risk, their personal budget, environmental quality and social welfare[4]. This utility can be represented with Equation 4.3

$$D_i = \beta_0 + \sum_{k=1}^{K} \beta_k X_{ik} + \varepsilon_i = \beta_0 + Z_i + \varepsilon_i = W_i + \varepsilon_i \quad (4.3)$$

where β_k is the coefficient associated with the k^{th} variable. However, we cannot measure with accuracy the exact quantity of a consumer's utility from recycled water. This is a latent variable. What we can observe in a more concrete way is consumer's attitude in front of certain edibles or other objects (such as the park) irrigated with recycled water.

Therefore, a consumer is classified as WTU_{1i} = "definitely negative in consuming product 3", WTU_{2i} = "maybe negative", WTU_{3i} = "maybe positive" or WTU_{4i} = "definitely positive". The categorization of the consumers in the sample in

[4] By social welfare we mean, in this context, the benefit society reaps from the introduction of recycled water in irrigation. See Figures 3.1 and 3.2 in chapter 3.

terms of the four levels of attitude is implicitly based on the values of the latent variable D_i in conjunction with "threshold" values[5] 0, μ_1, μ_2, such that:

$WTU_i = 1$, if $D_i \leq 0$ "consumer is definitely negative"

$WTU_i = 2$, if $0 \leq D_i \leq \mu_1$" consumer is maybe negative" (4.4)

$WTU_i = 3$, if $\mu_1 \leq D_i \leq \mu_2$ "consumer is maybe positive"

$WTU_i = 4$, if $D_i \geq \mu_2$ "consumer is definitely positive"

The probabilities of WTU_i taking values 1, 2, 3 and 4 are given[6] by:

$$\Pr(WTU_i = 1) = \Lambda(-x'\beta)$$

$$\Pr(WTU_i = 2) = \Lambda(\mu_1 - x'\beta) - \Lambda(-x'\beta)$$

$$\Pr(WTU_i = 3) = \Lambda(\mu_2 - x'\beta) - \Lambda(\mu_1 - x'\beta) \quad (4.5)$$

$$\Pr(WTU_i = 4) = 1 - \Lambda(\mu_2 - x'\beta)$$

Let N be the observations number we have in our sample. N_1 consumers are definitely negative, N_2 are maybe negative, N_3 consumers are maybe positive and N_4 are definitely positive in consuming product 3. The likelihood of observing this sample is the product of the probability of the individual observations presented in Equation 4.6.

$$L = [\Pr(WTU_i = 1)]^{N_1} \times [\Pr(WTU_i = 2)]^{N_2} \times [\Pr(WTU_i = 3)]^{N_3} \times [\Pr(WTU_i = 4)]^{N_4} \quad (4.6)$$

---

[5] For the four classifications of the dependent variable WTU_i, we should have μ_1, μ_2, and μ_3. Limdep normalizes the first cutoff point to zero and this is why it appears we get only two cutoff points for each of our models in Tables 4.18, 4.20 and 4.22 in appendix 6.5.

[6] Under a logistic distribution assumption, the cumulative distribution function of the random variable X is $\Pr(X \leq x) = \Lambda(x) = \exp(x)/[1+\exp(x)] = 1/(1+\exp(-x))$. Logit is called the transformation of the cumulative distribution which is ln (Λ(x)/1- Λ(x)).

4.1.2.The assumption of parallel slopes

A critical assumption of ordered logit (or probit) is that of parallel slopes. This assumption means that the slope coefficients of Equation 4.3 do not vary according to the attitude level being considered. Or better phrased, if there is a variable, which affects the likelihood of a person being in the ordered categories, then it is assumed that the coefficients linking the variable value to the different outcomes will be the same across all the outcomes (e.g. a given income will affect the same the likelihood of a consumer answering "maybe yes" or "definitely yes"). If this assumption is not valid, a multinomial model should be estimated instead. The multinomial model allows the slope coefficients to be different between the outcomes (attitude levels).

Borooah (2001) suggests a way of testing the parallel slopes assumption. He suggests that together with the ordered model, we should also estimate a multinomial one. If L_1 is the likelihood value from the ordered model and L_2 is the likelihood value from the multinomial one, then we can compute $2(L_2-L_1)$ and compare with χ^2 $(K(M-2))$[7]. But he also warns that this test is only suggestive, because it is not strictly a likelihood ratio test since the ordered model is not nested within the multinomial one.

We implemented the above test and its results say that, in WTU3, we should abide by an ordered model. The test gave: 2*(-321.9066+339,5175)=35.22 while the χ^2 with 26 degrees of freedom, is 38.9. Therefore, at 5% we cannot reject the null hypothesis that the slope coefficients are the same across all response categories and hence we proceed with the ordered model. For a full output of the ordered and multinomial version of Model 1, see Tables 4.18 and 4.19 respectively in appendix 6.5 of this chapter.

[7] The ordered model estimates K coefficients while the multinomial estimates K (M-1).

4.1.3. Model 1

Model 1 is represented by Equation 4.7. Numbers in parenthesis are p-values. Stars indicate significance at 5%.

$$WTU3 = \underset{(0.99)}{-0.00} + \underset{(0.00^{*})}{0.27}\,INFO + \underset{(0.10)}{0.18}\,LACKW + \underset{(0.03^{*})}{0.25}\,ACTIONS + \underset{(0.20)}{0.63}\,AGE1 + \underset{(0.12)}{0.64}\,AGE2 - \underset{(0.63)}{0.40}\,EDU1 - \underset{(0.65)}{0.19}\,EDU2 - \underset{(0.32)}{0.25}\,EDU3 - \underset{(0.04^{*})}{0.0003}\,INCOME + \underset{(0.00^{*})}{0.62}\,SEX + \underset{(0.83)}{0.06}\,CHID \quad (4.7)$$

4.1.3.1. Robustness of Model 1

Robustness (goodness of fit) of model 1, and of the others to follow, will be assessed as a combination of the following three things:

i) Pseudo R^2: For this model it is very low.

$$Pseudo - R^2 = 1 - \frac{-339.5175}{-357.9555} = 0.05$$

ii) Significance of the total model: The χ^2 value rejects (significance level 0.0001<0.05) the null hypothesis that the model did not have greater explanatory power than the "intercept only" model. Therefore, model 1 is significant as a whole.

iii) The predicted ability of the model: The model predicts 179/326=55%. The naïve model, which predicts WTU_i =2, because it has the higher probability (p>0.5), predicts 261/326=80%. Thus, the model does no better job than the naïve model. Train (2003) objects to using this statistic, because as he says "*it incorporates a notion that is opposed to the meaning of probabilities and the purpose of specifying choice probabilities*". He explains that "*in stating choice probabilities, we are saying*

that if the choice situation were repeated numerous times, each alternative would be chosen a certain proportion of the time. This is quite different from saying that the alternative with the highest probability will be chosen each time". We agree with this statement and this is one of reasons why we use a combination of statistics to examine robustness and validity of the above model.

4.1.3.2. Model 1 estimates

Significant at 5% are the following variables with a positive sign: INFO, ACTIONS, and SEX. According to this, ceteris paribus, the more a consumer is informed on environmental things, the more likely he is to answer "definitely yes" to consuming product 3 and less likely to answer "definitely no". Furthermore, ceteris paribus, male consumers or those who do more actions to save the environment, are more likely to fall in the category of "definitely yes" and the less likely to fall under "definitely no". INCOME is significant with a negative sign, which means that poor consumers are more likely to consume olive oil irrigated with recycled water of quality 2.

In addition to the above variables, significant at 10% (with a positive sign) is LACKW. This means that the higher the significance of the water lack problem attributed by respondents the more likely they were to say "definitely yes" rather than "definitely no". The signs of all the significant variables make sense and they were the expected ones.

Observing the marginal effects[8] (in Table 4.18 of appendix) for the significant variables, we get no more information than already had. We observe that marginal effects do not change sign in the first three categories of the dependent variable, i.e. "definitely no", "maybe no" and "maybe yes". Sign changes at the forth category, i.e. "definitely yes". Also, the size[9] of the absolute coefficient is decreasing in the first three categories showing that a very small change in the variable has a larger effect on the WTU when consumers are "definitely negative" rather than "maybe negative" or "maybe positive". Income has a zero marginal effect (0.001 under WTU3), revealing that WTU recycled water has little to do with the income situation of the consumer, although a significant variable.

As far as the ACTIONS variable is concerned, this is a count variable and its marginal effect tells how a person's probability of saying "definitely yes" compared to "definitely no" would change, if the consumer did one more action.

4.1.4. The cutoff points in Model 1

The model we practically described in section 4.1.1 and estimated in 4.1.3 is:

$$\log\left(\frac{\Lambda(\chi)}{1-\Lambda(\chi)}\right) = \mu_j - [\beta_k X_{ik}] \tag{4.8}$$

where j represents the four different outcomes of the ranked variable. The i and k are defined as previously (see Equation 4.3). As already said, the model is based on the

[8] Marginal effects in dummy variables are a comparison of the probabilities that result when the variable takes its two different values across all the consumers in the sample, with the values of the other variables held at their means. The difference between the two sets of probabilities is the effect of a consumer moving from one state of the dummy variable to the other, on the probability of being at different levels of acceptance for recycled water.

[9] The different size of coefficients among the different groups could again give rise to discussion towards the adoption of the multinomial model. However, first we do not have the standard errors of the marginal effects to decide which is significant and which is not and second the parallel lines test agrees with the route we have chosen, namely the ordered model.

notion that there is some latent continuous outcome variable (utility from recycled water), and that the ordinal outcome variable arises from discretizing this utility into ordered groups. The cutoff values that define the categories are estimated by the thresholds. The thresholds or constants in the model (corresponding to the intercept in linear regression models) depend only on which category's probability is being predicted. Values of the independent variables do not affect this part of the model (SPSS electronic manual Edn. 12).

Since Limdep normalizes the first cutoff point to zero, then the three cutoff points are 0, 0.53 and 3.13. The probabilities of belonging to each of the categories of the WTU3 variable are defined in terms of the underlying utility crossing particular thresholds, where these thresholds are established by the values of the model cutoff points. The cutoff points divide the utility in four unequal parts. The underlying utility consists of an observed and an unobserved part, as $U = \beta' x + \varepsilon$. The unobserved part ε, is considered random while U is distributed around $\beta' x$. Once we specify the distribution of ε, the probabilities in Equation 4.9 can be calculated exactly (Train, 2003). In our case we have assumed the distribution of ε to be the logistic, so the cumulative distribution is

$$F(\varepsilon) = \frac{\exp(e)}{1 + \exp(e)}$$

Figure 4.2 gives the following information:

$$\Pr(\beta x + u < 0) = \frac{e^{0-\beta'\bar{x}}}{1+e^{0-\beta'\bar{x}}} = 0.073$$

$$\Pr(0 < \beta x + u < 0.98) = \frac{e^{0.98-\beta'\bar{x}}}{1+e^{0.98-\beta'\bar{x}}} - \frac{e^{0-\beta'\bar{x}}}{1+e^{0-\beta'\bar{x}}} = 0.099 \quad (4.9)$$

$$\Pr(0.98 < \beta x + u < 2.80) = \frac{e^{2.80-\beta'\bar{x}}}{1+e^{2.80-\beta'\bar{x}}} - \frac{e^{0.98-\beta'\bar{x}}}{1+e^{0.98-\beta'\bar{x}}} = 0.388$$

$$\Pr(\beta x + u > 2.80) = 1 - \frac{e^{2.80-\beta'\bar{x}}}{1+e^{2.80-\beta'\bar{x}}} = 0.440$$

The estimated probabilities enter the log-likelihood function and the maximization of the latter provides estimation of the parameters.

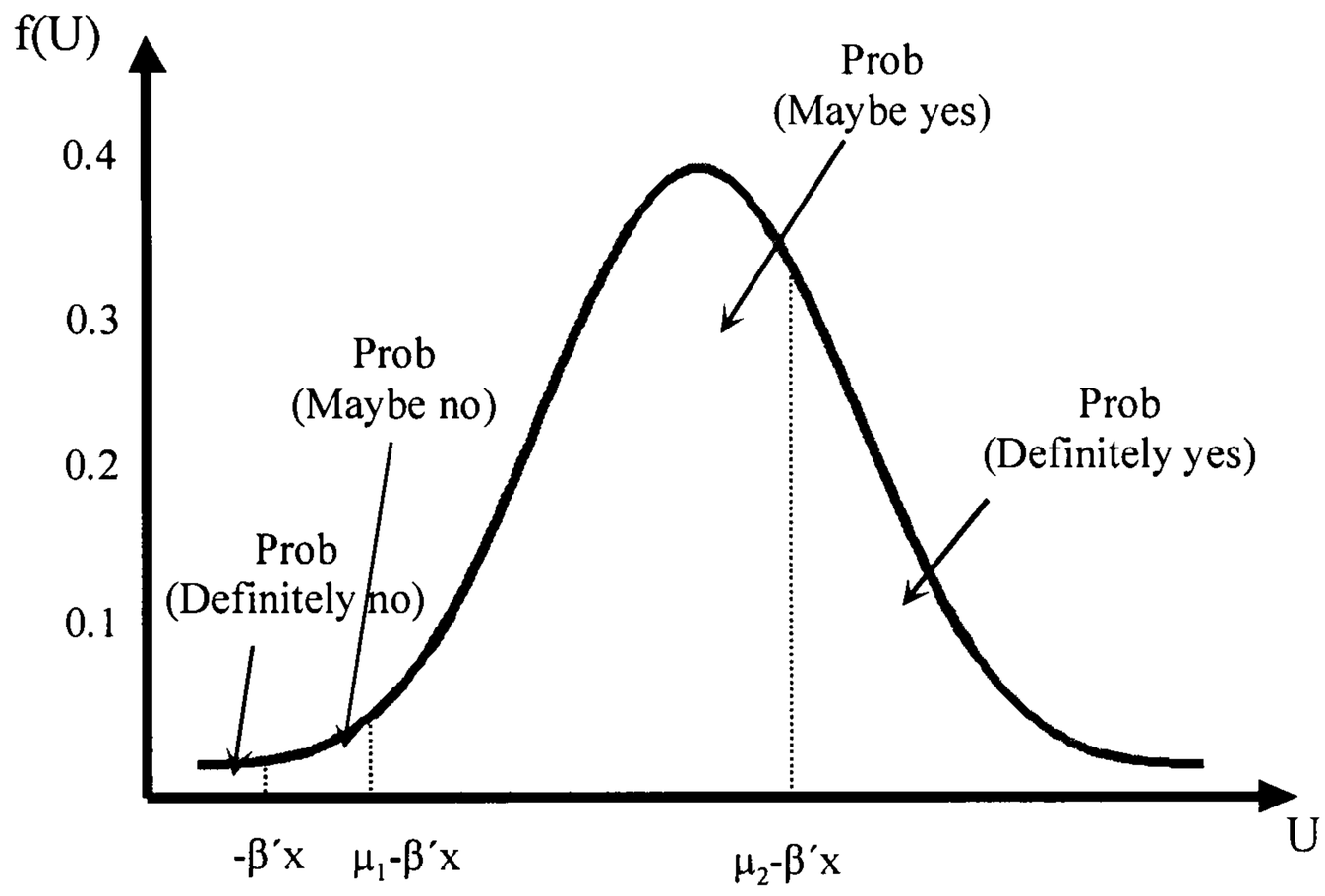


Figure 4.2. Cutoff points in model 1

4.2. Willingness to Consume Product 4

Following the same methodology as the one applied for product 3 (in section 4.1.1) we get the following results for product 4, i.e. willingness to use the tomato irrigated with recycled water of quality 3.

4.2.1. Model 2

Model 2 is represented by Equation 4.10. Numbers in parenthesis are p-values. Stars indicate significance at 5%.

$$WTU4 = \underset{(0.09)}{-1.31} + \underset{(0.04^{*})}{0.16}INFO + \underset{(0.02^{*})}{0.24}LACKW + \underset{(0.00^{*})}{0.31}ACTIONS + \underset{(0.00^{*})}{1.58}AGE1 + \underset{(0.05)}{0.87}AGE2 + \underset{(0.27)}{0.78}EDU1 - \underset{(0.39)}{0.31}EDU2 - \underset{(0.13)}{0.34}EDU3 - \underset{(0.13)}{0.0002}INCOME - \underset{(0.70)}{0.08}SEX + \underset{(0.09)}{0.52}CHID \quad (4.10)$$

4.2.1.1. Robustness of Model 2

Robustness is examined in the same fashion as in Model 1.

i) Pseudo-R^2: It is very low.

$$Pseudo - R^2 = 1 - \frac{-399.12}{-419.52} = 0.05$$

ii) Significance of the total model: The χ^2 value rejects the null hypothesis that the model did not have greater explanatory power than the "intercept only" model. Therefore, the model as a whole is significant.

iii) The predicted ability of the model (Table 4.20 in appendix 6.5): The model does no better job than the naïve model which predicts that WTU4=2. They have the same predictive ability.

4.2.1.2. Model 2 estimates

Significant at 5% (with positive signs) are INFO, LACKW, ACTIONS, AGE1 and AGE2. This translates into the following: Consumers who are more informed or consider water lack as a more serious problem or are involved in more environmental actions, or belong to ages from 18-54 are more likely to answer "definitely yes" and

less likely to answer "definitely no" to the consumption of product 4, compared to those consumers who are not informed or do not consider water lack as a serious problem or are not involved into environmental friendly actions, or do not belong to ages from 18 to 54.

CHID is significant at 10%. Worthy of interest is the fact that young people and those who have children appear more likely to consume product 4 which is supposed to be the most dangerous of the three we are studying.

The former could be attributed to the fact that young people understand new ideas better and are open to them. No interaction effect was confirmed between ages and education. Kendall's tau between AGE1 and EDU3 was small and insignificant (Table 4.13). The same was found for AGE2 and EDU3. Thus we cannot claim that the younger generation is more educated than the older and this is the reason they are open to these new products.

As far as the latter is concerned, it is surprising that consumers with children are more likely to be definitely WTU4. We would expect them to be afraid of it. This, combined with finding a significant correlation between AGE2 and CHID led us to try Model 2 with an interaction term between AGE2 and CHID. This was not significant itself, and had a negative sign, but it improved the significance of AGE1 and AGE2. Nevertheless, we kept the model without the interaction term.

4.2.2.The cutoff points in Model 2

The three cutoff points are: 0, 0.99 and 2.95. They are interpreted in an analogous fashion to that in Model 1.

4.2.3. Ordered vs Multinomial Model

Trying the same test we did for Model 1, we get 2(-390.77+399.12)=16.7. It is obvious that we should abide by the ordered model. See likelihood values in Tables 4.20 and 4.21 of appendix 6.5.

4.3. Willingness to Use Product 5

Following the same methodology as in section 4.1.1, we get the following results for product 5, i.e. willingness to visit a park irrigated with recycled water of quality 1. For a full outcome of the model see also Table 4.22 in appendix 6.5.

