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Department of Transport

DANISH LONG DISTANCE TRAVEL

A STUDY OF DANISH TRAVEL BEHAVIOUR AND THE ROLE OF INFREQUENT TRAVEL ACTIVITIES

PhD Thesis

Mette Aa. Knudsen, DTU Transport

May 2014

ABSTRACT

INTRODUCTION AND SUMMARY OF THE THESIS

Historically there has been a lack of knowledge with respect to long distance travel. Due to the considerable contribution of long distance travel to total travelled kilometres and the related energy consumption from the transport sector and derived impacts on greenhouse emissions, this is problematic. The average travel distance has steadily increased during the latest decades together with the increasing motorisation of daily travel and international aviation. Previously most focus has been on domestic daily travel activities, but globalisation has, together with changes in price structures and increasing income, emphasised a travel type segment with significant impact on the total level of travelling. International travel has increased its market shares considerably, and the strong relation with income changes suggests a travel type segment of significant importance regarding future travel behaviour and emissions from transportation in particular.

The work of this thesis is not limited to a distinct definition of long distance travel, but explores long distance travel in a broader context. The analysis applies data from three different travel surveys: The Danish National Travel Survey (TU), the TU overnight survey, and the Danish Tourism Statistics from the Business and Holiday Survey (HBS). This has enabled focus on infrequent travel activities segmented relative to travel purpose, distance threshold, or travelling with overnight stays. At an overall level the thesis has three main objectives: i) to describe and combine empirical knowledge on Danish travel behaviour in relation to long distance travel, ii) to provide information on the troubles and uncertainties related to different travel survey methodologies, and iii) to reveal some of the drivers of long distance travel related to e.g. socio-economic variables.

The analysis of Danish travel activities described in the three different travel surveys has outlined detailed information on Danish travel behaviour at an aggregated level during the past two decades. It has above all revealed the significant role of leisure travel. Private travel represents more than 60% of all travelled kilometres by individuals, and almost 25% alone stem from international holiday tourism even though international holiday travels represent only 0.1% of all travel activities.

The study of holiday tourism has outlined some apparent trends that are of high relevance when considering future emissions from transportation. Besides the fact that the share of Danish holiday travellers has increased, the characteristics of the holiday activities have changed as well. The number of domestic holiday activities has stayed more or less constant and the growth is mainly observed in international travel and travel by plane in particular. The development in destinations is two-fold, with a substantial growth in destinations outside Europe as well as a significant growth in European weekend holiday activities. These travel activities are furthermore found to be more sensitive to income changes.

The analyses of the three travel surveys also contribute to a validation of different survey methodologies and their ability to describe travels, with overnight stays, in a comprehensive way. The comparison of the travel surveys outlines the classical trade-off between sample sizes and survey uncertainties related to tailored retrospective travel surveys. From a three month retrospective survey it is found that travels with overnight stays are underestimated by 11%, but also that a retrospective survey period is necessary to achieve representative samples. The memory loss of respondents is certainly present in a retrospective survey focussing on multiday travel even though travel activities with overnight stays, intuitively should be easier to recall than e.g. travelling above a specific distance threshold. The analysis stresses the importance of further targeting the travel activities of interest to reduce the impacts of memory loss or on the contrary to reduce the survey period.

In addition to the descriptive statistics and the comparison of different travel surveys presented in part I of this thesis, the thesis includes four studies of travel behaviour presented in paper form in part II.

The first paper outlines and exemplifies the presence and magnitude of different survey biases in the Danish National Travel Survey (TU). The study finds that response biases are heterogeneously distributed across the population and that the bias leads to significant overestimation of car ownership and a consequently underestimation of the respective income elasticity. The study evaluates the impact of measurement error and reveals considerable problems in the data collection of income which in this case reduces the income elasticity.

The second paper includes all three Danish travel surveys in a study of leisure travel, with an analysis of the income elasticity of this travel segment. Due to the different survey methodologies, the samples of leisure activities describe the whole span from daily leisure travel activities embedded into people's daily routines to the infrequent holiday activities. The applied model describes the travel distance of leisure travel including the probability of having leisure activities or not. The study finds increasing income elasticities of travelling or not and increasing income elasticities of travel distances as the leisure purposes become less frequently completed activities. This includes larger elasticities for long distance journeys and journeys with an overnight stay. The paper furthermore reveals and analyses differences in travel patterns for different regions in Denmark, and contribute hereby to an understanding of how future changes in location of the population will influence leisure travelling and the length of long distance travel behaviour.

