TABLE OF CONTENTS

PREFACE vii
1. INTRODUCTION 1
1.1 Setting the Scene 1
1.2 The Science of Weather and Climate Change 1
1.3 Weather and Transport: Literature Review 2
1.4 Role of Weather and Climate Change for Travel Behaviour 8
1.5 Scope of the Thesis 10
1.6 Research Organization 11
Appendix 1A 13

PART I: WEATHER AND INDIVIDUAL TRAVEL CHOICES

2. WEATHER TO TRAVEL TO THE BEACH 17
2.1 Introduction 17
2.2 Data 19
2.3 Estimation Results 21
2.4 Conclusions 24
Appendix 2A 25
Appendix 2B 26

3. IMPACT OF WEATHER ON DAILY TRAVEL DEMAND 27
3.1 Introduction 27
3.2 Data and Variables 29
3.3 Theoretical Model and Estimation 31
  3.3.1 Demand Measured by Number of Trips 31
  3.3.2 Demand Measured by Total Distance Travelled 32
3.4 Empirical Results and Discussion 33
  3.4.1 Number of Trips 33
  3.4.2 Total Distance Travelled 38
3.5 Conclusions and Policy Implications 40
Appendix 3A 42
Appendix 3B 44
Appendix 3C 46

4. IMPACT OF WEATHER ON MODE CHOICE DECISIONS 49
4.1 Introduction 49
4.2 The Data and Model Specification 51
  4.2.1 Data and its Sources 51
  4.2.2 Model Specification and Explanatory Variables 54
4.3 Estimation and Results 55
  4.3.1 Estimation 55
  4.3.2 General Results 55
  4.3.3 Specific Results 56
4.4 Conclusions and Policy Implications 62
Appendix 4A 63
Appendix 4B 63
## PART II WEATHER AND TRAVEL TIME

### 5. ADVERSE WEATHER AND COMMUTING SPEED
- 5.1 Introduction 69
- 5.2 Theory and Estimation Methods 71
  - 5.2.1 Theoretical Background 71
  - 5.2.2 Assumptions Regarding Conditions of Error Terms 72
- 5.3 Data and Model Specification 73
- 5.4 Results 75
  - 5.4.1 Speed 75
  - 5.4.2 Reliability 78
- 5.5 Conclusions 79
- Appendix 5A 80

### 6. WEATHER AND TRAVEL TIME OF PUBLIC TRANSPORT TRIPS
- 6.1 Introduction 81
- 6.2 Data 84
- 6.3 Model Specification and Estimation Procedure 85
- 6.4 Results and Discussions 87
  - 6.4.1 Speed of Bus, Tram and Metro Trips 87
  - 6.4.2 Speed of Train Trips 90
- 6.5 Welfare Effects Through Changes in Travel Time 91
- 6.6 Conclusions 92
- Appendix 6A 94

## PART III: WEATHER AND ROAD SAFETY

### 7. WEATHER AND HOURLY ROAD ACCIDENTS
- 7.1 Introduction 97
- 7.2 Literature Survey 98
- 7.3 Econometric Model 101
- 7.4 Data 101
- 7.5 Estimation and Findings 103
- 7.6 Weather and Percentage Share of Road Accidents 108
- 7.7 Summary and Conclusion 112
- Appendix 7A 112
- Appendix 7B 113
- Appendix 7C 114
- Appendix 7D 115

## PART IV: SUMMARY AND POLICY IMPLICATIONS

### 8. SUMMARY AND POLICY IMPLICATIONS
- 8.1 Concluding Remarks 119
- 8.2 Part I 120
- 8.3 Part II 121
- 8.4 Part III 122
- 8.5 Relevance of Findings 122
- 8.6 Future Research 123

## REFERENCES

## SAMENVATTING (SUMMARY IN DUTCH)
### LIST OF TABLES

1.1 Weather and travel behaviour ........................................... 10
1A Summary of major future climate change expectations ........... 13
2.1 The marginal effects of weather conditions from the Nested Logit Model 23
2A.1 Descriptives of variables ............................................. 25
2A.2 Nested Logit Model for destination choice and mode choice .... 26
3.1 Impact of weather conditions on individual daily trips .......... 35
3.2 Impact of weather conditions on daily distance travelled per person 39
3A.1 Number of recorded trips and individuals .......................... 42
3A.2 Mode shares (percentages) year 1996-2005 ....................... 42
3A.1 Descriptives of daily weighted averages of variables .......... 43
3A.2 Descriptives of trips and distances per person per day .......... 43
3B.1 Negative binomial model for number of trips per person per day (for various transport modes) 44
3B.2 Negative binomial model for number of trips per person per day (for various trip purposes) 45
3C.1 Marginal effects of the Tobit model for number of kilometres travelled per person per day (for various transport modes) 46
3C.2 Marginal effects of the Tobit model for number of kilometres travelled per person per day (for various trip purposes) 47
4.1 Percentage of mode share of different trip purposes (1996-2005) 52
4.2 Weather and mode choice decision (summary of findings) ....... 56
4.3 Commuting trips (percentage-point changes) ...................... 57
4.4 Educational trips (percentage-point changes) ...................... 57
4.5 Recreational and sports trips (percentage-point changes) ....... 58
4.6 All trips combined (percentage-point changes) ................... 58
4A Descriptives of variables .............................................. 63
4B.1 MNL models, fit ...................................................... 63
4B.2 Marginal effects of MNL models ...................................... 64
5.1 Analysis of logarithm of speed of car commuting trips .......... 77
5A.1 Descriptive statistics of variables used in empirical model (N=45,534) 80
6.1 Analysis of the logarithm of speed of public transport commuting trips (individual specific effects) 88
6.2 Welfare effects of weather through changes in travel time ....... 92
6A.1 Descriptive statistics of variables included in the empirical analyses 94
7.1 Road accidents in the Netherlands (2000-2009) ................. 102
7.2 Descriptives of hourly road accidents per region (2000-2009) .... 102
7.3 Percentage changes in the number of hourly road accidents due to weather conditions 105
7.4 Percentage changes in number of hourly road accidents due to weather conditions 108
7.5 Percentage changes in shares of different types of accidents .... 109
7A Descriptives .......................................................... 112
7B Results of negative binomial models on numbers of hourly accidents 113
7C Direct influence of weather on road accidents (results of Poisson hourly-fixed-effects models) 114
7D Results of OLS .................................................. 115
LIST OF FIGURES

1.1 Thesis layout 12
2.1 Beach locations in the Netherlands 21
2.2 Destination choice and mode choice 22
3.1 Temperature variation and relative changes in number of trips 34
3.2 Impact of variation in wind and precipitation on number of trips 34
3.3 Seasonal variation and relative changes in number of trips 34
4.1 Temperature and mode choice 52
4.2 Wind strength and mode choice 53
4.3 Precipitation per hour and mode choice 53
4.4 Snow and mode choice 53
7.1 Hourly road accident outcomes (fatal, serious, minor, and other injury) (reference period: 12:00-13:00) 106
7.2 Hourly road accident outcomes (material damage, total injured, and total accidents) (reference period: 12:00-13:00) 108
7.3 Percentage change in share of fatal accidents (reference period: 12:00-13:00) 109
7.4 Percentage change in share of injury accidents (reference period: 12:00-13:00) 110
7.5 Percentage change in share of injuries (combined) and material-damage accidents (reference period: 1200-1300) 110