4.3.1. Model 3

Model 3 is given by Equation 4.11. Numbers in parenthesis are p-values. Stars indicate significance at 5%.

$$\begin{aligned} WTU5 = {} & \underset{(0.00^{*})}{2.67} + \underset{(0.74)}{0.03}INFO + \underset{(0.69)}{0.05}LACKW + \underset{(0.10)}{0.20}ACTIONS + \underset{(0.40)}{0.45}AGE1 \\ & + \underset{(0.13)}{0.70}AGE2 - \underset{(0.81)}{0.18}EDU1 + \underset{(0.69)}{0.15}EDU2 + \underset{(0.60)}{0.13}EDU3 \\ & + \underset{(0.34)}{0.0001}INCOME - \underset{(0.80)}{0.05}SEX - \underset{(0.03^{*})}{0.70}CHID \end{aligned} \tag{4.11}$$

4.3.1.1. Robustness of Model 3

i) Pseudo R^2: For this model it is very low.

$$Pseudo - R^2 = 1 - \frac{-310.194}{-318.738} = 0.03$$

ii) Significance of the total model: The zero hypothesis that all coefficients are zero cannot be rejected at 5%, so our model as a whole is not significant.

iii) The predicted ability of the model: The model predicts better (5 more observations) that the naïve model. It predicts 13+180=193, 193/331=58.3% while the naïve model, which predicts WTU5=3, is 91.54%.

4.3.1.2. Model 3 estimates

Only the CHID variable is significant at 5% with a negative sign. This means that consumers who were parents were less likely to answer "definitely yes" and more likely to answer "definitely no" to visiting a park irrigated with recycled water of quality 1. We expected that especially parents would be more apprehensive as regards recycled water. However, product 5 is the most innocent of the three. In spite of the fact that consumers were informed that the grass and flowers in the park would be irrigated during the night (i.e. there is no risk of themselves or their children being sprinkled with this water) parents remained skeptical. Reasons as to why this might be happening are given in section 5.1.

4.3.2.The cutoff points in Model 3

Cutoff points are 0, 1.48 and 3.48. Interpretation is analogous to model 1, in section 4.1.4.

4.3.3. Ordered vs Multinomial Model

According to the test of parallel lines, we get: 2(-298.68+310.19)=23.02. Therefore, we should abide by the ordered model. See likelihoods in Tables 4.22 and 4.23 in appendix 6.5.

4.3.4. Comparison of cutoff points and choice probabilities among the three models

In Figure 4.3, we schematically represent the difference in the utility cutoff points of the three models represented by Equations 4.7, 4.10 and 4.11.

Consumers are supposed to derive utility from indirect recycled water consumption, which is a function of their health risk, of their personal budget, environmental quality and social welfare (as defined in subsection 4.1.1). This utility ranges from 0 to infinity. It is important to note that in choice models such as the ones described in the three models of Figure 4.3, only differences in utility matter and not the absolute utility. The scale of utility is arbitrary and it can be quantified with the σ of the error of the representative utility (Train, 2003).

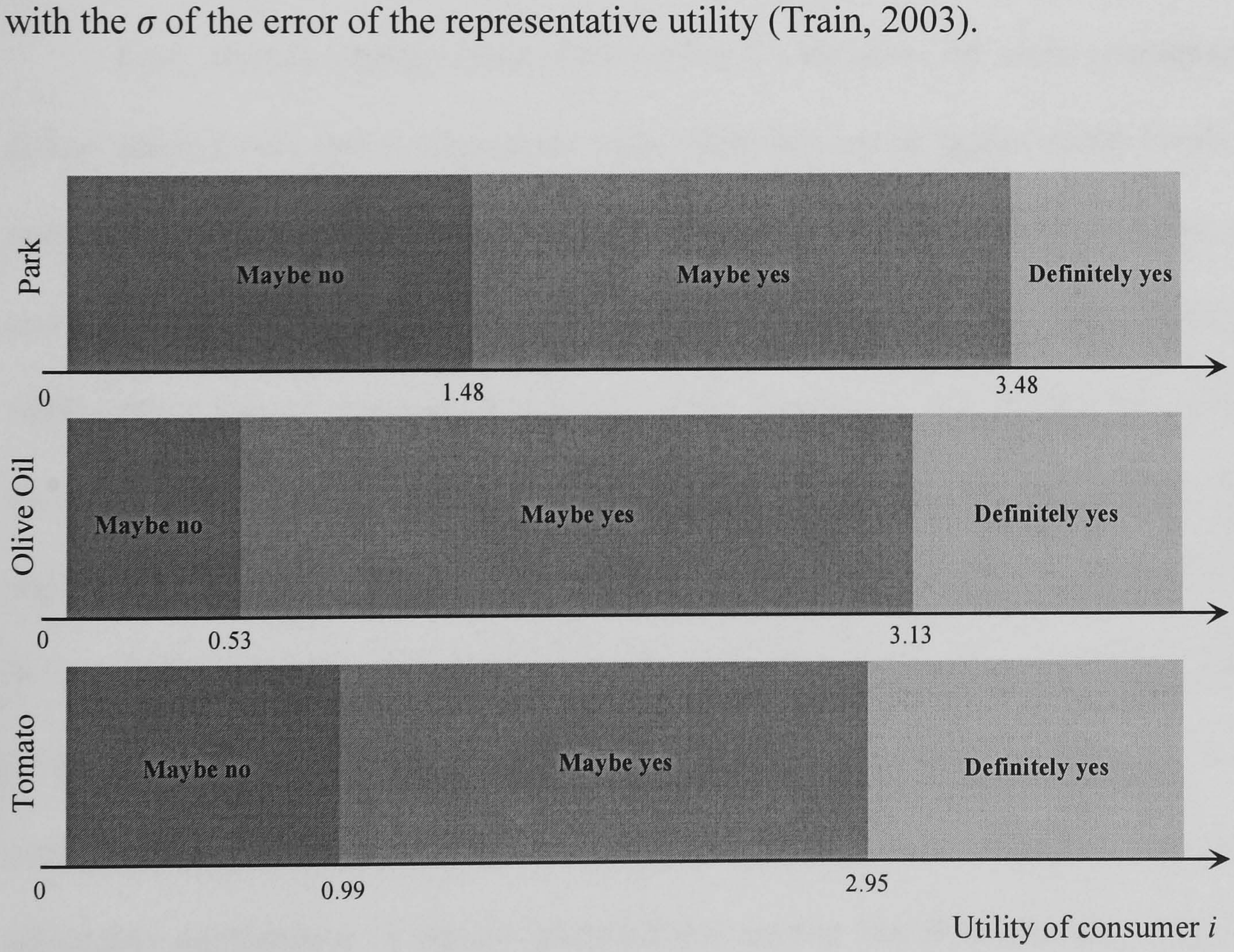


Figure 4.3. Cutoff points schematic comparison of models 3, 4 and 5.

As we see from the cutoff points of the three WTU Models (Models 1, 2 and 3), the utility level which makes consumers pass from "maybe no" to "maybe yes" is much lower in product 3 than in product 4 and 5. Also, the utility level which makes consumers pass from "maybe yes" to "definitely yes" occurs at a lower level for product 4, then for product 3 and last for product 5. This makes more concrete the role information can play. It will help people realize their utility from recycled water and make them pass to "definitely yes" at lower levels of utility.

Furthermore, recycled water attitude change takes place at lower utility levels when we speak of edibles rather than the park. Recycled water edibles are more useful to consumers than the park or they derive more utility from recycled water when it is used for the irrigation of the edibles compared to when it is used for landscape irrigation.

Last, attitude change takes place earlier for the olive oil when consumers are at low utility levels and it takes place later when they are at higher utility levels. The opposite holds for tomato. At higher levels of utility, consumers trust recycled water more and are willing to use it in more sensitive products. A high level of recycled water utility means that consumers have been convinced that health risk is small, financial benefit is high, social benefits are high (society does not throw recycled water away anymore). More detailed information to consumers will increase their WTU edibles irrigated with recycled water. As we see from WTU product 4, there is a lot of room for the role information can play and lead us to hope for the consumption of even more sensitive products than the tomato. Figure 4.4 provides a schematic comparison of choice probabilities among the three models. They have been calculated based on Equation 4.9.

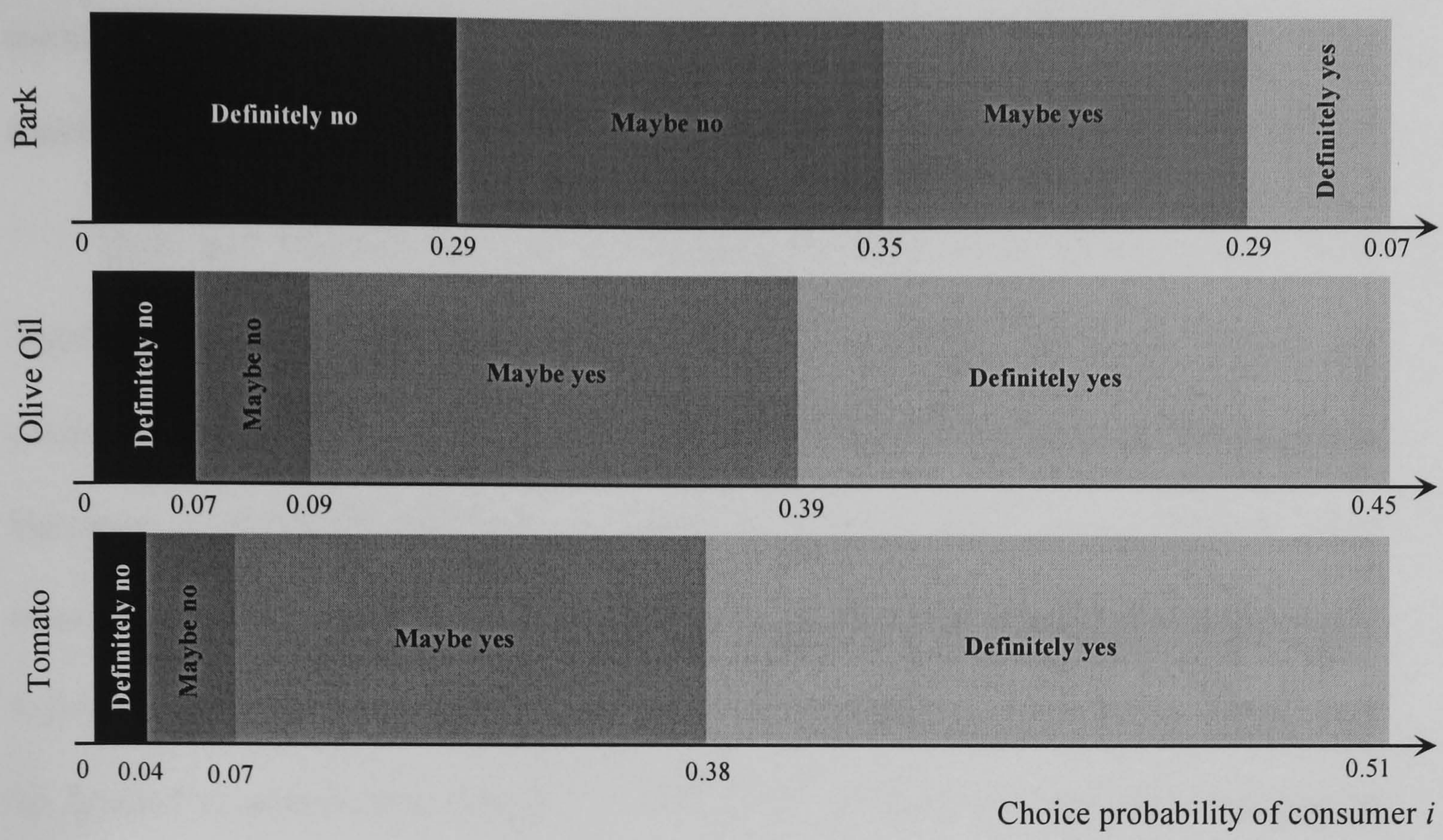


Figure 4.4. Choice probabilities schematic comparison of models 3, 4, and 5.

4.4. Willingness to Pay for Product 3

This part is going to investigate the socioeconomic factors that determine the WTP outcome for product 3, i.e. we are going to fill the second step of empirical analysis in contingent valuation: the parameter estimation in WTP. Furthermore we will implement a parametric estimation of mean WTP. The reason the thesis writer did this in the first place was because she had estimated mean WTP with the "imitated TSCA", which she feared would not be absolutely reliable. Therefore, the parametric mean WTP was estimated as a compensation for the improvised TSCA. Of course, now we have both the "true" and the "imitated" TSCA.

4.4.1.The log normal distribution assumption

The assumption of a distribution for the WTP is a crucial step in parametric contingent valuation data analysis. The WTP distribution assumption can change the

mean WTP result completely and thus not producing correct results useful for policy making.

Haab and MacConnell (2003) eloquently describe the consequences of WTP distributional misspecification; *The problems with the tails of the distributions are analogous to the problems of out-of-sample prediction in a regression model*, while Bateman *et al* (2002) state that *the choice of a distribution for the WTP is a key consideration in the analysis of contingent valuation data* and should depend on the following two factors: i) whether the distribution accounts for the limits that should be applied to permissible values of WTP (it is commonplace that WTP should be nonnegative and truncated from above with consumer's income), ii) how well the distribution fits the data.

As far as the first consideration is concerned, our sample has showed that there were not any negative bids and WTP could by no means reach or surpass total consumer's income. Since the object of our analysis is WTP on a kilogram of olive oil (and not let's say Amazon forests), we cannot expect a consumer to be WTP a bid as big as his income on this.

As far as the second consideration is concerned, we decided to employ a log-normal distribution, because it is a naturally non-negative one, described by the following mathematical equation:

$$f\left(z;\mu,\sigma^2\right)=\frac{1}{\sqrt{2\pi}}e^{-\frac{1}{2}\left(\frac{\ln z-\mu}{\sigma}\right)^2\left(\frac{1}{z\sigma}\right)} \tag{4.12}$$

Had we used the normal distribution, we would have allowed for negative values of WTP (even if our sample does not contain any) and consequently we would have

placed a large mass in the negative WTP region. The argument that we do not have negative bids is strengthened by the fact that we do not have many "*no*" answers in the low bids (interval 4) of Table 4.12.

4.4.2. Model 4 (open-question data)

Model 4 is given by Equation 4.13. Numbers in parenthesis are p-values. Stars indicate significance at 5%. We have taken the log of WTP as the dependent variable, because to be able to work under the assumptions of the log-normal distribution.

$$\begin{aligned} LOGWTP3O = & \underset{(0.00^{*})}{0.36} + \underset{(0.41)}{0.008}ACTIONS - \underset{(0.09^{*})}{0.01}INFO - \underset{(0.07)}{0.02}LACKW + \underset{(0.88)}{0.007}AGE1 \\ & - \underset{(0.37)}{0.045}AGE2 - \underset{(0.14)}{0.064}EDU2 - \underset{(0.90)}{0.002}EDU3 + \underset{(0.02)^{*}}{0.072}LOGINCOME \\ & - \underset{(0.43)}{0.02}CHID + \underset{(0.80)}{0.004}SEX \end{aligned} \quad (4.13)$$

4.4.2.1.Robustness of Model 4

i) Adjusted-R^2=0.10. This is very low.

ii) Significance of the total model: The model is significant at 5% (according to the F-statistic in Table 4.14 below.

4.4.2.2.Model 4 estimates

The full output of model 4 is given in Table 4.14. INFO is significant with a negative sign, meaning that the more informed a consumer is, the smaller amount he is WTP for product 3. This could make sense in that informed consumers realize that product 4 is safe and thus they are WTU it but since it is irrigated with a lower quality of water, it ends up being a product of lower production cost and should be paid for

less. The negative sign could also be due to the fact that more informed consumers act strategically and bid for "less".

LOGINCOME has a positive sign and is also significant. The log transformation gives the elasticity of WTP to INCOME. According to this, if logINCOME increases by 1 cent, WTP will increase by 0.072cents.

Table 4.14. Model 4 (WTP open-ended data)

Variable	Coefficient	Std. Error	t-Statistic	Prob.
Constant	0.366203	0.124391	2.943965	0.0039
LOGINCOME	0.072626	0.031280	2.321822	0.0220
INFO	-0.014474	0.008618	-1.679455	0.0958
LACKW	-0.023155	0.012735	-1.818204	0.0717
ACTIONS	0.008537	0.010500	0.813066	0.4179
AGE1	0.007788	0.055836	0.139480	0.8893
AGE2	-0.045982	0.051290	-0.896520	0.3719
EDU3	-0.002711	0.022943	-0.118144	0.9062
EDU2	-0.064909	0.044514	-1.458165	0.1475
CHID	-0.024470	0.030958	-0.790442	0.4309
SEX	0.004917	0.020111	0.244491	0.8073
R-squared	0.176587	F-statistic		2.444817
Adjusted R-squared	0.104358	Prob(F-statistic)		0.011091

4.4.3. Model 5 (DB-DC data)

It is important to start this section with a short summary of discrete choice model basics, which are necessary for understanding the estimated models in Tables 4.16 and 4.17.

4.4.3.1. A few words about discrete choice models

Discrete choice models appear as the usual regression models with a special caveat, i.e. the dependent variable is not observed, or better is observed under circumstances. For example let

$$Y_i^* = X_i'\beta + \varepsilon_i \tag{4.14}$$

X being a vector of the explanatory variables. Suppose the dependent variable is observed under the following rule:

$$Y_i^* = \begin{matrix} 1 & if & Y_i^* > 0 & or & X_i\beta + \varepsilon_i > 0 \\ 0 & if & Y_i^* \le 0 & or & X_i\beta + \varepsilon_i \le 0 \end{matrix} \tag{4.15}$$

Mean Y_i^* is given by:

$$\begin{aligned} &E(Y_i) = 1 * P(Y_i = 1) + 0 * P(Y_i = 0) = P[X_i\beta + \varepsilon_i > 0] \\ &= P[\varepsilon_i > -X_i\beta] = P\left(\frac{\varepsilon_i}{\sigma} > \frac{-X_i\beta}{\sigma}\right) \end{aligned} \tag{4.16}$$

This is estimated with maximum likelihood method after we make an assumption about the distribution of ε_i. However the error variance cannot be estimated and for convenience it is assumed to be 1. In the WTP framework we work here, we observe Y_i^* (which is the WTP) if people say yes to a certain bid, t_i. The presence of t_i allows σ to be identified, as

$$P\left[\frac{\varepsilon_i}{\sigma} > \frac{t_i - X_i'\beta}{\sigma}\right] \tag{4.17}$$

The coefficient of t is $1/\sigma$ (Cameron, 1991). Based on this, we show below in section 4.4.3.3, how the estimation output is explained.

4.4.3.2. The DB-DC methodology

The model we are seeking to estimate is of the form

$$\log WTP_i = Y_i^* = X_i\beta + \varepsilon_i \quad (4.18)$$

with *i* being the consumer index. This relationship does not work under the usual simple regression framework, because Y_i^* is not observed. What we observe is whether consumers say yes or no to a certain bid. We assume that respondents consult the same preferences for both bid questions. Responses to the two bid questions can be expressed as follows:

$$\underline{\text{Response for bid 1}}: Y_{1i} = 1 \text{ if } \log WTP_i = Y_i^* > t_{1i}$$
$$Y_{1i} = 0 \text{ if } \log WTP_i = Y_i^* \leq t_{1i} \quad (4.19)$$

$$\underline{\text{Response for bid 2:}}\ Y_{2i} = 1 \text{ if } \log WTP_i = Y_i^* > t_{2i}$$
$$Y_{2\,i} = 0 \text{ if } \log WTP_i = Y_i^* \leq t_{2i}$$

t_{1i} and t_{2i} stand for the two bids. Train (2003) writes that the estimation procedure in the DB-DC method is closely related to that just described for the ordered logit except that the cutoff points are given by the questionnaire.