The income elasticity of long distance travel is also examined in the third paper. This study is based on the Danish expenditure survey and analyses consumption of plane tickets and travel packages in relation to the consumption on other non-durable goods. This study finds these infrequent travel activities to be somewhat more sensitive to income changes than found from the three travel surveys. The two different studies of income elasticities outline a wide span of income elasticities for leisure travel that varies between 0.1-1.4 when measured in terms of travel demand and from 0.2-0.6 when measured in terms of travel distances.

The final paper differs from the others as it explores and evaluates the impacts of the Oresund Bridge ten years after its opening. The new bridge resulted in significant changes in travel behaviour that was not as dominated by long distance leisure travel activities as expected, but rather resulted in a considerable integration of daily travel behaviour between the two countries. The financial benefits were compared with the construction and maintenance costs of the bridge in an ex-post cost benefit assessment which suggests that the bridge is a sound socio-economic investment.

DANSK ABSTRAKT

INTRODUKTION OG SAMMENFATNING AF PH.D. AFHANDLING

Der har historisk set været begrænset viden om lange rejser. Det er problematisk da lange rejser bidrager betydeligt til det samlede transportarbejde og derfor også bidrager betydeligt til transportsektorens energiforbrug og udledningen af relaterede drivhusgasser. Den gennemsnitlige rejseafstand er steget parallelt med væksten i bilejerskab såvel som øget flytrafik. Tidligere har fokus i højere grad været på daglige rejser, men globalisering, ændring i prisstrukturer og stigende indkomster har fremhævet et rejsesegment med betydelig indflydelse på det samlede transportarbejde. Markedsandelen af internationale rejseaktiviteter er steget over de seneste årtier og den tydelige binding med indkomstændringer beskriver et rejsesegment som er vigtigt i forhold til fremtidig rejseadfærd, men også i forhold til de fremtidige miljømæssige udfordringer fra transport.

Arbejdet gennem ph.d. forløbet er ikke afgrænset til en bestemt definition for lange rejser, men udforsker emnet indenfor en bredere kontekst. Afhandlingen anvender hovedsagligt

data fra tre forskellige rejsevaneundersøgelser: Transportvaneundersøgelsen (TU), TU overnatningsundersøgelsen og Ferie- og forretningsrejse undersøgelsen (HBS). Det har muliggjort et studie af mere sjældne rejseaktiviteter inddelt relativt til rejseformål, rejseafstande eller rejser med overnatninger. Afhandlingen har tre overordnede mål: i) at beskrive og kombinere empirisk viden om dansk rejseadfærd i forhold til lange rejser, ii) at tilføje viden om problemer og usikkerheder relateret til forskellige rejsevaneundersøgelser og iii) at belyse nogle af de drivkræfter der ligger bag lange rejser som f.eks. socio-økonomiske variable.

Analysen af danske rejseaktiviteter beskrevet i de tre rejsevaneundersøgelser giver en detaljeret beskrivelse af danskernes rejseadfærd på et overordnet niveau med referencepunkter tilbage til 80erne og 70erne. Arbejdet har især kortlagt hvor betydelige fritidsrejser er. Private rejseformål udgør mere end 60 % af det samlede transportarbejde per dansker og næsten 25 % stammer alene fra internationale ferierejser selvom ferierejser kun udgør 0,1 % af alle rejseaktiviteter.

Ferierejser er analyseret separat og har beskrevet en række markante tendenser, som kan få betydelig indflydelse på det fremtidige transportarbejde. Udover at andelen af danskere som gennemfører ferierejser er steget, så har typen af rejser ligeledes ændret sig. Antallet af nationale ferierejser er forblevet relativt konstante, hvorfor væksten hovedsagligt er fundet blandt internationale rejser og flyrejser i særlig høj grad. Udviklingen går i to forskellige retninger: Antallet af rejser med destinationer udenfor Europa er steget betydeligt, men antallet af weekendrejser eller forlængede weekender indenfor Europa er også steget betragteligt. De samme rejsetyper er tilmed fundet betydeligt afhængige af indkomstniveau.