In the models in Tables 4.16 and 4.17, we have taken logs of the bids for the same reason we have taken the log of WTP in model 4. The four bid options consumers are confronted with are contained in Table 4.25 and Equations 4.20 to 4.23.

Table 4.15. Four bid options

1	Yes	-	Yes	$y_{1i}=1$	$y_{2i}=1$
2	Yes	-	No	$y_{1i}=1$	$y_{2i}=0$
3	No	-	Yes	$y_{1i}=0$	$y_{2i}=1$
4	No	-	No	$y_{1i}=0$	$y_{2i}=0$

1st option

$$P[Y_{i1}=1,Y_{i2}=1]=P[Y_i^*>t_{i1},Y_i^*>t_{i2}]=P\left[\varepsilon_i>\frac{t_{i1}-x_i'\beta}{\sigma},\varepsilon_t>\frac{t_{i2}-x_i'\beta}{\sigma}\right]$$
$$=P\left[\varepsilon_t>\frac{t_{i2}-x_i'\beta}{\sigma}\right] \quad (4.20)$$

2nd option

$$P[Y_{i1}=1,Y_{i2}=0]=P[Y_i^*>t_{i1},Y_i^*\le t_{i2}]=P\left[\frac{t_{i2}-x_i'\beta}{\sigma}<\varepsilon_i\le\frac{t_{i1}-x_i'\beta}{\sigma}\right] \quad (4.21)$$

3rd option

$$P[Y_{i1}=0,Y_{i2}=1]=P[Y_i^*\le t_{i1},Y_i^*>t_{i2}]=P\left[\frac{t_{i2}-x_i'\beta}{\sigma}<\varepsilon_i\le\frac{t_{i1}-x_i'\beta}{\sigma}\right] \quad (4.22)$$

4th option

$$P[Y_{i1}=0,Y_{i2}=0]=P\left[\varepsilon_i\le\frac{t_{i2}-x_i'\beta}{\sigma}\right] \quad (4.23)$$

The likelihood function we will maximize is the product of the four probabilities:

$$L=\prod_{(yes,yes)}P(y_{1i}=1,y_{2i}=1)\times\prod_{(yes,no)}P(y_{1i}=1,y_{2i}=0)\times\prod_{(no,yes)}P(y_{1i}=0,y_{2i}=1)$$
$$\times\prod_{(no,no)}P(y_{1i}=0,y_{2i}=0) \quad (4.24)$$

4.4.3.3. Explanation of EViews DB-DC estimation output

As is seen from the EViews code appendix 6.4, the starting values were taken from a simple probit model. The latter contains the log of bid as a 13th variable. The variable with the name scale2(1) estimates the inverse of the bid coefficient, which as it was explained in section 4.4.3.1 is the so called scale coefficient (with which we scale the variance of the unobserved utility component, i.e the variance of the error). Afterwards we ask for the estimation of twelve more variables from b2(1) to b2(12) (see code). We would like the output to give the results that would read as follows:

$\hat{\gamma}_1$ Coefficient of bid

$\hat{\gamma}_2$ Coefficient of x_1 (4.25)

$\hat{\gamma}_3$ Coefficient of x_2

$\hat{\gamma}_4$ Coefficient of x_3 etc

Because $\hat{\sigma} = -\frac{1}{\hat{\gamma}_1}$, then (4.26)

$\hat{\beta}_1 = \hat{\gamma}_2 * \hat{\sigma}$

$\hat{\beta}_2 = \hat{\gamma}_3 * \hat{\sigma}$ (4.27)

$\hat{\beta}_3 = \hat{\gamma}_4 * \hat{\sigma}$ etc

Therefore, all variable coefficients contain a denominator, which is the bid coefficient. For a more technical account on this, see Cameron (1991), page 417.

Table 4.16. Model 5 (WTP DB-DC data).

	Coefficient	Std. Error	z-Statistic	Prob.
B2(1)	2.241327	0.392483	5.710628	0.0000
B2(2)= INFO	-0.020615	0.028581	-0.721303	0.4707
B2(3)= LACKW	0.042560	0.041524	1.024960	0.3054
B2(4)= ACTIONS	0.015404	0.035405	0.435070	0.6635
B2(5)= AGE1	0.040227	0.203413	0.197759	0.8432
B2(6)= AGE2	0.105399	0.194864	0.540887	0.5886
B2(7)= CHID	-0.004371	0.083804	-0.052156	0.9584
B2(8)= EDU1	0.068528	0.460471	0.148822	0.8817
B2(9)= EDU2	-0.022510	0.122058	-0.184416	0.8537
B2(10)= EDU3	-0.046609	0.060323	-0.772666	0.4397
B2(11)= LOGINCOME	0.039741	0.082025	0.484492	0.6280
B2(12)= GENDER	-0.059420	0.054315	-1.093985	0.2740
SCALE2(1)= SCALE COEFFICIENT	0.274306	0.025720	10.66499	0.0000
Log likelihood	-192.6843	Avg. log likelihood		-1.338085

Note: The code for this model is on appendix 6.4. Starting values were taken from a simple probit model. Also we have taken logs of the bids in order to be able to work under the log normal distribution assumption framework.

4.4.3.4. Model 5 estimates

With maximum likelihood estimation, we choose the parameters so as to maximize probability that the observed sample of data is generated by our DB-DC model described in Equation 4.24.

At 5% only the bid is significant with a negative sign. It is obvious that the results of this model are poor. We believe this has to do with the fact that data were too few for running this type of model. Because the model is poor, it should not be relied for the estimation of mean WTP. Nevertheless, we calculate it in the following section.

To improve the significance of Model 5, we have re-estimated it, after dropping EDU1, EDU2, AGE1 and CHID. We have confirmed this with a Likelihood Ratio test,

$$LR = -2\left(LR_{restricted} - LR_{unrestricted}\right) \tag{4.28}$$

Because $LR < \chi^2_{(5,0.05)}$ at 5% significance level, we could drop the above non-significant variables and we are left with the specification given in Model 6 (Table 4.17).

Table 4.17. Model 6 (WTP DB-DC data)

	Coefficient	Std. Error	z-Statistic	Prob.
Constant	0.362545	0.055469	6.536004	0.0000
INFO	-0.003575	0.004385	-0.815237	0.4149
LACKW	0.007216	0.007017	1.028298	0.3038
ACTIONS	0.002704	0.005489	0.492719	0.6222
EDU3	-0.007380	0.008938	-0.825687	0.4090
AGE2	0.011320	0.009744	1.161830	0.2453
LOGINCOME	0.005480	0.013873	0.395007	0.6928
GENDER	-0.010304	0.009058	-1.137534	0.2553
σ	0.046820	0.004271	10.96123	0.0000
Log likelihood	-194.1852	Avg. log likelihood		-1.348508

2.2.2.2. Parametric estimation of mean WTP (DB-DC question) and confidence intervals

To remedy the situation of the improvised TSCA in section 2.2.2, we have additionally calculated the parametric mean WTP with the following formula in Equation 4.30, set up by Cameron (1988) and Cameron (1991), also presented in Bateman *et al.* (2003). Mean WTP is a function of the means of the explanatory variables we have chosen, the estimated coefficients of the variables and the error variance:

$$WTP_{mean} = f\left(\bar{x}, \hat{\beta}, \hat{\sigma}\right) \tag{4.29}$$

The formula according to which the mean WTP is:

$$WTP_{mean} = \exp\left(-\bar{x}\beta + \frac{\sigma^2}{2}\right) \tag{4.30}$$

The knowledge of the WTP variance, which is necessary for the estimation of intervals, is estimated based on Delta method (Cameron, 1991) as described by Equations 4.31 to 4.34. For space convenience we are illustrating this in an example of four parameters.

$$\mathrm{var}(WTP) = \left(\frac{\partial f}{\partial parameters}_{(1\times 4)} \right) * \mathrm{var}\left(parameters_{(4\times 4)} \right) * \left(\frac{\partial f}{\partial parameters}_{(4\times 1)} \right) \tag{4.31}$$

The 4*4 matrix is:
$$\begin{bmatrix} \mathrm{var}(a) & \mathrm{cov}(a,\beta_1) & \mathrm{cov}(a,\beta_2) & \mathrm{cov}(a,\sigma) \\ \mathrm{cov}(a,\beta_1) & \mathrm{var}(\beta_1) & \mathrm{cov}(\beta_1,\beta_2) & \mathrm{cov}(\beta_1,\sigma) \\ \mathrm{cov}(a,\beta_2) & \mathrm{cov}(\beta_1,\beta_2) & \mathrm{var}(\beta_2) & \mathrm{cov}(\beta_2,\sigma) \\ \mathrm{cov}(a,\sigma) & \mathrm{cov}(\beta_1,\sigma) & \mathrm{cov}(\beta_2,\sigma) & \mathrm{var}(\sigma) \end{bmatrix} \tag{4.32}$$

The 4*1 matrix is:
$$\begin{bmatrix} \partial f/\partial a \\ \partial f/\partial \beta_1 \\ \partial f/\partial \beta_2 \\ \partial f/\partial \sigma \end{bmatrix} = \begin{bmatrix} \exp\left(a + \beta_1 \bar{x}_1 + \beta_2 \bar{x}_2 + \frac{\sigma^2}{2} \right) \\ \exp\left(a + \beta_1 \bar{x}_1 + \beta_2 \bar{x}_2 + \frac{\sigma^2}{2} \right) * \bar{x}_1 \\ \exp\left(a + \beta_1 \bar{x}_1 + \beta_2 \bar{x}_2 + \frac{\sigma^2}{2} \right) * \bar{x}_2 \\ \exp\left(a + \beta_1 \bar{x}_1 + \beta_2 \bar{x}_2 + \frac{\sigma^2}{2} \right) * \sigma \end{bmatrix} \tag{4.33}$$

The 1*4 matrix is the transpose of 4*1. The intervals are estimated as follows:

$$meanWTP \pm 1.96\sqrt{\mathrm{var}(WTP)} \tag{4.34}$$

Conclusively, the parametric mean WTP is estimated to be 1.49 € with a 95% confidence interval of (1.48- 1.51).

5. CONCLUSIONS

The conclusions derived in this chapter stem from both the WTU and WTP model results. They can be used for designing policies on the pricing of olive oil irrigated with recycled water of quality 2 and the marketing approaches that must be used for products 3,4 and 5 in order to be launched in market. Sections 5.1 and 5.3 attempt to do the latter, while sections 5.2 and 5.4 do the former.

5.1. Willingness to Consume/Use

The underlying variable we are studying is the utility derived from three types of recycled water. This utility is manifested through the preferences of consumers for certain products irrigated with recycled water.

We used three products as a means to this end. We formulated three ordered logit models, one for each of products 3, 4 and 5. Significant variables in the models led us to discover what are the factors that affect the probability of a consumer answering "definitely yes" to "definitely no" as far as the consumption of these products is concerned.

Two of the awareness variables, INFO and ACTIONS were significant for both products 3 and 4, while the third awareness variable, namely LACKW was significant only in product 4. The significance of awareness variables means that consumers who appear to have a stronger environmental profile (they consider themselves as being more informed about environmental matters, they do more actions to save the environment and they rank water shortage higher in its significance as an environmental problem) are more likely to have shaped a positive

concrete opinion (i.e. being in the category of "definitely yes") on whether to consume edibles irrigated with recycled water.

The fact that LACKW is significant in product 4 and not in product 3, reveals that people who declare themselves as WTU product 4, are more environmentally conscious and more sensitive on water shortage than those who will consume product 3. And indeed those who recognize water shortage as a serious problem are ready to do more about this. They are WTU more controversial products such as the tomato.

Age explained only WTU4. Younger ages seem more determined in consuming product 4.

Education did not play any role in determining consumers' WTU of any of the products. Also, no significant correlation patterns were confirmed among awareness and education variables. The latter is because, after all, a highly educated person does not necessarily have environmental knowledge. Or, seen differently, an educated person is expected to be able to be aware of the situations he does not have knowledge of, while an uneducated person may think that he knows but in reality he does not know.

Income was significant in WTU3 with a negative sign meaning that poor people were WTU product 3. Olive oil is a product used daily in large quantities, in Greek cuisine. Poorer people's budget would be relieved by a cheaper olive oil. It is probably the same people who vote for a lower price of olive oil in the WTP question. Furthermore, we did not find out the well expected pattern of richer people, who are also the more educated and the most informed, that have the most well-defined ideas as to whether they want to consume these products. No correlation was confirmed between income and education.

Gender explained only WTU3. According to this, male consumers seemed more determined to consume product 3. But if we see this the traditional way, namely that men are braver or riskier than women, then male consumers should make a difference as far as the consumption of product 4 is concerned and not of product 3, because product 4 is supposed to be more "dangerous" than product 3.We believe the resulted pattern has probably to do with the order questions have been asked. Women were more hesitant and conservative in expressing their real opinion in product 3, because the question with product 3 came first in order. As soon as they familiarized themselves with the context of the research, gender made no difference in shaping WTU4.

Parenthood has appeared to determine only WTU5. Although children are the potential consumers of olive oil or tomatoes irrigated with different types of recycled water, parents seem to be hesitant only in the case of product 5. This can lead to reflection on whether parents have been honest in answering about products 3 and 4. A reason for the observed result might be the warning of the kind "it will be irrigated at night time" which was put in the wording of the corresponding question and probably made parents extra careful and skeptical. So, citizens with no children are more probable to be definitely determined to visit a park irrigated with recycled water of quality 2, because only children can come in touch with the ground and grass in the park. Consequently if there is any risk of infection at all, it is the children who are supposed to be running it.

5.2. Willingness to Pay

LOGINCOME and the BID were significant in models 8 and 9 respectively. According to the former, consumers with higher incomes will pay higher bids.

According to the latter, the higher the bid, the less probable respondents are to say yes to paying that, in Model 9. However both these models come from small samples and they have poor fits and results. This applies especially for model 5. Therefore, our initial aim to find out whether elicitation effects were present has not been fulfilled. A common conclusion from both Models 4 and 5 is that WTP is affected by money related variables.

5.3. Policy conclusions derived from WTU

Consumers need to be informed in a more detailed and repeated fashion about the capabilities and restrictions of recycled water in irrigating edibles. When people have been given the information and have understood it, then they can formulate an informed attitude towards edibles irrigated with recycled water. We believe that consumers could not get all the appropriate information in one off session as it happened in our research, because time was not enough for them to process the information and overcome their prejudice (e.g. confusion with organic food). Furthermore, we believe that with information, the number of the answer categories "maybe yes" and "maybe no" will decrease, because more people will make up their minds on whether they definitely want or do not want to consume products irrigated with recycled water.

Information dissemination can be achieved through the schooling system, media, special target information sessions, advertisement, peer imitation[10] etc. Information should reach especially older people who are away from education and the other information sources available to younger ages. Because Greek population is

[10] Get informed that consumers in other countries consume these products, e.g. in Australia.

shrinking and older ages are more numerous compared to the young, the information of older people (as represented by AGE3 variable) should be emphasized on.

Another group that should be informed is parents. They should be assured that parks would be irrigated at night. They should be answered queries of the type: If their children play in a park as the one meant in product 5, what is the risk they run? What is the risk run compared to when they are near mobile telephone antennas, consume vegetables with raw pesticides, breathe intoxicated air in big cities etc. Nevertheless, if parents themselves use the parks but forbid their children to do so, society as a whole is still benefited, because as we said previously, adults in Greece outnumber children.

Last but not least, consumers should be assured that there would be a strict supervision on farmers in their applying recycled water in agriculture. This is one of the caveats that make consumers distrustful and it is verified by the fact that some farmers in the farmers' survey said they would use recycled water for irrigation but made it clear that they would not consume these products themselves. Establishing an authority responsible for supervising the correct application of recycled water in irrigation would be necessary. However, this is not close to happening, because there is not such an authority even for the correct application for pesticides, let alone recycled water.

5.4. Policy conclusions derived from WTP

Pricing conclusions can be derived from the size of the stated WTP. From the estimated mean WTP, consumers seem ready to buy 1kg of olive oil irrigated with recycled water of quality 2 at the 74%- 89% (see Table 4.11) of the price of olive oil irrigated with fresh water. If product 3 is initially launched in market with this price,

consumers say they will buy. In case this price is not attractive to producers, government might be interested in subsidizing the gap up to a price which producers would also find profitable to produce. The difference in WTP for product 3 from the market price, could be seen as a compensation consumers demand for the risk their health runs from this product.

Since WTP for product 3 lies from 74 -86% of the fresh water irrigated product, and this product is of low risk compared to product 4, then we would expect consumers' WTP for product 4 to be much below the market price, namely consumers would demand a larger compensation for the potential health risks they would run from its consumption.

As for most products when they are launched in market for the first time, they are attached a lower price so that consumers can become acquainted with them, so must happen for olive oil irrigated with recycled water of quality 2. As soon as consumer trust is developed, government could try putting a tax on edibles irrigated with fresh water and thus render them more expensive. Consumers would then take their customs to edibles irrigated with recycled water.

Mean WTP is lower in the DB-DC form, rather than the open-ended. This could mean that people cannot tell what the right price for recycled water is. Given this, people might be willing to pay what it is presented as a fair price to them, thus making the task of the introduction of products irrigated with recycled water a much easier task.

References

Barton D.N. (2002). The transferability of benefit transfer: contingent valuation of water quality improvements in Costa Rica. *Ecological Economics*, **42**, 147-164.

Bateman I.J., Carson R.T., Day B., Hanemann M., Hanley N., Hett T., Jones-Lee M., Loomes G., Mourato S., Özdemiroğlu E., Pearce D.W., Sugden R. and Swanson J. (2002). *Economic Valuation with Stated Preference Techniques, A Manual*, Edward Elgar, pp 458.

Bateman I.J., Langford I.H., Turner R.K., Willis K.G. and Garrod G.D. (1995). Elicitation and truncation effects in contingent valuation studies. *Ecological Economics*, **12**, 161-179.

Bergland O. and Day B. (2001). Self-consistent estimation of non-parametric maximum likelihood problem for interval censored CVM data, Version 1.1, Gauss Code, Calahonda, Costa del Sol.

Bergland O. and Day B. (2005). Bootstrap Results for Turnbull's SC Algorithm, Ver.1.1. Gauss Code.

Borooah V.K. (2001). *Logit and Probit, Ordered and Multinomial Models*, Sage Publications, pp 97.

Cameron T.A. (1991). Interval Estimates of Non-Market Resource Values from Referendum Contingent Valuation Surveys. *Land Economics*, **67(4),** 413-21.

Cameron T.A. (1988). A new paradigm for valuing non-market goods using referendum data: maximum likelihood estimation by censored logistic regression. *Journal of Environmental Economics and Management*, **15,** 355-79.

Genious M. (2004). Lecture notes on Discrete choice models, Department of Economics, University of Crete.

Genious M. (2004). EViews code on DB-DC data, University of Crete.

Genious M. (2004). Personal communication, University of Crete.

Greene W.H. (2003). Econometric analysis, 5th edition, Prentice Hall, pp 1026.