Analysen af de tre rejsevaneundersøgelser bidrager til en general validering af forskellige undersøgelsesmetoder og deres evne til at beskrive rejser med overnatning fyldestgørende. Sammenligningen af undersøgelserne belyser den klassiske afvejning mellem antallet af observationer og usikkerheder forbundet med specielt designede undersøgelser med længere tidshorisonter. Respondenternes evne til at huske rejser gennemført længere tilbage i tiden medfører et underestimat på 11 %, men undersøgelsen viser også at en længere tidshorisont er nødvendig for at undgå for små stikprøver som i modsat fald tilføjer andre usikkerheder. Hukommelsesproblemer er tydeligt til stede i retrospektive undersøgelser med fokus på rejser med overnatninger selvom de intuitivt burde være lettere at huske sammenlignet med rejser over et bestemt antal kilometer. Analysen understreger relevansen af en yderligere målretning af rejsevaneundersøgelsen mod de rejseaktiviteter som har særligt interesse for dermed at minimere usikkerhederne forbundet med hukommelse. Alternativt bør undersøgelsesperioden reduceres til mindre end tre måneder og stikprøven kan øges.

I forlængelse af den statistiske gennemgang af dansk rejseadfærd og sammenligningen af forskellige rejsevaneundersøgelser præsenteret i del I af afhandlingen, indeholder afhandlingen fire studier af rejseadfærd som er præsenteret i artikelform i del II.

Den første artikel beskriver skævheder i TU og effekten af disse skævheder eksemplificeret ved en simpel bilejerskabsmodel. Analysen finder en heterogen fordelt skævhed i de respondenter som deltager i undersøgelsen. Det udsnit af befolkningen som deltager i undersøgelsen overestimerer bilejerskab betydeligt og underestimerer dermed indkomstelasticiteten. Analysen evaluerer ydermere indflydelsen af målefejl og finder betydelige problemer forbundet med indsamling af viden om personindkomster. I dette tilfælde reduceres indkomstelasticiteten af bilejerskab yderligere.

Den anden artikel inddrager alle tre danske rejsevaneundersøgelser i et studie af fritidsrejser, herunder en analyse af indkomstelasticiteten af dette rejsesegment. Ved at anvende alle tre undersøgelser beskrives et bredt spektrum af fritidsrejser, fra de daglige fritidsaktiviteter som udgør en vigtig del af danskernes daglige rutiner til de mere sjældne ferierejser. Modellen beskriver rejseafstande for fritidsrejser og medtager sandsynligheden for at have en fritidsrejse eller ej. Jo mere sjælden en rejse er, jo højere er indkomstelasticiteten for at gennemføre rejsen og jo højere er indkomstelasticiteten af rejseafstanden, herunder er elasticiteterne større for lange rejser og rejser med overnatning. Artiklen belyser og analyserer ydermere forskelle i rejsemønstre for forskellige regioner i Danmark, og bidrager til forståelse af hvordan fremtidige ændringer i bosætning vil have betydning for fremtidig rejseadfærd.

Indkomstelasticitet for lange rejser er også undersøgt i den tredje artikel. Studiet er baseret på den danske forbrugsundersøgelse og analyserer andelen af danskeres forbrug på flybilletter og pakkerejser i forhold til forbruget på andre ikke-varige forbrugsgoder. Analysen viser at forbruget på fly og pakkerejser er noget mere følsomme overfor indkomstændringer end fundet fra de tre rejsevaneundersøgelser. Indkomstelasticitet af fritidsrejser fundet i de to studier er mellem 0,1-1,4 i forhold til rejseefterspørgsel og 0,2-0,6 i forhold til rejseafstande.

Den sidste artikel adskiller sig fra de foregående og evaluerer indflydelsen af Øresundsbron 10 år efter den åbnede. Broen har medført betydelige ændringer i rejseadfærd som ikke kun relaterer sig til lange rejser, men særligt har bidraget til en generel integration af regionen med daglige rejser på tværs af Øresund. De økonomiske fordele blev sammenlignet med anlægs- og vedligeholdelsesomkostninger i en ex post cost-benefit analyse som har vist at Øresundsbron er en sund socioøkonomisk investering.

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INTRODUCTION

INTRODUCTION TO LONG DISTANCE TRAVEL

According to the 2010 EU report on CO_2 emissions in EU27 (European Commission, 2010), the transport sector is the sector having the second highest share of CO_2 emissions after the energy industry. The transport sector is also the only sector with increasing emissions throughout all the years from 1990 to 2007. In Denmark, the Transport sector contributes to 26.3% of the CO_2 emissions which have increased from 19.9% in 1990. An important driver of the growth in transport CO_2 is long distance travel and aviation in particular (Gemeinschaften, 2001). Long distance travel has previously achieved less focus as the travel activities are few in numbers, but they contributes significantly to the total level of travelled kilometres and are consequently central in the discussion of emissions from transportation. Due to this there has been an increasing attention on long distance travel.