Haab T.C. and McConnell K.E. (2003). *Valuing Environmental and Natural Resources, The Econometrics of Non-Market Valuation*, Edward Elgar pp 326.

Hanemann M. and Kanninen B. (1999). The Statistical Analysis of Discrete-Response CV Data **In:** Bateman I.J. and Willis K.G. (eds), *Valuing Environmental Preferences* (1999), Oxford University Press, pp 645.

Hanemann W.M. (1989).Welfare Evaluations in Contingent Valuation Experiments with Discrete Response Data: Reply. *American Journal of Agricultural Economics*, **71(4),** 1057-61. [In**:** Roach B., Boyle K.J. and Welsh M. (2002). Testing Bid Design Effects in Multiple-Bounded, Contingent-Valuation Questions. *Land Economics*, **78(1),** 121-131]

Hanemann W.M. (1984). Welfare Evaluations in Contingent Valuation Experiments with Discrete Responses. *American Journal of Agricultural Economics*, **66**, pp 332-341.

Levine D.M., Berenson M.L. and Stephen D. (1998). *Statistics for managers*, Prentice Hall, pp 743.

Malhotra N.K.,(1999). *Marketing Research, An Applied Orientation*, 3rd edition, Prentice Hall, pp 763.

Markowska A. and Zylicz T. (1999). Costing an international public good: the case of the Baltic Sea. *Ecological Economics*, **30,** 301-316.

Murad H., Fleischman A., Sadetzki S., Geyer O. and Freedman L.S. (2003). Small samples and ordered logistic regression: Does it help to collapse categories of outcome? *The American Statistician*, **57**, 155-60

Roach B., Boyle K.J. and Welsh M. (2002). Testing Bid Design Effects in Multiple-Bounded, Contingent-Valuation Questions. *Land Economics*, **78(1),** 121-131.

Strazzera E., Genius M., Scarpa R. and Hutchinson G. (2000). The effect of protest votes on the estimates of willingness to pay for use values of recreational sites, Paper presented in the 10th Conference of the European Association of Environmental and Resource Economics held in Crete, June 2000.

Train K.E. (2003). *Discrete Choice Methods with Simulation*, Cambridge, pp 334.

6. APPENDICES

6.1. Consumers' questionnaire

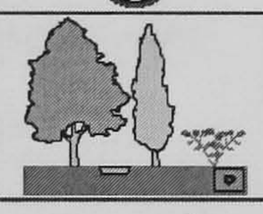
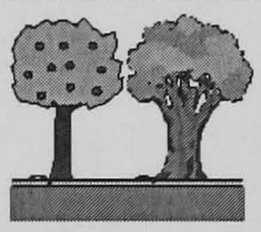
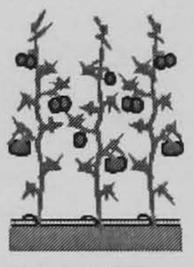
ΕΘΙΑΓΕ
ΕΘΝΙΚΟ ΙΔΡΥΜΑ ΑΓΡΟΤΙΚΗΣ ΕΡΕΥΝΑΣ

NATIONAL FOUNDATION OF AGRICULTURAL RESEARCH
HERAKLION INSTITUTE
P.O. 2229, 71307 Heraklion Crete
2810 245851, Fax: 2810 245873
Responsible for the project: Dr. Tsagarakis Konstantinos

INTRODUCTION

The Greek Ministry of Environment, Physical Planning and Public Works (MEPPPW) has assigned this project to the National Foundation of Agricultural Research, the Technological Institute of Crete (TEI) and the Union of Cretan Municipalities (TEDK) with the purpose of information collection for the formation of recycled water policy. This is why your answers must be honest and true (based on what you really believe and can afford). Your answers will be anonymous and confidential.

What is recycled water? Each household consumes water for the house cleanness, toilet etc. which, through the wastewater network, ends up in the wastewater treatment plant of the region. There, through special processes, it is cleaned (there are 5 levels of cleanness which are presented below) and has been proved scientifically that this water is appropriate for irrigation and outdoor cleanness, but not for drinking. Nevertheless this water ends up in the sea and rivers. Water recycling is an imposing need , because water shortage becomes more intensive year by year.

WATER QUALITY STARS	EXPLANATION	APPROPRIATE USES	
0	**Unprocessed wastewater:** polluted wastewater in the form it is found in the wastewater network	None!	
1 ★	**Primary treatment:** Wastewater has been subject to a first cleaning stage. The pollution level (organic load and pathogens) has been reduced by 30-40%.	Appropriate for the irrigation of forestland in a controlled way (on land with limited access) on surface or sub-surface.	
2 ★ ★	**Secondary treatment:** Wastewater has been subject to a second cleaning stage. The pollution level (organic load) has been reduced by 95%. Usually this type of water has received disinfection.	It is appropriate for surface tree irrigation such as olive trees, vineyards, industrial trees and other trees where water does not come in touch with the crops.	
3 ★ ★ ★	**Tertiary treatment:** Wastewater has been subject to a third cleaning stage. The pollution level (organic load) is minimized up to 99%. Disinfection has taken place and there are no pathogens.	Appropriate for the irrigation of cultivations, which are consumed by the human being on the condition that the edible parts do not come in touch with this water.	
4 ★ ★ ★ ★	**Potable water**	Appropriate for the irrigation of every type of human use and irrigation.	

It is stressed that if the majority of respondents answer that they do not wish to use recycled water or that they wish it but they will not support it financially, then the state will not use it but they will go on throwing it into the sea. This means a) that we leave recycled water-a natural resource (which contains nutrients for the cultivations), unexploited while simultaneously we will continue using fresh water for irrigation, thus aggravating the environment more and b) we will not have fully exploited the investments done in the wastewater treatment plants, which have been paid by all Greek tax-payers. *It is noted that the construction of the wastewater treatment plants has cost (today's prices) 500 m. euros (i.e. roughly 170 b. GRD).*

MINISTRY OF ENVIRONMENT PHYSICAL PLANNING AND PUBLIC WORKS

Page 1

PART A

1. How informed do you think you are on environmental problems?

☐ Absolutely informed
☐ Very well informed
☐ Well informed
☐ Little informed
☐ Very little informed
☐ Not at all informed

2. Put in circle the degree of significance for the following environmental problems (1: the least important and 5: the most important).

Forest fires	1	2	3	4	5
Rare species extinction	1	2	3	4	5
Sea petrol smears	1	2	3	4	5
Uncontrolled rubbish dropping	1	2	3	4	5
Water shortage	1	2	3	4	5

3. How much do environmental problems worry you?

☐ Very much
☐ A lot
☐ Little
☐ Very little
☐ Not at all

4. Which of the following do you do to save the environment?

☐ I keep my car (and every other vehicle I own) in a good mechanical condition, so that I will not pollute the environment with exhaust fumes or noise.
☐ I never throw rubbish in the environment.
☐ I try as much as I can, to reduce water consumption in my house.
☐ Other .....
☐ I do not do any action to save the environment.

PART B

5. Would you consume olive oil produced by olive trees irrigated with 2-star recycled water?

☐ Definitely yes ☐ Maybe yes ☐ Maybe no ☐ Definitely no ☐ I do not know/I do not answer

.....
.....

6. If (in question 5) you have answered DEFINITELY NO or MAYBE NO, would you consume olive oil produced by trees irrigated with 3-star recycled water?

☐ Definitely yes ☐ Maybe yes ☐ Maybe no ☐ Definitely no ☐ I do not know/I do not answer

.....
.....

7. If in questions 5 or 6 you have answered DEFINITELY YES or MAYBE YES, how much would you pay to buy it?

A. ☐ More than the olive oil produced by trees irrigated with fresh water
B. ☐ As much as the olive oil produced by trees irrigated with fresh water
C. ☐ Less than the olive oil produced by trees irrigated with fresh water

8. For those, who in question 7 have given the answer C, " Suppose that today 1 kg of olive oil costs 3 euros in the supermarket, would you pay 2 euros to buy olive oil produced by olive trees irrigated with recycled water?

☐ Yes
↓
Would you pay 2.25 euros/kg?
☐ Yes ☐ No

☐ No
↓
Would you pay 1.75 euros/kg?
☐ Yes ☐ No

9. For those in Question 7 who gave answer "A": Suppose that today 1kg of olive oil costs 3 euros in the supermarket, how much would you pay?
Report on the reason the respondent thinks like this:
.....
.....

10. Would you consume tomatoes irrigated with 3 star recycled water?
☐ Definitely yes ☐ Maybe yes ☐ Maybe no ☐ Definitely no ☐ I do not know/I do not answer
Explain the reason of a negative answer:
.....
.....

11. Would you visit a park irrigated with 1 star recycled water?
☐ Definitely yes ☐ Maybe yes ☐ Maybe no ☐ Definitely no ☐ I do not know/I do not answer
Explain the reason of a negative answer:
.....
.....

12. Would you like, if you were asked, to participate in a next phase of this research which will take place at a weekend during the following semester, outside your village/town? The participants will be compensated with the daily amount of €30. If you are sure that you can participate, leave your phone number. ☐ NO ☐ YES

Name: ..... Tel.: .....

P A R T C

9. AGE
☐ 18-24
☐ 25-34
☐ 35-44
☐ 45-54
☐ 55-64
☐ 65-and above

10. EDUCATIONAL LEVEL
☐ Illiterate
☐ Primary school
☐ Junior high school
☐ Senior high school
☐ Tertiary education (AEI-TEI)
☐ Post-graduate

11. MONTHLY FAMILY INCOME (in €):

A. 0-300	Δ. 901-1.200	H. 1.801- 2.100	K. 2.701- …
B. 301-600	E. 1.201-1.500	Θ. 2.101- 2.400	
Γ. 601-900	ΣΤ. 1.501- 1.800	I. 2.401-2.700	

12. SEX
☐ Male ☐ Female

13. NUMBER OF CHILDREN .....

Date of questionnaire completion.....
Area of completion .....
Researcher's code .....
Researcher's code (briefly mention your impressions from the interview you took).....
.....
.....
.....
.....
.....

6.2. Consumers' questionnaire structure

The structure of this questionnaire bears strong similarities with the one for the agricultural sample. The introduction, part A, part C and D are identical for the two questionnaires. Part B changes though, and it is this part we are explaining below. A copy of the consumers' questionnaire is on the Appendix of chapter 5. Its structure bears strong similarities with the questionnaire for the agricultural sample. The introduction, part A, part C and D are identical in the two questionnaires. Part B is different, and it is this part we break down below. Part B consisted of eight questions.

- Question 5. It asked respondents whether they would consume product 3. Researchers also asked for the reason of a negative answer (to facilitate data analysis). They did this in an informal way and they kept notes of consumers' reactions.

- Question 6. This question was destined for consumers having answered negatively in question 5. We wanted to see whether people would consume product 3a, namely olive oil irrigated with a better quality of water (quality 3), appropriate for unrestricted irrigation[11]. In this way we would check for the existence of scope effects. Again the reason of a negative answer was sought with a direct conversation with the respondent.

- Question 7. If respondents had answered positively in any of the questions 5 or 6, they were then asked their WTP for these products as a general characterization: "more", "less", or "as much as" the product irrigated with

[11] Hygienically appropriate for irrigating everything.

fresh water. This question served as a precursor for the pecuniary WTP question. It introduced the respondent gradually to the context of the question that would follow.

- Question 8. It was intended for consumers, who in question 7 had answered "less". We constructed both an open question and a DB-DC question here in order to investigate whether the two question formats would have an effect on the stated WTP (i.e. as a means of testing for elicitation effects). For the DB-DC question we picked up six different starting values. Prices were not realistic all of them because, due to irrigation fresh water price fluctuations from the different areas of olive oil production, it was impossible to tell how much the introduction of recycled water in the irrigation of olive oil would be reflected in olive oil price. For example, it is doubtful that a kilo of olive oil irrigated with recycled water would cost 2 €, i.e. 33% cheaper than the hypothetical standard supermarket price. However, consumers were pretty unlikely to know how much this would be reflected in price.

- Question 9. This question enquired on the WTP of consumers who had answered "more" in question 7.

- Question 10. It asked respondents simply whether they would consume product 4. Here we did not elaborate with any other follow-up questions relevant to 7, 8 and 9. The reason for this is that water cost is a trivial part of the tomato production cost.

- Question 11. It asked whether respondents would use product 5.

Question 12. It was identical to question 8 (about participation in a citizen jury) in the agricultural questionnaire. Contrary to the farmers' survey that no farmer was

willing to participate in a citizen jury, here some consumers, but not many of them, said yes to participation in a citizen jury.

6.3. The Turnbull Self- Consistency Algorithm (TSCA)

6.3.1. Calculations for the "imitated TSCA"

	0	1.75	2	2.2	2.25	2.4	2.45	2.5	2.6	2.65	2.7	2.75	2.8	2.85	2.95	INFINITY=3.00	
1.		0%	0.68%		1.35%											3.38%	
obs		*0#175*	*1#25*		*2#25*											*5#75*	*8*
corresponds		0.00	1.00	1.60	0.40	1.00	0.33	0.33	0.67	0.33	0.33	0.33	0.33	0.33	0.67	0.33	**8.00**
2.			0.68%			1.35%			1.35%							0.68%	
obs			*1#200*			*2#40*			*2#20*							*1#40*	*6*
corresponds		0.875	0.125	1	0.25	0.75	0.5	0.5	1	0.125	0.125	0.125	0.125	0.125	0.25	0.125	**6**
3.					4.05%			2.03%				4.73%				1.35%	
obs					*6#225*			*3#25*				*7#25*				*2#25*	*18*
corresponds		4.67	0.67	0.53	0.13	1.80	0.60	0.60	2.80	1.40	1.40	1.40	0.40	0.40	0.80	0.40	**18.00**
4.						24.32%			20.95%				16.22%			8%	
obs						*36#245*			*31#20*				*24#20*			*12#15*	*103*
corresponds		25.71	3.67	2.94	0.73	2.20	0.73	7.75	15.50	7.75	6.00	6.00	6.00	6.00	8.00	4.00	**103.00**
5.						0.00%				2.03%				1.35%		0.68%	
obs						*0#245*				*3#25*				*2#25*		*1#5*	*6*
corresponds		0.00	0.00	0.00	0.00	0.00	0.00	0.60	1.20	0.60	0.60	0.40	0.40	0.40	0.80	1.00	**6.00**
6.									0%			3.38%			0.68%	0.68%	
obs									*0#265*			*4#15*			*1#15*	*1#5*	*6*
corresponds		0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.33	1.33	1.33	0.33	0.67	1.00	**6.00**
																GRAND TOTAL	**147**

Figure 4.5. Calculations for the "imitated TSCA"

6.3.2. Gauss output from true TSCA

6.3.2.1. Non-parametric Mean WTP

```
GAUSS for Windows NT/95  Version 3.2.38  ( Feb 12 1999 )
(C) Copyright 1984-1999 Aptech Systems, Inc. Maple Valley, WA.
All Rights Reserved.
4128752 bytes workspace
(gauss) run a:\sc1.prg
 +-----------------------------------------------+
 | SELF-CONSISTENT ESTIMATION OF NPML PROBLEM FOR |
 |         INTERVAL CENSORED CVM DATA             |
 |       ----------------------------            |
 | Estimates SC estitmates of the NP distribution |
 |    using Turnbull's algorithm. SC estimates    |
 |     are compared to ML estimates using the     |
 |        procedure of Gentleman & Geyer          |
 |  Includes code adapted from code written by    |
 |              Olvar Bergland                    |
 |    Version 1.1, December 2001, (c) Brett Day   |
 +-----------------------------------------------+
  Observations in the dataset :     146
  Points in the support vector :      8
```

```
  Time used preparing data (s) :       0.000
+-----------------------------------------------+
|     Turnbull's Self-Consistency Algorithm     |
 +-----------------------------------------------+
  ***> Convergence criterion not satisfied <***
  Maximum allowed number of iterations exceeded
  Iterations used              :     500
  Convergence criterion        :     1.000e-010
  Time used in estimation (s)  :       0.040
  Log likelihood value         :    -136.679
 ------------------------------------------------------------
 Equivilance Class:   Probabilities:                 Interval
 Lower   Upper        Interval  CDF      Survival      se
 ------------------------------------------------------------
   1.75    2.00       0.0188    0.0188   0.9812       0.0188
   2.20    2.25       0.0565    0.0753   0.9247       0.0338
   2.25    2.40       0.0000    0.0753   0.9247       0.0462
   2.45    2.50       0.4336    0.5089   0.4911       0.1137
   2.50    2.60       0.1489    0.6578   0.3422       0.1149
   2.65    2.70       0.0054    0.6632   0.3368       0.1621
   2.70    2.75       0.2793    0.9425   0.0575       0.1627
   2.80    2.85       0.0575    1.0000   0.0000       0.0388
==========================================================================
=
+-----------------------------------------------+
| MEAN WTP Estimates:                           |
|  WTP distribution is assumed to be non-negative |
|  and truncated at highest bid level, that is;  |
|   - Lowest possible WTP assumed to be ZERO     |
|   - Higest possible WTP taken as highest bid   |
+-----------------------------------------------+
 ------------------------------------------------
  Lower bound          :       2.521
  Upper bound          :       2.582
  Linear Interpolation :       2.552
 ================================================
+-----------------------------------------------+
| Gentleman & Geyer's Test of Lagrange Multipliers |
| --------------------------------------------- |
|  If Lagrange Mutipliers are positive or zero   |
|     then SC estimates are NPML estimates       |
 +-----------------------------------------------+
Rank of d = J: ML estimates will be unique
 ------------------------------------------------------
  Equivilance Class      Interval       Lagrange
  Lower   Upper          Probability    Multiplier
 ------------------------------------------------------
    1.75    2.00         0.0188         -0.0000
    2.20    2.25         0.0565         -0.0000
    2.25    2.40         0.0000         72.1528
```

2.45	2.50	0.4336	-0.0000
2.50	2.60	0.1489	-0.0009
2.65	2.70	0.0054	0.3960
2.70	2.75	0.2793	-0.0072
2.80	2.85	0.0575	0.0003

(gauss)

6.3.2.2. Non parametric 95% confidence intervals for mean WTP

```
|  Includes code adapted from code written by     |
|              Olvar Bergland                     |
|   Version 1.1, August 2005, (c) Brett Day       |
 +-----------------------------------------------+
+-------------------------------------------------+
 | Bootstrap Results for Turnbull's SC Algorithm  |
 +-----------------------------------------------+
  Num Obs in data:                 146
  Num bootstrap iterations:        100
  Convergence tolerance:        1.0E-008
  Max iters to converge:           5000
  Num BS not converge:                2
  ---------------------------------------------------------------
                  Lower      Linear          Upper
                  Bound      Interpolation   Bound
  ---------------------------------------------------------------
  Actual  Estimate      2.521    2.552        2.583
  ---------------------------------------------------------------
  Bootstrap Estimates:
  Means                 2.519    2.551        2.582
  95% CIs Upper         2.414    2.507        2.552
        Lower           2.548    2.577        2.614
  Range   Lowest        2.399    2.480        2.542
        Highest         2.559    2.585        2.623
```

=Math coprocessor exceptions:
Underflow
(gauss)