From a broad sample of different European travel surveys, the development in travel behaviour during the latest 20-30 years has been driven by increasing travel distances rather than more travel activities. Historically, this development has been strongly related to the development in transport modes and increasing car ownership in particular. Price shock effects might influence the development as seen in the 1970s and from the recent global economic recession. But the strong relationship between transport and the economy cannot be neglected.

This is e.g. illustrated by the passenger statistics for Copenhagen airport in Figure 1. Aviation from Denmark has increased considerably during the latest 40-50 years and the correlation with the growth in GDP is apparent. The correlation with international economy and the political situation in the oil producing countries is however also obvious.

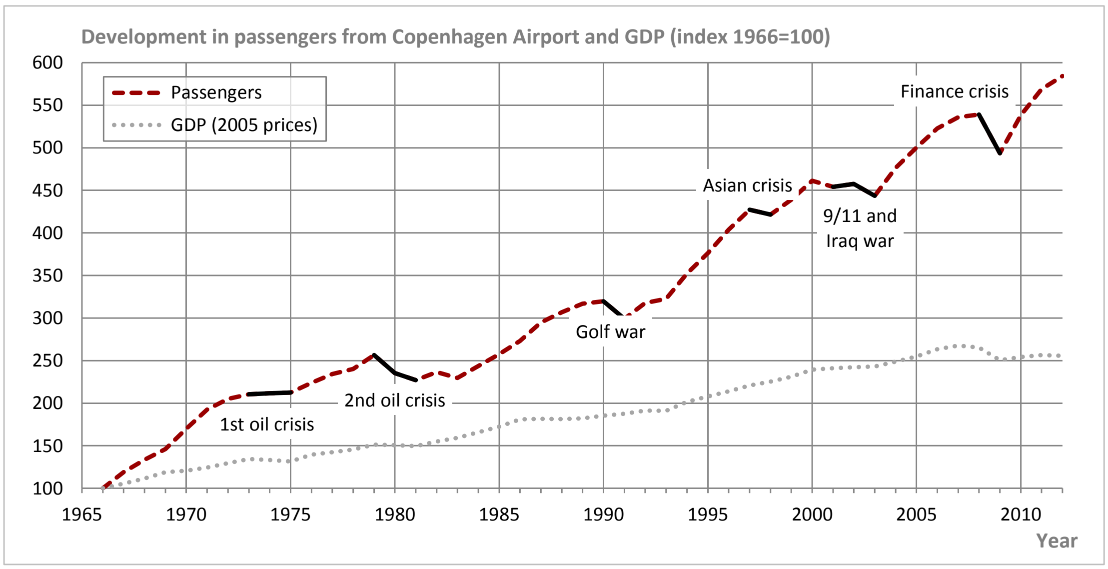

FIGURE 1: DEVELOPMENT IN PASSENGERS FROM COPENHAGEN AIRPORT AND GDP FROM 1966 TO 2010 HAVING 1966 AS INDEX YEAR

This PhD thesis explores Danish travel behaviour in a study of three different travel surveys that describe different facets of travel activities at various aggregation levels based on different survey methodologies. In this sense, "Danish travel behaviour" represents the travel behaviour of residents registered in the Danish civil registration system (CPR), that is Danish citizens, but also international residents having an officially approved stay in Denmark.

The work is motivated by the lack of knowledge about Danish long distance travel behaviour and the sparse knowledge on the relation with daily travel behaviour. But the work is also motivated by the increasing focus on the negative externalities from transportation that are driven by increasing car ownership, increasing travel distances, and the growth in air travelling.

The overall objective of this thesis is to frame Danish long distance travel in a broader context and to consider the relevance of different travel characteristics that might improve knowledge of the drivers behind long distance travel. An additional aim is to validate the different data sources available to describe Danish travel behaviour and the infrequent travel activities in particular. This involves an evaluation and discussion of different survey methodologies and the necessary trade-offs between small samples of long distance travel activities from daily mobility surveys compared with the increased uncertainties related to retrospective travel surveys.