6.4. EViews code for double-bounded dichotomous choice data

The following code has been written by Dr Margarita Genious, University of Crete.

```
coef (12) b2
coef (1) scale2
equation eq1.binary(d=p) dep1 c x1 x2 x3 x4 x5 x6 x7 x8 x9 x10 x11 logbid1
scale2(1)=-1/eq1.@coefs(13)
b2(1)=(-1/eq1.@coefs(13))*eq1.@coefs(1)
b2(2)=(-1/eq1.@coefs(13))*eq1.@coefs(2)
b2(3)=(-1/eq1.@coefs(13))*eq1.@coefs(3)
b2(4)=(-1/eq1.@coefs(13))*eq1.@coefs(4)
b2(5)=(-1/eq1.@coefs(13))*eq1.@coefs(5)
b2(6)=(-1/eq1.@coefs(13))*eq1.@coefs(6)
b2(7)=(-1/eq1.@coefs(13))*eq1.@coefs(7)
b2(8)=(-1/eq1.@coefs(13))*eq1.@coefs(8)
b2(9)=(-1/eq1.@coefs(13))*eq1.@coefs(9)
b2(10)=(-1/eq1.@coefs(13))*eq1.@coefs(10)
b2(11)=(-1/eq1.@coefs(13))*eq1.@coefs(11)
b2(12)=(-1/eq1.@coefs(13))*eq1.@coefs(12)
logl double
double.append @logl logl2
double.append arg1=(logbid1-b2(1)-b2(2)*x1-b2(3)*x2-b2(4)*x3-b2(5)*x4-
b2(6)*x5-b2(7)*x6-b2(8)*x7-b2(9)*x8-b2(10)*x9-b2(11)*x10-
b2(12)*x11)*(1/scale2(1))
double.append arg2=(logbid2-b2(1)-b2(2)*x1-b2(3)*x2-b2(4)*x3-b2(5)*x4-
b2(6)*x5-b2(7)*x6-b2(8)*x7-b2(9)*x8-b2(10)*x9-b2(11)*x10-
b2(12)*x11)*(1/scale2(1))
double.append prnn=@cnorm(arg2)*(1-dep1)*(1-dep2)
double.append pryy=(1-@cnorm(arg2))*dep1*dep2
double.append pryn=(@cnorm(arg2)-@cnorm(arg1))*dep1*(1-dep2)
double.append prny=(@cnorm(arg1)-@cnorm(arg2))*((1-dep1)*dep2)
double.append logl2=log(prnn+pryy+pryn+prny)
double.ml (showopts, m=1000,c=1e-5)
show double.output
```

6.5. Limdep outputs

Table 4.18. Limdep full output for Model 1 (ordered logit)

```
--> RESET
--> READ;file="C:\MENEGAKI\PhD CHAPTERS\chapter4\WTU1S (Consumers).xls";forma...
 this is record 512. expect len=10, found  10
--> ORDERED;Lhs=WTU1;Rhs=ONE,INFO,LACKW,ACTIONS,AGE1,AGE2,CHID,EDU1,EDU2,EDU3
    ,INCOME,SEX;Logit;Marginal Effects$

+----------------------------------------------------------------------+
| Dependent variable is binary, y=0 or y not equal 0                   |
| Ordinary    least squares regression    Weighting variable = none    |
| Dep. var. = Y=0/Not0 Mean=   .9018404908    , S.D.=   .2979875873    |
| Model size: Observations =     326, Parameters =  12, Deg.Fr.=    314 |
| Residuals:  Sum of squares= 701.2147951    , Std.Dev.=        1.49438 |
| Fit:        R-squared=*********, Adjusted R-squared =      -24.14925 |
| Diagnostic: Log-L =   -587.4184, Restricted(b=0) Log-L =     -67.3839 |
|             LogAmemiyaPrCrt.=     .840, Akaike Info. Crt.=      3.677 |
+----------------------------------------------------------------------+
+---------+-------------+---------------+--------+---------+----------+
|Variable | Coefficient | Standard Error |b/St.Er.|P[|Z|>z] | Mean of X|
+---------+-------------+---------------+--------+---------+----------+
 Constant  .4048971752      .67117919        .603   .5463
 INFO      .2384160829E-01  .71844875E-01    .332   .7400  2.7423313
 LACKW     .3488763770E-01  .95090529E-01    .367   .7137  4.6411043
 ACTIONS  -.2685073260E-02  .92823348E-01   -.029   .9769  1.7116564
 AGE1      .2791252340      .42318976        .660   .5095  .59202454
 AGE2      .2264860476      .37110904        .610   .5417  .33742331
 CHID      .1504424235E-01  .25276711        .060   .9525  .44171779
 EDU1      .6687556495E-01  .74475085        .090   .9284  .15337423E-01
 EDU2     -.9328985861E-02  .35026524       -.027   .9788  .11042945
 EDU3      .2594817848E-02  .18779005        .014   .9890  .45705521
 INCOME    .1133131634E-04  .13157142E-03    .086   .9314  1095.1227
 SEX       .2466770768E-01  .16887733        .146   .8839  .50000000

Normal exit from iterations. Exit status=0.

                +-----------------------------------------+
                | Ordered Logit Model                     |
                | Maximum Likelihood Estimates            |
                | Dependent variable                WTU1  |
                | Weighting variable                 ONE  |
                | Number of observations             326  |
                | Iterations completed                18  |
                | Log likelihood function       -339.4098 |
                | Restricted log likelihood     -357.9555 |
                | Chi-squared                    37.09132 |
                | Degrees of freedom                 11  |
                | Significance level          .1112406E-03 |
                |    Cell frequencies for outcomes        |
                |  Y Count Freq  Y Count Freq  Y Count Freq |
                |  0    32 .098  1    18 .055  2   165 .509 |
                |  3   110 .337                           |
                | Logistic Probability Model              |
                +-----------------------------------------+
+---------+-------------+---------------+--------+---------+----------+
|Variable | Coefficient | Standard Error |b/St.Er.|P[|Z|>z] | Mean of X|
+---------+-------------+---------------+--------+---------+----------+
          Index function for probability
 Constant  .9517430884E-04  .85690380         .000   .9999
 INFO      .2727891576      .85580191E-01    3.188   .0014  2.7423313
 LACKW     .1808914819      .11124828        1.626   .1039  4.6411043
 ACTIONS   .2512790356      .11977850        2.098   .0359  1.7116564
 AGE1      .6315110961      .49799720        1.268   .2048  .59202454
 AGE2      .6451097142      .41811531        1.543   .1229  .33742331
 CHID      .6870436147E-01  .32674633         .210   .8335  .44171779
 EDU1     -.4009698486      .84322687        -.476   .6344  .15337423E-01
 EDU2     -.1950833236      .43696284        -.446   .6553  .11042945
 EDU3     -.2543201646      .25766660        -.987   .3236  .45705521
 INCOME   -.3798515871E-03  .19212902E-03   -1.977   .0480  1095.1227
 SEX       .6285881329      .22831835        2.753   .0059  .50000000
          Threshold parameters for index
```

Mu(1)	.5381637052	.12689797	4.241	.0000
Mu(2)	3.139782741	.21140892	14.852	.0000

Matrix: Las
[14,4]

Marginal Effects for OrdLogit				
Variable	WTU1=0	WTU1=1	WTU1=2	WTU1=3
ONE	.0000	.0000	.0000	.0000
INFO	-.0209	-.0110	-.0276	.0595
LACKW	-.0139	-.0073	-.0183	.0395
ACTIONS	-.0193	-.0101	-.0255	.0548
AGE1	-.0484	-.0254	-.0640	.1378
AGE2	-.0494	-.0260	-.0654	.1408
CHID	-.0053	-.0028	-.0070	.0150
EDU1	.0307	.0161	.0406	-.0875
EDU2	.0149	.0079	.0198	-.0426
EDU3	.0195	.0102	.0258	-.0555
INCOME	.0000	.0000	.0000	-.0001
SEX	-.0482	-.0253	-.0637	.1372

Frequencies of actual & predicted outcomes
Predicted outcome has maximum probability.

	Predicted				
Actual	0	1	2	3	Total
0	1	0	28	3	32
1	0	0	17	1	18
2	0	0	142	24	166
3	0	0	74	36	110
Total	1	0	261	64	326

Table 4.19. Limdep output for multinomial version of Model 1

```
--> LOGIT;Lhs=WTU1;Rhs=ONE,INFO,LACKW,ACTIONS,AGE1,AGE2,CHID,EDU1,EDU2,EDU3
    ,INCOME,SEX$

            +---------------------------------------------+
            | Multinomial logit model                     |
            | There are  4 outcomes for LH variable WTU1  |
            | These are the OLS start values based on the |
            | binary variables for each outcome Y(i) = j. |
            | Coefficients for LHS=0 outcome are set to 0.0 |
            +---------------------------------------------+
+---------+-------------+----------------+-------+---------+----------+
|Variable | Coefficient | Standard Error |b/St.Er.|P[|Z|>z] | Mean of X|
+---------+-------------+----------------+-------+---------+----------+
         Characteristics in numerator of Prob[Y = 1]
 Constant  .8947321445E-01  1.0150602         .088   .9298
 INFO     -.1589235592E-01  .10865485        -.146   .8837  2.7423313
 LACKW    -.1420126590E-01  .14381050        -.099   .9213  4.6411043
 ACTIONS  -.1048190910E-01  .14038172        -.075   .9405  1.7116564
 AGE1      .8649096610E-01  .64001254         .135   .8925  .59202454
 AGE2      .4156622879E-01  .56124808         .074   .9410  .33742331
 CHID      .1140949817E-01  .38227325         .030   .9762  .44171779
 EDU1      .1939384074      1.1263266         .172   .8633  .15337423E-01
 EDU2      .5195325475E-01  .52972489         .098   .9219  .11042945
 EDU3      .1623529114E-01  .28400495         .057   .9544  .45705521
 INCOME    .1515942648E-04  .19898251E-03     .076   .9393  1095.1227
 SEX      -.1965782166E-01  .25540223        -.077   .9386  .50000000
         Characteristics in numerator of Prob[Y = 2]
 Constant  .1440985274      .83111079         .173   .8624
 INFO     -.1104202835E-01  .88964396E-01    -.124   .9012  2.7423313
 LACKW     .4369721525E-01  .11774913         .371   .7106  4.6411043
 ACTIONS  -.6395718501E-01  .11494171        -.556   .5779  1.7116564
 AGE1      .2388351957      .52402932         .456   .6486  .59202454
 AGE2      .2092687398      .45953857         .455   .6488  .33742331
 CHID     -.1123635037E-01  .31299760        -.036   .9714  .44171779
 EDU1     -.7989770485E-01  .92221345        -.087   .9310  .15337423E-01
 EDU2     -.5219367713E-01  .43372803        -.120   .9042  .11042945
 EDU3      .5508924148E-01  .23253751         .237   .8127  .45705521
 INCOME    .1241923714E-03  .16292286E-03     .762   .4459  1095.1227
 SEX      -.1183729958      .20911818        -.566   .5714  .50000000
         Characteristics in numerator of Prob[Y = 3]
 Constant  .1713254334      .89137691         .192   .8476
 INFO      .5077599256E-01  .95415448E-01     .532   .5946  2.7423313
 LACKW     .5391688351E-02  .12628744         .043   .9659  4.6411043
 ACTIONS   .7175402085E-01  .12327645         .582   .5605  1.7116564
 AGE1     -.4620092778E-01  .56202812        -.082   .9345  .59202454
 AGE2     -.2434892097E-01  .49286097        -.049   .9606  .33742331
 CHID      .1487109455E-01  .33569391         .044   .9647  .44171779
 EDU1     -.4716513763E-01  .98908566        -.048   .9620  .15337423E-01
 EDU2     -.9088563481E-02  .46517883        -.020   .9844  .11042945
 EDU3     -.6872971477E-01  .24939943        -.276   .7829  .45705521
 INCOME   -.1280204815E-03  .17473684E-03    -.733   .4638  1095.1227
 SEX       .1626985252      .22428191         .725   .4682  .50000000

Normal exit from iterations. Exit status=0.

            +---------------------------------------+
            | Multinomial Logit Model               |
            | Maximum Likelihood Estimates          |
            | Dependent variable            WTU1    |
            | Weighting variable            ONE     |
            | Number of observations        326     |
            | Iterations completed          7       |
            | Log likelihood function       -323.1017 |
            | Restricted log likelihood     -357.9555 |
            | Chi-squared                   69.70750  |
            | Degrees of freedom            33      |
            | Significance level            .1964333E-03 |
            +---------------------------------------+
+---------+-------------+----------------+-------+---------+----------+
|Variable | Coefficient | Standard Error |b/St.Er.|P[|Z|>z] | Mean of X|
+---------+-------------+----------------+-------+---------+----------+
         Characteristics in numerator of Prob[Y = 1]
 Constant -3.492799203     2.0925811        -1.669   .0951
```

INFO	-.4471513914E-01	.25974203	-.172	.8633	2.7423313
LACKW	.3429531575E-01	.26508355	.129	.8971	4.6411043
ACTIONS	-.3019809207	.34819114	-.867	.3858	1.7116564
AGE1	3.302987233	1.5471345	2.135	.0328	.59202454
AGE2	1.711699421	1.3239620	1.293	.1961	.33742331
CHID	.3209876466	.91488305	.351	.7257	.44171779
EDU1	2.844756934	1.9598029	1.452	.1466	.15337423E-01
EDU2	1.007629631	1.1563662	.871	.3835	.11042945
EDU3	.4323720374	.73413618	.589	.5559	.45705521
INCOME	.4033991175E-03	.51316919E-03	.786	.4318	1095.1227
SEX	-.3165828577	.65000680	-.487	.6262	.50000000
	Characteristics in numerator of Prob[Y = 2]				
Constant	-2.506988447	1.4130630	-1.774	.0760	
INFO	.2156799787	.17148599	1.258	.2085	2.7423313
LACKW	.3511082560	.19132011	1.835	.0665	4.6411043
ACTIONS	-.1829453410	.22576496	-.810	.4177	1.7116564
AGE1	2.410017230	.89566908	2.691	.0071	.59202454
AGE2	1.746614461	.72061693	2.424	.0154	.33742331
CHID	.1413146531	.62439225	.226	.8209	.44171779
EDU1	-.9776603350E-01	1.6642812	-.059	.9532	.15337423E-01
EDU2	-.1766797961	.75972915	-.233	.8161	.11042945
EDU3	.9537425767E-01	.49099421	.194	.8460	.45705521
INCOME	.3099840046E-03	.35122418E-03	.883	.3775	1095.1227
SEX	-.2383411703E-01	.42685325	-.056	.9555	.50000000
	Characteristics in numerator of Prob[Y = 3]				
Constant	-2.513304102	1.4667074	-1.714	.0866	
INFO	.4149723747	.18080512	2.295	.0217	2.7423313
LACKW	.2587415796	.19844264	1.304	.1923	4.6411043
ACTIONS	.1982198830	.23411173	.847	.3972	1.7116564
AGE1	1.539008011	.88250602	1.744	.0812	.59202454
AGE2	1.036758026	.68322096	1.517	.1292	.33742331
CHID	.1930775278	.65248723	.296	.7673	.44171779
EDU1	.1445480537	1.4999265	.096	.9232	.15337423E-01
EDU2	-.3400971911E-02	.77936368	-.004	.9965	.11042945
EDU3	-.2162301357	.51100197	-.423	.6722	.45705521
INCOME	-.3968322363E-03	.37131078E-03	-1.069	.2852	1095.1227
SEX	.7462279810	.44346110	1.683	.0924	.50000000

Frequencies of actual & predicted outcomes

Matrix: Las
[36,4]

Predicted outcome has maximum probability.

	Predicted				
Actual	0	1	2	3	Total
0	5	0	19	8	32
1	0	0	15	3	18
2	1	1	136	28	166
3	6	0	59	45	110
Total	12	1	229	84	326

Table 4.20. Limdep full output for Model 2 (ordered logit)

```
--> RESET
--> READ;file="C:\MENEGAKI\PhD CHAPTERS\chapter4\WTU2S (Consumers).xls";forma...
 this is record 512. expect len=10, found  10
--> ORDERED;Lhs=WTU2;Rhs=ONE,INFO,LACKW,ACTIONS,AGE1,AGE2,CHID,EDU1,EDU2,EDU3
    ,INCOME,SEX;Logit;Marginal Effects$

+----------------------------------------------------------------------+
| Dependent variable is binary, y=0 or y not equal 0                   |
| Ordinary    least squares regression    Weighting variable = none    |
| Dep. var. = Y=0/Not0 Mean=   .8348909657    , S.D.=   .3718585970    |
| Model size: Observations =     321, Parameters =  12, Deg.Fr.=    309 |
| Residuals:  Sum of squares= 580.7312115    , Std.Dev.=        1.37091 |
| Fit:        R-squared=*********, Adjusted R-squared =      -12.59130 |
| Diagnostic: Log-L =   -550.6312, Restricted(b=0) Log-L =    -137.4319 |
|             LogAmemiyaPrCrt.=     .668, Akaike Info. Crt.=      3.505 |
+----------------------------------------------------------------------+
+---------+--------------+----------------+-------+---------+----------+
|Variable | Coefficient  | Standard Error |b/St.Er.|P[|Z|>z] | Mean of X|
+---------+--------------+----------------+-------+---------+----------+
 Constant  .2284930296      .58567901         .390   .6964
 INFO      .1551109430E-01  .65767966E-01     .236   .8136  2.7538941
 LACKW     .5040504166E-01  .87265929E-01     .578   .5635  4.6355140
 ACTIONS   .6575946309E-01  .84859393E-01     .775   .4384  1.7102804
 AGE1      .2254477047      .37597175         .600   .5487  .59190031
 AGE2      .1600856317      .33002229         .485   .6276  .33644860
 CHID      .5359066396E-01  .23562249         .227   .8201  .43613707
 EDU1      .1618569272      .48401582         .334   .7381  .28037383E-01
 EDU2     -.8224639182E-01  .28309546        -.291   .7714  .12461059
 EDU3     -.2735435373E-01  .16618362        -.165   .8693  .46728972
 INCOME    .1996277596E-04  .12190553E-03     .164   .8699  1093.0156
 SEX       .7140466196E-02  .15579930         .046   .9634  .49844237

Normal exit from iterations. Exit status=0.

                +----------------------------------------+
                | Ordered Logit Model                    |
                | Maximum Likelihood Estimates           |
                | Dependent variable              WTU2   |
                | Weighting variable              ONE    |
                | Number of observations          321    |
                | Iterations completed             18    |
                | Log likelihood function      -399.3017 |
                | Restricted log likelihood    -419.5207 |
                | Chi-squared                   40.43808 |
                | Degrees of freedom                11   |
                | Significance level        .3009847E-04 |
                |    Cell frequencies for outcomes       |
                |  Y Count Freq  Y Count Freq  Y Count Freq |
                |  0    53 .165  1    53 .165  2   134 .417 |
                |  3    80 .252                          |
                | Logistic Probability Model             |
                +----------------------------------------+
+---------+--------------+----------------+-------+---------+----------+
|Variable | Coefficient  | Standard Error |b/St.Er.|P[|Z|>z] | Mean of X|
+---------+--------------+----------------+-------+---------+----------+
          Index function for probability
 Constant -1.317879899      .77845459      -1.693   .0905
 INFO      .1629351614      .82503453E-01    1.975   .0483  2.7538941
 LACKW     .2449625126      .10569853        2.318   .0205  4.6355140
 ACTIONS   .3151690545      .11692259        2.696   .0070  1.7102804
 AGE1     1.581336594       .51077919        3.096   .0020  .59190031
 AGE2      .8705237340      .45727608        1.904   .0569  .33644860
 CHID      .5274337729      .31210586        1.690   .0910  .43613707
 EDU1      .7898036789      .72096322        1.095   .2733  .28037383E-01
 EDU2     -.3177736981      .36972428        -.859   .3901  .12461059
 EDU3     -.3495403890      .23202840       -1.506   .1320  .46728972
 INCOME   -.2539494928E-03  .17166396E-03   -1.479   .1390  1093.0156
 SEX      -.8130400121E-01  .21372790        -.380   .7036  .49844237
          Threshold parameters for index
 Mu( 1)    .9950550518      .13163542        7.559   .0000
 Mu( 2)   2.953908157       .19328969       15.282   .0000

                +----------------------------------------+
```

Matrix: Las
[14,4]

Marginal Effects for OrdLogit				
Variable	WTU2=0	WTU2=1	WTU2=2	WTU2=3
ONE	.1644	.1206	-.0492	-.2359
INFO	-.0203	-.0149	.0061	.0292
LACKW	-.0306	-.0224	.0091	.0438
ACTIONS	-.0393	-.0288	.0118	.0564
AGE1	-.1973	-.1447	.0590	.2830
AGE2	-.1086	-.0797	.0325	.1558
CHID	-.0658	-.0483	.0197	.0944
EDU1	-.0985	-.0723	.0295	.1414
EDU2	.0396	.0291	-.0119	-.0569
EDU3	.0436	.0320	-.0130	-.0626
INCOME	.0000	.0000	.0000	.0000
SEX	.0101	.0074	-.0030	-.0146

Frequencies of actual & predicted outcomes
Predicted outcome has maximum probability.