RESEARCH SUBJECTS AND MAIN CONTRIBUTIONS

This thesis is divided into two separate parts: "Travel behaviour and travel surveys" in part I and "Assessment of long distance travel" in part II. Together part I and part II consider a broad span of different research themes that all relate to long distance travel.

PART I - "TRAVEL BEHAVIOUR AND TRAVEL SURVEYS"

The objectives of this first part of the thesis are to provide an up-to-date base of empirical knowledge on Danish travel behaviour and furthermore to outline and describe the available data sources. This has resulted in an overall description of daily domestic travel behaviour and travel trends described from the Danish National Travel Survey (TU), and an additional description of Danish multiday travel behaviour and travel trends described mainly from the Danish tourism statistics available in the Business and Holiday Survey (HBS).

Besides providing an overview of Danish travel behaviour, the focus of this part of the thesis is to reveal and analyse the characteristics of different travel types that contribute considerably to the total mileage of the Danish population. This furthermore contributes to the discussion of an appropriate definition of long distance travel that is more comprehensive than the most commonly applied distinction relative to a 100 kilometres distance threshold. This distinction is first of all uncertain due to the individual perception of travel distances compared with actual travel distances. Travelling above or below 100 kilometres does not necessarily correspond to different travel segments. In relation to this, three different Danish travel surveys are analysed and compared according to a segmentation of travel activities into travels with overnight stays or not.

This evaluation furthermore finds the segmentation into domestic and international travel relevant in the discussion of an appropriate design of a tailored travel survey to describe travels with overnight stay(s). Even though the definition seems more intuitive to interpret by the respondents, the analyses of part I show that domestic travel with overnight stay is affected by uncertainties related to an unclear definition of visits that are either difficult to recall or not considered relevant. Increasing survey horizons increase the probability of memory loss, but to analyse e.g. international travels into greater details, a longer survey horizon is required. From this study it is found that travels with overnight stays are in average underestimated by 11% during a three month period. It is also found that the limited samples available from shorter survey horizons estimate a representative picture of the total level of travelling with overnight stay(s). The comparison does however also show that international travel activities are more difficult to describe sufficiently from small survey horizons. But to describe travels with overnight stay(s) in a comprehensive way requires a more specific definition of the travel types of interest, or at least to reduce the survey horizon to minimise recall effects.

Even though commuting and daily routines contribute considerably to the total level of travelling, this contribution is primarily related to their high frequencies and not the travel distances alone. Leisure travel is throughout part I found central in the discussion of long distance travel. This is motivated by the high variety in leisure travel distances and the significant contribution to the daily mileage of individuals, but also the significant contribution from travels with overnight stays and international travelling in particular. Leisure travelling holds considerable complexities due to the diversity of travel activities that are often motivated by less measurable variables such as personal needs, differences in lifestyle, and social relations which are not available from traditional travel surveys.

Reading guide

Part I consist of the chapters from 1-5. **Chapter 1** includes an introduction to travel surveys and long distance travel surveys in particular. In continuation of this **Chapter 2** describes the

Danish National Travel Survey (TU), daily domestic travel behaviour, and travel trends. Danish multiday travel behaviour and travel trends are described in **Chapter 3** from the Danish tourism statistics of the Holiday and Business survey (HBS). Chapter 3 is supplemented with a validation of the different travel surveys that register Danish travel activities with overnight stay(s). The overall trends in Danish travel behaviour and long distance travel in particular are summarised in **Chapter 4**. This chapter furthermore contains a discussion of the advantages and disadvantages found in the different survey methodologies as well as a discussion of the possible future trends in an environmental context. The literature references of the first part of the thesis are listed in **Chapter 5**. Part II consists of the four papers that are presented separately.

Part II - "Assessment of long distance travel"

Part II includes four papers that explore long distance travel behaviour in different ways with different agendas and different contributions. The four papers are not further introduced and discussed in part II, why the following description of the papers and their contributions additionally includes some overall perspectives.

Paper #1

Knudsen, M. Aa. (2014). "Household and income biases in transport surveys". *Working paper*

This study analyses the response bias present in the Danish National Travel Survey (TU) and the impacts on the estimation of car ownership. The survey is considerably biased relative to family structure as single-family households are less likely to participate in the survey and the responses are furthermore biased with respect to lower incomes groups. The impacts of such bias increases as TU is an individual-based survey compared with a household-based survey, but this is accounted for in the analysis.