	Predicted				
Actual	0	1	2	3	Total
0	8	0	43	2	53
1	4	0	45	4	53
2	9	0	113	12	134
3	2	0	66	13	81
Total	23	0	267	31	321

Table 4.21. Limdep output for multinomial version of Model 2

```
--> LOGIT;Lhs=WTU2;Rhs=ONE,INFO,LACKW,ACTIONS,AGE1,AGE2,CHID,EDU1,EDU2,EDU3
    ,INCOME,SEX$

            +--------------------------------------------+
            | Multinomial logit model                    |
            | There are  4 outcomes for LH variable WTU2 |
            | These are the OLS start values based on the|
            | binary variables for each outcome Y(i) = j.|
            | Coefficients for LHS=0 outcome are set to 0.0 |
            +--------------------------------------------+
+---------+-------------+---------------+--------+---------+----------+
|Variable | Coefficient | Standard Error |b/St.Er.|P[|Z|>z] | Mean of X|
+---------+-------------+---------------+--------+---------+----------+
        Characteristics in numerator of Prob[Y = 1]
Constant  .2305461876      .82324369         .280   .7794
INFO     -.8186896065E-02  .92444944E-01    -.089   .9294  2.7538941
LACKW    -.4514878123E-02  .12266297        -.037   .9706  4.6355140
ACTIONS   .5431541221E-02  .11928029         .046   .9637  1.7102804
AGE1     -.1166491183      .52847442        -.221   .8253  .59190031
AGE2     -.7585892847E-01  .46388681        -.164   .8701  .33644860
CHID      .1064336785E-01  .33119631         .032   .9744  .43613707
EDU1      .2695183072E-01  .68034361         .040   .9684  .28037383E-01
EDU2     -.2311327802E-01  .39792540        -.058   .9537  .12461059
EDU3      .4228966561E-01  .23359147         .181   .8563  .46728972
INCOME    .2439841346E-04  .17135318E-03     .142   .8868  1093.0156
SEX       .2882671206E-01  .21899503         .132   .8953  .49844237
        Characteristics in numerator of Prob[Y = 2]
Constant  .3768725706E-02  .72959011         .005   .9959
INFO     -.7462445656E-02  .81928252E-01    -.091   .9274  2.7538941
LACKW     .4052213898E-01  .10870862         .373   .7093  4.6355140
ACTIONS   .5343705908E-02  .10571076         .051   .9597  1.7102804
AGE1      .1401750813      .46835428         .299   .7647  .59190031
AGE2      .1825282468      .41111427         .444   .6571  .33644860
CHID     -.7913352009E-01  .29351887        -.270   .7875  .43613707
EDU1     -.9183399391E-02  .60294658        -.015   .9878  .28037383E-01
EDU2     -.1872981798E-01  .35265674        -.053   .9576  .12461059
EDU3      .1220645678E-01  .20701771         .059   .9530  .46728972
INCOME    .1097752819E-03  .15185976E-03     .723   .4698  1093.0156
SEX       .8588245753E-02  .19408179         .044   .9647  .49844237
        Characteristics in numerator of Prob[Y = 3]
Constant -.5821883695E-02  .78175513        -.007   .9941
INFO      .3116043602E-01  .87786047E-01     .355   .7226  2.7538941
LACKW     .1439778080E-01  .11648119         .124   .9016  4.6355140
ACTIONS   .5498421596E-01  .11326898         .485   .6274  1.7102804
AGE1      .2019217417      .50184118         .402   .6874  .59190031
AGE2      .5341631337E-01  .44050856         .121   .9035  .33644860
CHID      .1220808162      .31450519         .388   .6979  .43613707
EDU1      .1440884958      .64605670         .223   .8235  .28037383E-01
EDU2     -.4040329581E-01  .37787137        -.107   .9148  .12461059
EDU3     -.8185047612E-01  .22181929        -.369   .7121  .46728972
INCOME   -.1142109194E-03  .16271759E-03    -.702   .4827  1093.0156
SEX      -.3027449161E-01  .20795846        -.146   .8843  .49844237

Normal exit from iterations. Exit status=0.

            +--------------------------------------------+
            | Multinomial Logit Model                    |
            | Maximum Likelihood Estimates               |
            | Dependent variable                  WTU2   |
            | Weighting variable                  ONE    |
            | Number of observations              321    |
            | Iterations completed                  5    |
            | Log likelihood function        -389.6508   |
            | Restricted log likelihood      -419.5207   |
            | Chi-squared                     59.73993   |
            | Degrees of freedom                    33   |
            | Significance level             .2956981E-02 |
            +--------------------------------------------+
+---------+-------------+---------------+--------+---------+----------+
|Variable | Coefficient | Standard Error |b/St.Er.|P[|Z|>z] | Mean of X|
+---------+-------------+---------------+--------+---------+----------+
        Characteristics in numerator of Prob[Y = 1]
Constant -2.696260642      1.3734867       -1.963   .0496
INFO      .4767940594E-01  .16623521         .287   .7743  2.7538941
```

LACKW	.1841838265	.19607621	.939	.3476	4.6355140
ACTIONS	.4623012267	.22349554	2.069	.0386	1.7102804
AGE1	.5736129435	.86888701	.660	.5091	.59190031
AGE2	.3655678183	.70163003	.521	.6023	.33644860
CHID	.4443058822	.63707096	.697	.4855	.43613707
EDU1	1.137221398	1.3206438	.861	.3892	.28037383E-01
EDU2	-.3967927462	.69414153	-.572	.5676	.12461059
EDU3	.6945151859E-01	.44999937	.154	.8773	.46728972
INCOME	.2843798823E-03	.32966609E-03	.863	.3883	1093.0156
SEX	.2094685770	.40919289	.512	.6087	.49844237
	Characteristics in numerator of Prob[Y = 2]				
Constant	-3.478784035	1.2812616	-2.715	.0066	
INFO	.9364692329E-01	.14124129	.663	.5073	2.7538941
LACKW	.3509417995	.17531119	2.002	.0453	4.6355140
ACTIONS	.4632847039	.19312371	2.399	.0164	1.7102804
AGE1	1.712422022	.83067029	2.061	.0393	.59190031
AGE2	1.345975326	.70399320	1.912	.0559	.33644860
CHID	.2104857899	.55138144	.382	.7027	.43613707
EDU1	1.014792873	1.2841056	.790	.4294	.28037383E-01
EDU2	-.3789525744	.61661522	-.615	.5388	.12461059
EDU3	-.1811856861	.38385575	-.472	.6369	.46728972
INCOME	.3803372425E-03	.28232823E-03	1.347	.1779	1093.0156
SEX	.7418384096E-01	.34877090	.213	.8316	.49844237
	Characteristics in numerator of Prob[Y = 3]				
Constant	-4.101801277	1.4249747	-2.879	.0040	
INFO	.2407318839	.16088790	1.496	.1346	2.7538941
LACKW	.3136118033	.20276159	1.547	.1219	4.6355140
ACTIONS	.7073192232	.21717099	3.257	.0011	1.7102804
AGE1	2.133081933	.92106977	2.316	.0206	.59190031
AGE2	.9701351429	.78819722	1.231	.2184	.33644860
CHID	1.017802030	.62001230	1.642	.1007	.43613707
EDU1	1.625764655	1.3048559	1.246	.2128	.28037383E-01
EDU2	-.5274470143	.67725037	-.779	.4361	.12461059
EDU3	-.5488961899	.42070827	-1.305	.1920	.46728972
INCOME	-.4180645397E-03	.33178449E-03	-1.260	.2077	1093.0156
SEX	-.8376848850E-01	.38559056	-.217	.8280	.49844237

Matrix: Las
[36,4]

Frequencies of actual & predicted outcomes
Predicted outcome has maximum probability.

	Predicted				
Actual	0	1	2	3	Total
0	11	1	37	4	53
1	5	2	38	8	53
2	7	1	111	15	134
3	1	2	53	25	81
Total	24	6	239	52	321

Table 4.22. Limdep full output for Model 3 (ordered logit)

```
--> RESET
--> READ;file="C:\MENEGAKI\PhD CHAPTERS\chapter4\WTU3S (Consumers).xls";forma...
 this is record 512. expect len=10, found  10
--> ORDERED;Lhs=WTU3;Rhs=ONE,INFO,LACKW,ACTIONS,AGE1,AGE2,CHID,EDU1,EDU2,EDU3
    ,INCOME,SEX;Logit;Marginal Effects$

+----------------------------------------------------------------------+
| Dependent variable is binary, y=0 or y not equal 0                   |
| Ordinary    least squares regression    Weighting variable = none    |
| Dep. var. = Y=0/Not0 Mean=   .9758308157    , S.D.=   .1538067119    |
| Model size: Observations =     331, Parameters =  12, Deg.Fr.=    319 |
| Residuals:  Sum of squares= 901.7876856    , Std.Dev.=        1.68134 |
| Fit:        R-squared=*********, Adjusted R-squared =     -118.49866 |
| Diagnostic: Log-L =   -635.5428, Restricted(b=0) Log-L =     150.4835 |
|             LogAmemiyaPrCrt.=    1.075, Akaike Info. Crt.=      3.913 |
+----------------------------------------------------------------------+
+---------+-------------+----------------+--------+---------+----------+
|Variable | Coefficient | Standard Error |b/St.Er.|P[|Z|>z] | Mean of X|
+---------+-------------+----------------+--------+---------+----------+
 Constant  .8999166894      .71951263        1.251   .2110
 INFO      .1125282133E-01  .78872300E-01     .143   .8865  2.7160121
 LACKW     .1106130144E-01  .11047373         .100   .9202  4.6586103
 ACTIONS  -.2964311791E-02  .10291015        -.029   .9770  1.6948640
 AGE1     -.8063317700E-02  .44660069        -.018   .9856  .59818731
 AGE2     -.2090326495E-01  .39704851        -.053   .9580  .32930514
 CHID     -.6872324908E-02  .27892087        -.025   .9803  .43202417
 EDU1      .4505796652E-01  .55975849         .080   .9358  .30211480E-01
 EDU2     -.2804499672E-01  .34042359        -.082   .9343  .12386707
 EDU3      .2886816924E-01  .20069262         .144   .8856  .47432024
 INCOME    .6862888944E-05  .14375513E-03     .048   .9619  1096.7039
 SEX      -.1120515794E-01  .18862834        -.059   .9526  .49848943

Normal exit from iterations. Exit status=0.

                +-----------------------------------------+
                | Ordered Logit Model                     |
                | Maximum Likelihood Estimates            |
                | Dependent variable                WTU3  |
                | Weighting variable                ONE   |
                | Number of observations            331   |
                | Iterations completed               19   |
                | Log likelihood function       -310.8425 |
                | Restricted log likelihood     -318.7380 |
                | Chi-squared                    15.79096 |
                | Degrees of freedom                 11   |
                | Significance level             .1490706 |
                |    Cell frequencies for outcomes        |
                |  Y Count Freq  Y Count Freq  Y Count Freq|
                |  0     8 .024  1    24 .072  2   108 .326|
                |  3   191 .577                           |
                | Logistic Probability Model              |
                +-----------------------------------------+
+---------+-------------+----------------+--------+---------+----------+
|Variable | Coefficient | Standard Error |b/St.Er.|P[|Z|>z] | Mean of X|
+---------+-------------+----------------+--------+---------+----------+
          Index function for probability
 Constant  2.676396391      .95107203        2.814   .0049
 INFO      .3203576881E-01  .10028762         .319   .7494  2.7160121
 LACKW     .5147571305E-01  .13065284         .394   .6936  4.6586103
 ACTIONS   .2073934098      .12716481        1.631   .1029  1.6948640
 AGE1      .4510191239      .54116566         .833   .4046  .59818731
 AGE2      .7090066070      .47773304        1.484   .1378  .32930514
 CHID     -.7094027922      .33301004       -2.130   .0331  .43202417
 EDU1     -.1794704312      .76535862        -.234   .8146  .30211480E-01
 EDU2      .1545905394      .40039214         .386   .6994  .12386707
 EDU3      .1327559219      .25356368         .524   .6006  .47432024
 INCOME    .1765752245E-03  .18591259E-03     .950   .3422  1096.7039
 SEX      -.5726936257E-01  .23028503        -.249   .8036  .49848943
          Threshold parameters for index
 Mu( 1)    1.481188155      .33483127        4.424   .0000
 Mu( 2)    3.476361186      .38263089        9.085   .0000

           +-------------------------------------------------+
```

Matrix: Las
[14,4]

Marginal Effects for OrdLogit				
Variable	WTU3=0	WTU3=1	WTU3=2	WTU3=3
ONE	-.0576	-.1618	-.4331	.6526
INFO	-.0007	-.0019	-.0052	.0078
LACKW	-.0011	-.0031	-.0083	.0126
ACTIONS	-.0045	-.0125	-.0336	.0506
AGE1	-.0097	-.0273	-.0730	.1100
AGE2	-.0153	-.0429	-.1147	.1729
CHID	.0153	.0429	.1148	-.1730
EDU1	.0039	.0109	.0290	-.0438
EDU2	-.0033	-.0093	-.0250	.0377
EDU3	-.0029	-.0080	-.0215	.0324
INCOME	.0000	.0000	.0000	.0000
SEX	.0012	.0035	.0093	-.0140

Frequencies of actual & predicted outcomes
Predicted outcome has maximum probability.

	Predicted				
Actual	0	1	2	3	Total
0	0	0	1	7	8
1	0	0	3	21	24
2	0	0	13	95	108
3	0	0	11	180	191
Total	0	0	28	303	331

Table 4.23. Limdep output for multinomial version of Model 3

```
--> LOGIT;Lhs=WTU3;Rhs=ONE,INFO,LACKW,ACTIONS,AGE1,AGE2,CHID,EDU1,EDU2,EDU3
    ,INCOME,SEX$

            +---------------------------------------------+
            | Multinomial logit model                     |
            | There are  4 outcomes for LH variable WTU3  |
            | These are the OLS start values based on the |
            | binary variables for each outcome Y(i) = j. |
            | Coefficients for LHS=0 outcome are set to 0.0 |
            +---------------------------------------------+
+---------+-------------+---------------+-------+---------+----------+
|Variable | Coefficient | Standard Error |b/St.Er.|P[|Z|>z] | Mean of X|
+---------+-------------+---------------+-------+---------+----------+
         Characteristics in numerator of Prob[Y = 1]
 Constant  .7780266780E-01  1.0884994         .071   .9430
 INFO      .1864436852E-02  .11932028         .016   .9875  2.7160121
 LACKW     .1070956654E-01  .16712782         .064   .9489  4.6586103
 ACTIONS  -.1085409331E-01  .15568543        -.070   .9444  1.6948640
 AGE1     -.4135621898E-01  .67563034        -.061   .9512  .59818731
 AGE2     -.1219501639E-01  .60066638        -.020   .9838  .32930514
 CHID      .7905389770E-01  .42195950         .187   .8514  .43202417
 EDU1     -.1047707866E-01  .84681871        -.012   .9901  .30211480E-01
 EDU2     -.2929530062E-01  .51500257        -.057   .9546  .12386707
 EDU3      .5830404532E-02  .30361356         .019   .9847  .47432024
 INCOME   -.4463699086E-04  .21747689E-03    -.205   .8374  1096.7039
 SEX       .5778168228E-02  .28536237         .020   .9838  .49848943
         Characteristics in numerator of Prob[Y = 2]
 Constant  .5808196037      .98401590         .590   .5550
 INFO      .1723995758E-02  .10786690         .016   .9872  2.7160121
 LACKW    -.1645312302E-01  .15108547        -.109   .9133  4.6586103
 ACTIONS  -.4843563405E-01  .14074141        -.344   .7307  1.6948640
 AGE1     -.1181323510      .61077758        -.193   .8466  .59818731
 AGE2     -.2444640715      .54300930        -.450   .6526  .32930514
 CHID      .7030035680E-01  .38145623         .184   .8538  .43202417
 EDU1      .1753892687      .76553383         .229   .8188  .30211480E-01
 EDU2     -.7275412638E-01  .46556823        -.156   .8758  .12386707
 EDU3     -.5131739480E-02  .27447014        -.019   .9851  .47432024
 INCOME    .3031413085E-04  .19660161E-03     .154   .8775  1096.7039
 SEX      -.1359884301E-01  .25797086        -.053   .9580  .49848943
         Characteristics in numerator of Prob[Y = 3]
 Constant  .2412944179      .87714245         .275   .7832
 INFO      .7664388717E-02  .96151533E-01     .080   .9365  2.7160121
 LACKW     .1680485792E-01  .13467615         .125   .9007  4.6586103
 ACTIONS   .5632541556E-01  .12545556         .449   .6535  1.6948640
 AGE1      .1514252523      .54444134         .278   .7809  .59818731
 AGE2      .2357558230      .48403334         .487   .6262  .32930514
 CHID     -.1562265794      .34002647        -.459   .6459  .43202417
 EDU1     -.1198542235      .68238960        -.176   .8606  .30211480E-01
 EDU2      .7400443029E-01  .41500311         .178   .8585  .12386707
 EDU3      .2816950419E-01  .24466008         .115   .9083  .47432024
 INCOME    .2118574895E-04  .17524881E-03     .121   .9038  1096.7039
 SEX      -.3384483157E-02  .22995277        -.015   .9883  .49848943

Normal exit from iterations. Exit status=0.

              +-----------------------------------------+
              | Multinomial Logit Model                 |
              | Maximum Likelihood Estimates            |
              | Dependent variable                WTU3  |
              | Weighting variable                ONE   |
              | Number of observations            331   |
              | Iterations completed              30    |
              | Log likelihood function       -298.1922 |
              | Restricted log likelihood     -318.7380 |
              | Chi-squared                    41.09152 |
              | Degrees of freedom                33    |
              | Significance level             .1574038 |
              +-----------------------------------------+
+---------+-------------+---------------+-------+---------+----------+
|Variable | Coefficient | Standard Error |b/St.Er.|P[|Z|>z] | Mean of X|
+---------+-------------+---------------+-------+---------+----------+
         Characteristics in numerator of Prob[Y = 1]
 Constant -1.691626844      2.9162233        -.580   .5619
```

INFO	.5666275102	.36309055	1.561	.1186	2.7160121
LACKW	.3701450091	.41269715	.897	.3698	4.6586103
ACTIONS	-.2996828102	.44717122	-.670	.5027	1.6948640
AGE1	-.1184972907	1.9338883	-.061	.9511	.59818731
AGE2	-.6624155204	1.3915616	-.476	.6341	.32930514
CHID	.9734458712	1.5165127	.642	.5209	.43202417
EDU1	28.03743442	1348938.9	.000	1.0000	.30211480E-01
EDU2	.2363052562	1.3796327	.171	.8640	.12386707
EDU3	2.092231035	1.2897256	1.622	.1048	.47432024
INCOME	-.4292908012E-03	.79273249E-03	-.542	.5881	1096.7039
SEX	-.4649064529	.88190126	-.527	.5981	.49848943
	Characteristics in numerator of Prob[Y = 2]				
Constant	.6826078926	2.5211694	.271	.7866	
INFO	.5334666818	.32897614	1.622	.1049	2.7160121
LACKW	.1553441386	.31790915	.489	.6251	4.6586103
ACTIONS	-.2864277322	.39520171	-.725	.4686	1.6948640
AGE1	.4369926518E-01	1.7735558	.025	.9803	.59818731
AGE2	-1.222291200	1.2621293	-.968	.3328	.32930514
CHID	-.1733246801	1.3704839	-.126	.8994	.43202417
EDU1	28.84231864	1348938.9	.000	1.0000	.30211480E-01
EDU2	.4262312553	1.2435387	.343	.7318	.12386707
EDU3	2.046630110	1.2143463	1.685	.0919	.47432024
INCOME	.5907830945E-03	.66362060E-03	.890	.3733	1096.7039
SEX	-.5940360890	.79784459	-.745	.4565	.49848943
	Characteristics in numerator of Prob[Y = 3]				
Constant	-.2517631947	2.5061846	-.100	.9200	
INFO	.5417320765	.32482780	1.668	.0954	2.7160121
LACKW	.2443309217	.31223398	.783	.4339	4.6586103
ACTIONS	-.2320820068E-01	.38673764	-.060	.9521	1.6948640
AGE1	.7336469971	1.7674726	.415	.6781	.59818731
AGE2	.3779839202E-01	1.2595443	.030	.9761	.32930514
CHID	-.6770343615	1.3556352	-.499	.6175	.43202417
EDU1	28.02713129	1348938.9	.000	1.0000	.30211480E-01
EDU2	.8216990654	1.2184533	.674	.5001	.12386707
EDU3	2.112078411	1.2065991	1.750	.0800	.47432024
INCOME	.5423405402E-03	.65617900E-03	.827	.4085	1096.7039
SEX	-.5471482733	.78669556	-.696	.4867	.49848943

Matrix: Las
[36,4]

Frequencies of actual & predicted outcomes
Predicted outcome has maximum probability.

	Predicted				
Actual	0	1	2	3	Total
0	0	0	1	7	8
1	0	0	4	20	24
2	0	1	16	91	108
3	0	4	7	180	191
Total	0	5	28	298	331

6.6. EViews outputs

Table 4.24. EVIEWS full output of Model 4.

Dependent Variable: LOGWTP3O
Method: Least Squares
Sample: 1 128
Included observations: 125
Excluded observations: 3

Variable	Coefficient	Std. Error	t-Statistic	Prob.
Constant	0.366203	0.124391	2.943965	0.0039
LOGINCOME	0.072626	0.031280	2.321822	0.0220
INFO	-0.014474	0.008618	-1.679455	0.0958
LACKW	-0.023155	0.012735	-1.818204	0.0717
ACTIONS	0.008537	0.010500	0.813066	0.4179
AGE1	0.007788	0.055836	0.139480	0.8893
AGE2	-0.045982	0.051290	-0.896520	0.3719
EDU3	-0.002711	0.022943	-0.118144	0.9062
EDU2	-0.064909	0.044514	-1.458165	0.1475
CHID	-0.024470	0.030958	-0.790442	0.4309
SEX	0.004917	0.020111	0.244491	0.8073
R-squared	0.176587	Mean dependent var		0.415108
Adjusted R-squared	0.104358	S.D. dependent var		0.113201
S.E. of regression	0.107132	Akaike info criterion		-1.545634
Sum squared resid	1.308397	Schwarz criterion		-1.296742
Log likelihood	107.6021	F-statistic		2.444817
Durbin-Watson stat	0.361848	Prob(F-statistic)		0.011091

Table 4.25. EVIEWS output for Model 5 (DB-DC data).

LogL: DOUBLE
Method: Maximum Likelihood (Marquardt)
Sample: 1 144
Included observations: 144
Evaluation order: By observation
Convergence achieved after 73 iterations

	Coefficient	Std. Error	z-Statistic	Prob.
B2(1)	2.241327	0.392483	5.710628	0.0000
B2(2)= INFO	-0.020615	0.028581	-0.721303	0.4707
B2(3)= LACKW	0.042560	0.041524	1.024960	0.3054
B2(4)= ACTIONS	0.015404	0.035405	0.435070	0.6635
B2(5)= AGE1	0.040227	0.203413	0.197759	0.8432
B2(6)= AGE2	0.105399	0.194864	0.540887	0.5886

B2(7)= CHID	-0.004371	0.083804	-0.052156	0.9584
B2(8)= EDU1	0.068528	0.460471	0.148822	0.8817
B2(9)= EDU2	-0.022510	0.122058	-0.184416	0.8537
B2(10)= EDU3	-0.046609	0.060323	-0.772666	0.4397
B2(11)= LOGINCOME	0.039741	0.082025	0.484492	0.6280
B2(12)= SEX	-0.059420	0.054315	-1.093985	0.2740
SCALE2(1)= -1/BID	0.274306	0.025720	10.66499	0.0000
Log likelihood	-192.6843	Akaike info criterion		2.856726
Avg. log likelihood	-1.338085	Schwarz criterion		3.124834
Number of Coefs.	13	Hannan-Quinn criter.		2.965670

Table 4.26. EVIEWS output for Model 6 for (DB-DC data)

LogL: DOUBLE7
Method: Maximum Likelihood (Marquardt)
Sample: 1 144
Included observations: 144
Evaluation order: By observation
Convergence achieved after 19 iterations

	Coefficient	Std. Error	z-Statistic	Prob.
Constant	0.362545	0.055469	6.536004	0.0000
INFO	-0.003575	0.004385	-0.815237	0.4149
LACKW	0.007216	0.007017	1.028298	0.3038
ACTIONS	0.002704	0.005489	0.492719	0.6222
EDU3	-0.007380	0.008938	-0.825687	0.4090
AGE2	0.011320	0.009744	1.161830	0.2453
LOGINCOME	0.005480	0.013873	0.395007	0.6928
GENDER	-0.010304	0.009058	-1.137534	0.2553
σ	0.046820	0.004271	10.96123	0.0000
Log likelihood	-194.1852	Akaike info criterion		2.822017
Avg. log likelihood	-1.348508	Schwarz criterion		3.007630
Number of Coefs.	9	Hannan-Quinn criter.		2.897439

CHAPTER 5.

CONCLUSIONS

This thesis is partly one more contingent valuation application among the numerous ones that have been conducted and presented in Contingent Valuation Method literature, up till today. Although this application does not add to the improvement and development of the contingent valuation method itself (i.e. the technical part or the econometrics of the method), its novelty lies on its being applied on a new concept, that of recycled water, which attracts the interest of countries with fresh water shortage problems.

The idea of pursuing this study was drawn by specific articles and principles of the 60/2000 Water Framework Directive. According to them, recycled water evaluation can be viewed as a corollary of this directive (Tsagarakis, 2005). Since Crete is a European region with intense water shortage problems, this was a good opportunity to apply the suggestions of the directive: solve the problem of water shortage internally (i.e. in Crete, with the island's own means and plans, since Crete can be regarded as a single river basin district), make the most of marginal waters while at the same time enhancing the environment.

The purpose of this chapter is to summarize and connect the content and the conclusions we derived in the previous four chapters and answer whether and how these results could lead to policy results or policy suggestions. Emphasis is laid

specifically on the issues of recycled water pricing and the information of the public as regards recycled water potential.

In addition to the above, this chapter looks back at the initial aims and objectives of the study and answers whether and up to what degree they have been fulfilled. Last, directions for further research are provided.

1. Summary results

This section gives a summary of the most important findings of this research. Section 1.1 summarizes main results from chapter 2 while section 1.2 does the same for chapters 3 and 4.

1.1. Irrigation water shortage in Crete

Although our research has been motivated by the water shortage situation experienced in Crete, we realize, contrary to this, that water quantity if taken as a yearly total is adequate to cover water needs for the island of Crete. Water shortage problems appear because of the peculiar morphology of the island and the lack of infrastructure capable to save winter water and use it during the dry summer months (Tsagarakis *et al*. 2004) when demand is higher due to irrigated agriculture and tourism.

This is the reason why water shortage is reflected in the demand function (section 3 in chapter 2), but it is not reflected in the production function (section 4 in chapter 2). Therefore when we study total, average and marginal products of recycled water, we experience falling average and marginal product (also sometimes negative) in the production of olive oil. This contradicts our claim about water shortage, because if the claim about water shortage were valid, then we would

witness an increasing average and marginal product (at least for the first water units) in olive oil production. However, the water shortage claim is valid, indeed, during summer months. Thus, it would be more suitable to speak of water imbalances rather than water shortage that lead us to seek resource to recycled water.

There is not a significant relationship between water quantity and price. Demand is little responsive to price changes, namely it is inelastic showing that water is necessary for the cultivations.

1.2. Social acceptability and evaluation of recycled water in Crete

The reason we have performed the two surveys, one for farmers (chapter 3) and one for consumers (chapter 4) is because the usage of recycled water in agriculture presupposes consumers' consent, since the latter are the indirect users of recycled water through the consumption of food products irrigated with recycled water. If farmers were willing to use recycled water for irrigation, but consumers were not willing to consume the products irrigated with recycled water, then there would be no point for the former to cultivate any products irrigated with recycled water and maybe vice versa. Namely there is not much point for consumers to be willing to consume products which farmers are not willing to cultivate. Therefore, we needed to study both sides of the coin. The basic conclusion is that there is social acquiescence on the usage of recycled water. Farmers agree to use recycled water for irrigation purposes and consumers accept it as an ingredient of their food, because they are willing to incorporate it in their food purchasing habits.

Furthermore, based on the results of the models we have estimated in chapters three and four, we generally conclude that the reasons that will make farmers use recycled water is fresh water scarcity (which implies that it will be costly

as well) together with their profit maximizing behavior as businessmen. Consumers, on the other hand, will use recycled water if they become more informed on recycled water benefits and perils from its usage. This way they will be able to realize the utility they can derive from recycled water and use it.

Table 5.1. Research product directory.

Product	Sample of:	Product description:
1	Farmers	Recycled water of quality 2 for the irrigation of the olive tree
1a	Farmers	Recycled water of quality 3 for the irrigation of the olive tree
2	Farmers	Recycled water of quality 3 for the irrigation of the tomato plant
3	Consumers	Olive oil irrigated with recycled water of quality 2
3a	Consumers	Olive oil irrigated with recycled water of quality 3
4	Consumers	Tomatoes irrigated with recycled water of quality 3
5	Consumers	Park irrigated with recycled water of quality 2

Note: Products 1a and 3a have been used as some means of investigating the existence of scope effects.

The aforementioned social acquiescence on recycled water usage is confirmed by the general correspondence of willingness to use recycled water between farmers and consumers (Table 5.2). Farmers are willing to use recycled water in agriculture (products 1, 1a and 2) and consumers are willing to use the food products produced with recycled water irrigation (products 3, 3a and 4). Table 5.2 shows that as regards product 1 (the equivalent for consumers is product 3) and product 1a (for consumers it is 3a), consumers are more willing to use them than farmers.

For the most dangerous products, consumers are more willing to use product 4 than farmers are for product 2, but this probably has to do with a defect of our research, i.e. that most of the research participating farmers were not systematic tomato cultivators. And since they cultivated tomatoes only occasionally, the willingness to use question on product 2 was more of a hypothetical nature to farmers.

Table 5.2. Willingness to Use comparison between farmers and consumers.

Farmers \ Consumers	Olive oil irrigated with recycled water of quality 2	Olive oil irrigated with recycled water of quality 3	Tomato irrigated with recycled water of quality 3
Recycled water of quality 2 for the irrigation of the olive tree	80.7%		
Recycled water of quality 3 for the irrigation of the olive tree	75.7%	92.7%	
Recycled water of quality 3 for the irrigation of tomato		78.4%	63.2% 65.3%

Note: This is a double-entry table where only diagonal cells contain information.

1.3. Factors affecting society's Willingness to Use and Willingness to Pay for recycled water

Willingness to Use and Willingness to Pay should not be seen in isolation from each other. From the first, we derive conclusions about which characteristics of people (farmers and consumers) are more likely to lead to the acceptance of recycled water from society. From the second, we conclude which characteristics will lead to the formation of a higher or lower bid for recycled water or the products irrigated with recycled water.

Table 5.3 contains a summary of all the models for both farmers and consumers (model enumeration in this table is independent from chapter 3 and 4). The significant variables are those that affect Willingness to Pay or Willingness to Use. Studying them leads to the following policy conclusions: A comparison between Models 1 and 2 and Models 3 to 5 leads us to believe that consumers in their attitude towards recycled water behave more as citizens while farmers behave as businessmen. This means that consumers appear to care for society welfare while

farmers are driven by profit considerations. We are led to believe so because awareness variables became significant mostly in consumers' models. This means that their Willingness to Use is affected by how high their environmental concern is.

Farmers' Willingness to Use on the other side, was mainly and dominantly affected by income. This is why we believe they behave as businessmen. This point of view is also strengthened by the fact that no other demographic variables were found to affect farmers' Willingness to Use for product 1, e.g. age did not affect farmers' Willingness to Use. It did affect consumers' Willingness to Use though. Younger consumers were more willing to Use the "more dangerous" (lower quality and higher health risk bearing) recycled water products.

Table 5.3. Willingness to Use and Willingness to Pay models for farmers and consumers

	WTU Models					WTP Models			
	Farmers		Consumers			Farmers		Consumers	
Variable	Product 1 (Model 1)	Product 2 (Model 2)	Product 3 (Model 3)	Product 4 (Model 4)	Product 5 (Model 5)	Product 1 (Model 6)	Product 2 (Model 7)	Product 3 (Model 8)	Product 3 (Model 9)
INTERCEPT	0.81 (0.47)	-2.29 (0.02*)	-0.00 (0.99)	-1.31 (0.09*)	2.67 (0.00*)	-0.91 (0.00*)	-1.04 (0.00*)	0.36 (0.00*)	2.24 (0.00*)
INFO	-0.05 (0.61)	0.15 (0.16)	0.27 (0.00*)	0.16 (0.04*)	0.03 (0.74)	0.00 (0.56)	0.0001 (0.51)	-0.01 (0.09)	-0.02 (0.47)
LACKW	0.26 (0.01*)	0.05 (0.69)	0.18 (0.10)	0.24 (0.02*)	0.05 (0.69)	-0.00 (0.77)	-0.0004 (0.26)	-0.02 (0.07)	0.04 (0.30)
ACTIONS	0.09 (0.51)	-0.33 (0.02*)	0.25 (0.03*)	0.31 (0.00*)	0.20 (0.10)	0.00 (0.63)	0.0005 (0.13)	0.008 (0.41)	0.01 (0.66)
WPRICE	0.85 (0.37)	0.01 (0.95)	---	---	---	0.00 (0.15)	0.0006 (0.02*)	---	---
INCOME	0.00 (0.08)	0.00 (0.68)	-0.0003 (0.04*)	-0.0002 (0.13)	0.0001 (0.34)	---	---	---	---
LOGINCOME	---	---	---	---	---	0.0003 (0.00*)	0.0001 (0.08)	0.072 (0.02*)	0.04 (0.62)
AGE1	-0.17 (0.77)	0.47 (0.40)	0.63 (0.20)	1.58 (0.00*)	0.45 (0.40)	0.02 (0.77)	0.05 (0.50)	0.007 (0.88)	0.04 (0.84)
AGE2	-0.53 (0.12)	0.06 (0.84)	0.64 (0.12)	0.87 (0.05*)	0.70 (0.13)	0.06 (0.15)	0.01 (0.72)	-0.045 (0.37)	0.10 (0.58)
EDU1	-0.98 (0.25)	0.02 (0.97)	-0.40 (0.63)	0.78 (0.27)	-0.18 (0.81)	0.12 (0.03*)	0.06 (0.42)	---	0.06 (0.88)
EDU2	-0.63 (0.35)	1.12 (0.02*)	-0.19 (0.65)	-0.31 (0.39)	0.15 (0.69)	-0.02 (0.46)	-0.00 (0.96)	-0.064 (0.14)	-0.02 (0.85)
EDU3	-0.80 (0.21)	1.07 (0.01*)	-0.25 (0.32)	-0.34 (0.13)	0.13 (0.60)	-0.09 (0.01*)	-0.06 (0.18)	-0.002 (0.90)	-0.04 (0.43)
SEX	-0.36 (0.45)	0.78 (0.03*)	0.62 (0.00*)	-0.08 (0.70)	-0.05 (0.80)	0.04 (0.48)	0.104 (0.10)	0.004 (0.80)	-0.06 (0.27)
CHID	-0.41 (0.43)	0.35 (0.46)	0.06 (0.83)	0.52 (0.09)	-0.70 (0.03*)	0.007 (0.90)	0.108 (0.15)	-0.02 (0.43)	-0.004 (0.95)
HERA	0.62 (0.05*)	1.58 (0.00*)	---	---	---	-0.01 (0.78)	-0.014 (0.82)	---	---
σ	---	---	---	---	---	---	---	---	0.27 (0.00*)
Cutoff Points	---	---	0, 0.53, 3.13	0, 0.99, 2.95	0, 1.48, 3.48	---	---	---	---
Sample size	383	346	326	321	331	288	239	125	144
Pseudo R^2	0.07	0.11	0.05	0.05	0.03	---	---	---	---
Adj R^2	---		---	---	---	0.038	0.02	0.10	---

INFO: How informed the respondent thinks he is on environmental problems (categorical variable with values from 1-5, with 1=the least informed and 5=the most informed) **LACKW:** What is the significance of water shortage as an environmental problem? (Categorical variable with 1= least significant and 5= very significant, **ACTIONS:** How many of the following environmental friendly actions are you engaged to? (count variable ranging from 1 to 3), **WPRICE:** Fresh water price in € per m^2, **INCOME:** Monthly family income in € (10 income groups available), **LOGINCOME:** Logarithm of income, **AGE1:** Dummy variable (DM) with 1if respondent is from 18-34 years old, 0 if otherwise, **AGE2:** D.V. (1if respondent is from 35-54 years old, 0 if otherwise), **EDU1:** D.V.(1if respondent is illiterate, 0 if otherwise), **EDU2:** D.V.(1if respondent is primary school graduate, 0 if otherwise), **EDU3:** D.V.(1if respondent is secondary school graduate, 0 if otherwise), **SEX:** D.V. 1 if respondent is a man and 0 a woman, **CHID:** D.V. with 1 if respondent has children and 0 if he does not, **HERA:** D.V. with 1= if respondent comes from Heraklion prefecture and 0 if otherwise. Note: Numbers in parenthesis are p-values. Stars indicate significance at 5%.

The supply of more detailed recycled water relevant information to consumers will increase their Willingness to Use of food products irrigated with recycled water. As we see from Willingness to Use of product 4, there is a lot of room for the role information can play and make us hope for the consumption of even more sensitive products than the tomato. Namely, if more information makes consumers realize the utility they can derive from the consumption of products irrigated with recycled water (this will be done by reducing their risk worries), all the cutoff points of models 3, 4 and 5 would be moved to the left, because more consumers would be positively rather than negatively positioned in front of products irrigated with recycled water and more would be "definitely positive" rather than "maybe positive" or "maybe negative".

As far as Willingness to Pay is concerned, both consumers' and farmers' Willingness to Pay was affected mainly by income and pecuniary variables such as the price of fresh water. Especially for farmers' Willingness to Pay, we need to note first that it is negatively affected by the years spent in education. Second, for the more dangerous products (such as product 2) farmers make a tradeoff between profit and health. They obviously acknowledge that the cost of the risk their health runs from recycled water consumption is very small compared to the benefit of cost minimization. This is why no other variable was significant except for fresh water price. A policy conclusion from this, is that if government charges fresh water with an economic price so that it reflects its scarcity, fresh water will become more expensive. More farmers (large and small incomes) will turn to recycled water then.

2. Policy conclusions

Based on the results we received from Willingness to Use and Willingness to Pay models, we conclude that two major instruments could be used for persuading people to use recycled water and its related products. One is both recycled water and fresh water pricing and the other is information and learning about the concept of recycled water.

2.1. Recycled water pricing clues

Pricing is one of the tools in the marketing mix (planning and strategy) used for a product. From the model results in Table 5.3 we gather that recycled water pricing will have a role to play in whether it will be used and bought by society. Therefore, it is worth spending some time discussing how a price for recycled water should be set.

All standard marketing textbooks (e.g. Kotler, 1991) report the factors that affect price formation. These prices can be summarized as the ones "inside the business" and the "out-of business factors". The former include: i) aims and objectives of pricing, ii) all the other elements included in the marketing mix for a product and iii) the cost of the product. The latter include: iv) competitors' prices, v) buyers' behavior, vi) the economic environment, vii) legislation.

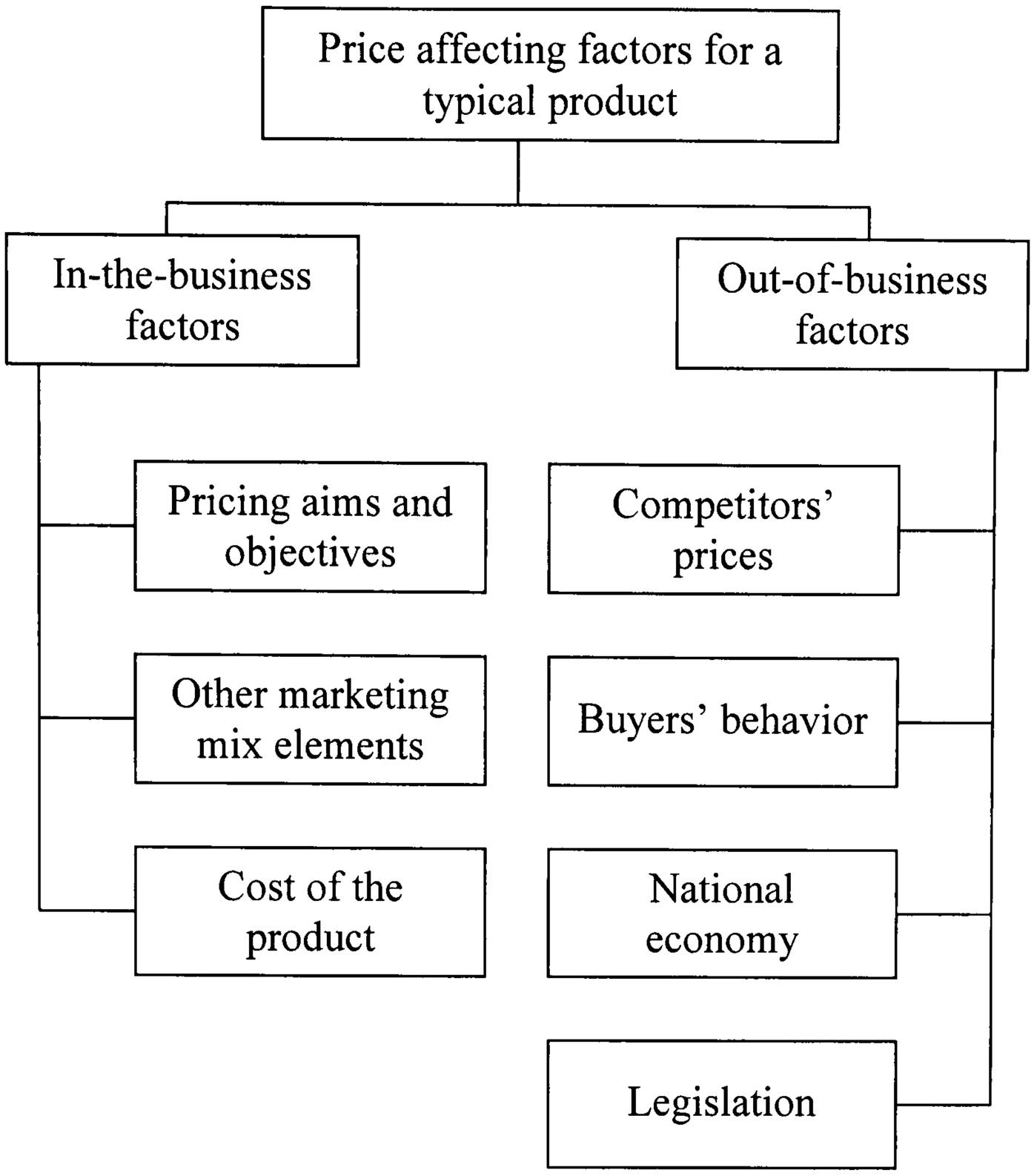


Figure 5.1. Factors determining the price of a product (Malliaris, 2001)

Before commenting on how each of the above factors affects the price for recycled water, we need to say who the seller of recycled water will be. Sellers of recycled water are going to be municipality enterprises (they are called DEYAs in Greek), which are currently the owners and administrators of wastewater treatment plants. Therefore, all the other seller types mentioned in section 1.7 in chapter 1 cannot exist in this market. For example, the private well owner cannot be a seller of recycled water, because he does not have property rights on it. Municipality enterprises are not-for-profit organizations (Law 1069/1980) and they exist in municipalities with a population higher than 10,000 inhabitants. This, of course, renders the application of irrigation with recycled water an infeasible option for smaller municipalities.

Now let us see how the factors presented in Table 5.1 are taken into consideration to form a price for recycled water. As regards the first factor, the only

aim of a non-for profit business is the coverage of cost (whatever that includes). Profit maximization, sales increase, confrontation of competitive firms, strengthening of qualitative superiority or cost leadership can constitute some of the objectives of a for-profit business but the not-for profit business cares only about covering the cost and sometimes not even that, because it is subsidized by government.

Factor number two concerns taking into account which stage of the product cycle the product under study is in, e.g. it is a common practice that when a product is launched in the market for a first time, a high price is assigned because there is no competition, production cost is high and consumers will buy the product anyway (Malliaris, 2001). In addition to the above, factor number two encompasses product distribution and promotion plans. Noteworthy is that for recycled water, there is no distribution network available for the irrigation of the olive tree or the tomato for the moment and, which is more, no estimation of its cost is available either. As regards the promotion of recycled water, both "push" and "pull" strategies are necessary. Our surveys bear elements of a push strategy. Push strategy means that the seller goes to a potential buyer and exerts influence on him, trying to persuade him to buy. Pull strategy means that the seller waits for buyers to come to him and order for products. Push strategies are maybe necessary, at the beginning, until consumers of recycled water become acquainted with it.

According to factor 3, the price of a product must cover at least its production cost. Recycled water production cost consists of the depreciation cost for the wastewater treatment plants, their administration cost and the depreciation cost of the infrastructure and distribution network for recycled water. The latter has not been calculated yet. Of course, we know that wastewater treatment plants would be constructed anyway since societies want cleaner seas and a cleaner environment. So,

they were not constructed with the sole purpose to produce recycled water for irrigation. This turned out to be a kind of side-purpose. Therefore, some of the construction cost of wastewater treatment plants should be paid through the price of recycled water and another part through taxes paid by all tax-payers, who must bear the cost for cleaning the seas and the environment (which are public goods) from raw wastewater.

Table 5.4. Calculation of a price for recycled water

Total fixed cost (the part allocated to recycled water for irrigation)	X1
Total variable cost	X2
Total cost	X1+ X2
Recycled water quantity in m3	X3
Average cost	X4 =(X1+ X2)/ X3
Mark up (a minor plus above cost)	X5
Selling price of recycled water	X4 + X5

Normally the price of recycled water will be placed somewhere between its production cost which is the floor pricing and a ceiling price which depends on the evaluation of the characteristics of recycled water by its buyers (this is going to give the fixed mark up, X_5 as shown in Table 5.4). The priority, at a first stage, would be to set prices so that revenue covers cost (pricing at the break-even point). Next, after learning and information effects will have taken over, recycled water can be priced based on its "perceived value", namely the value that has been realized from practical experience from this good. This will increase the price mark up. Two elements form the "perceived value" of recycled water. The first is that recycled water, under ideal conditions can fully replace fertilizers and the second is the environmental benefit we get from saving fresh water for other purposes and safeguarding water resources equilibrium. When people understand and believe in these two attributes of recycled water, sellers may be able to set prices higher. Last,

to encourage consumption, authorities could try discriminating pricing with specific deductions, which will reward increased demand.

Passing to out-of-business factors, we start with competitors' prices, which in the case of recycled water, are fresh water prices. Fresh water is cheap, as we have explained in chapter 1. Recycled water has to be cheaper than fresh water in order to be bought by farmers. Evidence for this is willingness to pay of farmers for recycled water, which is about one third of the price of fresh water. It is understandable that wastewater pricing cannot be correctly implemented unless fresh water pricing is rectified to reflect all relevant costs, i.e. unless "full cost pricing" or the "polluter pays principle" takes place in fresh water sector. We are using the word "correctly" because, since it is generally admitted that fresh water is too cheap and this is a problematic situation, not signaling its true economic value, leading to its reckless use, then, if recycled water price is anchored to the fresh water price, the same problematic situation is going to be perpetuated.

Buyers' behavior is factor number five. This factor encompasses elements such as the idea buyers have for the product, the quantity and the frequency they buy, the elasticity of demand with respect to price. Studying the Willingness to Use of both farmers and consumers, we see that they are positive towards the product. Of course, this is stated and not revealed preference. Society says they want to use recycled water, but it is not known whether they will use it when they are actually offered it. This is also the reason why we cannot build a reliable demand curve for recycled water.

Factor number six is about the state of the economy. Macroeconomic figures such as inflation, unemployment etc influence prices of all products.

Factor number seven can give the answer to the formation of a price for recycled water, by forcing, or better, motivating farmers to use recycled water when available. Since, not all the irrigation water demand can be covered by recycled water, emphasis could be placed on the irrigation of specific products such as the olive tree under study. Currently, there are no laws imposing the use of recycled water. Understandably enough, this is not going to be easy, because more planning has to be done. For example, a special service for the surveillance on safe recycled water practice has to be set up first and foremost. This was a major concern expressed by the majority of respondents in the surveys and if it is not established, it will put at stake the whole venture.

An example of fresh water price correction supported by a legal framework would be the "pay-as-you-don't use recycled water in cases where you could" analogously to the "pay-as-you-pollute" principle. When it is about uses except for the domestic ones, recycled water is safe to use. If people nevertheless do not use it, they could be penalized for this. The penalty should be incorporated in the fresh water price bills they are charged.

2.2.The dissemination of information

The topic of the present thesis was part of a larger project that, among others, included the dissemination of information to people in Crete about recycled water potential. The questionnaire completion was preceded by a comprehensive information session and the distribution of a booklet with pictures and examples, most of which are included in part 2 of chapter 1.

Another part of the project involves the dissemination of recycled water information to schoolchildren by experts and to citizens in municipal hall rooms.

Such actions are very important for familiarizing people with recycled water. Informed consumers of environmental problems and water shortage have been found to be more likely to use recycled water food products. Therefore, information constitutes another important instrument besides pricing that can lead to the wider and quicker acceptance of recycled water. Contrary to our belief, an Australian report by Po *et al.* (2005) reveals that knowledge did not emerge as a factor in people's decisions to drink recycled water. They also add that there is frequent rejection of recycling schemes in the world despite any comprehensive communication and education programmes. The impact of emotions cannot be reduced. Last they admit *that the provision of comprehensive and open information is a factor of engendering trust, so the role of knowledge should not be underestimated, but also not be seen as an end in itself. It should form an integral part of the community partnership in the development of acceptable recycling schemes.*

3. Research problems; an account

During the present research a couple of problems were encountered and modified the perspectives from which things had to be examined (all of them concerned the analysis in chapter 2). These problems could not have been predicted, because the thesis writer had not been familiarized, well in advance, with all the theoretical tools she was going to need later in the research. Besides, as it often happens in research, one learns by doing and sometimes one cannot see the problem unless he is faced with it. Although a more descriptive analysis of the data has been performed in chapter 2, we still managed to get some useful insights.

The first problem is about the production function data in the farmers' questionnaire. The initial aim was to get the shadow price of water through the

typical maximization of the farmers' profit function and come up with an economic price of water, which in turn would give some suggestions about the price of recycled water. However, because Crete is a small territory, there is no variability in input prices among farmers and hence no cost function could be estimated. Under these circumstances, only a production function was feasible to estimate.

Another problem was the numerous missing values received from farmers in the various input questions. Farmers did not have all these numbers ready in their minds and it was difficult for them to make estimations. Thus, if one input response would be left unanswered, this invalidated the whole observation, since no logs could be taken in zeros. Initially the writer thought she could overcome the problem by replacing zeros with a very small number, like 0.001. The idea was abandoned, since this would destroy the mean and variance properties of the data, and the numeric coefficients she would estimate would be meaningless (Malley, 2004).

Although on first sight, the number of observations collected for both surveys is satisfactory (neither large nor small), after having observed the poor fits of most models, it is felt that the double or triple number of data would probably have produced models with better fits. Furthermore the usage of sensitivity analysis during the data collection, i.e. its usage in a prognostic way rather than in a diagnostic would have given more information on the sample. However, we have used it only as a diagnostic tool.

The data at hand have been collected through a project that was financed by the Greek Ministry of Environment, with the valuable contribution of ten trained undergraduate students plus two more people one of which is the writer of the thesis. Data collection took place in summer 2003. It is understandable that the farmers' data were the most difficult to collect, since farmers had to be reached in distant

villages all over Crete through a bad road network. Communication with farmers was also difficult, since they could not perceive the meaning of the research and we could not dissolve their natural suspicion that we may use the data for purposes other than the ones stated.

4. Directions for further research

The study of a certain topic usually generates new queries, which demand further studying and constitute themselves topics for further research sometimes capable of filling the content of a whole new PhD thesis. Below, we report some of these points only for chapters 3 and 4, because chapter 2 has been discussed under section 3. All the points raised in the previous section constitute potential points for further research in chapter 2.

4.1. Further research for chapter 3

This sub-section summarizes some points for further research that could take place for chapter 3. Items 4 and 5 could be realized only in the context of a new financing programme similar to the one financing the survey, where this chapter stemmed from.

i. By taking the log WTP, we have worked under the normal distribution assumption. It would be interesting to see what other assumptions produce such as the beta or gamma distributions.

ii. We have omitted "Don't know" answers assuming they meant nothing, i.e. they were random. It would be interesting to see how coefficients and mean WTP would have changed if we took them to mean "no" and then "yes".

iii. The usage of a different link function, such as probit instead of logit etc.

iv. Because recycled water is a relatively new concept for farmers and given their generally low education level, we could further study how they are affected by information. We could for example repeat the survey in the same villages, not necessarily the same respondents, a year later and find out whether more farmers are WTU recycled water for irrigation or whether they are WTP higher amounts. After the day the survey took place, farmers would certainly have talked with their peers and other villagers about this and information must have spread. Repeating the survey would lead to measuring this effect.

v. Replacing the term "recycled water" in the survey with "recycled wastewater" could also constitute a point for further research. This would give evidence of the sensitive role the wording in a contingent valuation study plays.

vi. Of course more variations of the WTP question could be adopted such as a payment card etc.

vii. Split the survey in two shorter ones; one aiming only at the collection of production function data and one aiming at the WTU and WTP of farmers. This would have safeguarded more the quality of the farmers' survey, making sure that farmers would not get tired of answering such a long questionnaire such as the one they did.

4.2. Further research for chapter 4

All the above points mentioned in sub-section 4.1 could be applied for the consumers' sample too. In addition to the above, we could also suggest the following:

i. Collapse the adjacent WTU categories so that we have a simple dichotomous answer pattern and compare the results, between the ordered logit and simple binary logit results.

ii. Achieve a larger sample in the double bound dichotomous choice question so that we get more reliable results.

iii. Choice modeling could be perused in consumers survey instead of CVM or together with CVM for reasons of comparison.

References

Kotler P. (1991). Marketing Management, EMI Interbooks, pp.616.

Malley J. (2004). Personal communication, University of Glasgow

Malliaris P.G. (2001). Introduction in Marketing, 3rd Edt., Stamoulis Publications, pp.718

Po M.B., Nancarrow B.E., Levinston Z., Porter N.B., Syme G.J., and Kaercher J.D. (2005). Predicting Community Behavior in Relation to Wastewater Reuse, What Drives Decisions to Accept or Reject?, supported by the Natural Heritage Trust in Australia, National Programme on Sustainable Irrigation and CSIRO, pp. 117.

Tsagarakis K.P. (2005). Recycled water valuation as a corollary of 2000/60/EC directive, *Agricultural Water Management*, **72**, 1-14.

Tsagarakis K.P., Dialynas G.E. and Angelakis A.N. (2004). Water resources management in Crete (Greece) and proposed quality criteria for use of recycled water in the Mediterranean region. *Agricultural Water Management* **66(1)**, 35-47.