The impact of the response bias is exemplified by a simple car ownership model. The estimates show that the overrepresentation of couples and underrepresentation of lower income groups significantly underestimates the income elasticity of car ownership. The study furthermore finds the survey to be downward biased with respect to stated income by the respondents. It is furthermore apparent from the analysis that people might have considerable problems in registering sufficiently and homogeneously defined incomes. This gives cause for concern as these are often applied for model purposes and are often the only information available on income. Weighting of the samples only partly compensate for the bias.

Paper #2

Knudsen, M. Aa. & Nielsen, O. A. (2014). "Analysing the spatial distribution of leisure and holiday travel – an assessment of Danish travel behaviour". Res*ubmitted for Transport Geography.*

The second study evaluates the drivers behind the growth and spatial distribution of Danish leisure travel described by three different travel surveys. Leisure travel distance is modelled from a Heckman selection procedure that takes the probability of having a leisure activity or not into account. The model specification includes household income as a central determinant, but it also includes the impact of other spatial and socio-economic variables. This provides a better basis for forecasting the growth in leisure travel and how migration of the population will affect future leisure travelling. The study finds a positive correlation between income and leisure travel distances that furthermore vary considerably between more specifically defined leisure purposes. The income elasticity generally increases when the leisure activities become less frequent such as holiday travels, travels with overnight stay(s), and visiting friends and relatives. These relations are supported by the selection criteria estimating the probability of having a leisure activity or not. In total the study of leisure activities finds income to be a significant determinant of infrequent leisure travelling in terms of both travelling or not and travel distances.

The study furthermore reveals considerable geographical differences. Daily leisure distances are longer outside the Copenhagen Region, whereas holiday travel distances are longer when living in Copenhagen. The first is likely related to a general difference in the perception of distances outside the Copenhagen Region as well as longer distances to the activities of relevance. The latter is likely related to better accessibility to air transport in Copenhagen and differences in lifestyle. The study furthermore finds higher probability of having leisure activities for people living in the city, which again can be explained by the larger number of possible activities available in Copenhagen.

The paper furthermore discusses the possibility of generally underestimating income elasticities as travel costs are not included in the model specification. Including travel costs in the model specification is expected to increase the income elasticity due to an expected negative correlation between travel costs and travel demand. This possible underestimation also corresponds with the higher income elasticities revealed in paper#3.

Paper #3

Knudsen, M. Aa. & Rich, J. (2014). "Tourism expenditures on plane tickets and travel packages – a pre-crisis assessment". Resubmitted *to Tourism Management Perspectives*

Presented at the Young Researchers Seminar June 8-10 2011, Technical University of Denmark and rewritten for publication.

The third study analyses the consumption of plane tickets and travel packages. The work is based on the Danish expenditure survey from 1996 to 2007. The study analyses the distribution of expenditures on six overall samples of commodities based on the Almost Ideal Demand System at the top most level. The overall income expenditure elasticity of the commodities of transportation and leisure is estimated slightly above unity. Based on the Tobit model it is secondly found that the consumption of plane tickets and travel packages is perceived as a luxury for individual households. Travel package is found to have an income elasticity of 1.4 compared to an income elasticity of 0.9 for plane tickets in the fully constrained Tobit model.

In this study travel costs are included, but it has not been possible to estimate a significant relation between travel costs and travel demand. The most reasonable explanations are lack of variation in data and missing travel units; only total expenditures on travel are available, but not the number of tickets.

Paper #4

Knudsen, M. Aa. & Rich, J. (2013). "Ex post socio-economic assessment of the Oresund Bridge". *Published in Transport Policy, 27(2013), 53-65.*

The last paper is related to long-distance travel in a different way as it represents an ex-post study of the Oresund Bridge. Although the bridge turned out to be a massive success for daily travelling and in particular for business and commuting, it additionally serves a significant share of long distance transport. The study is based on dedicated travel surveys describing travel behaviour across the strait of Oresund. This is adjusted relative to crossing statistics and applied to reconstruct the travel patterns of the crossings of Oresund before and after the opening of the bridge. The benefits of the changes in travel behaviour are compared with the construction costs and the cost profile of running the bridge in an ex post cost benefit assessment of the Oresund Bridge.

In this study, the benefits found from the construction of the Oresund Bridge are analysed and discussed relative to the construction of the Channel tunnel between France and England. Whereas the Channel Tunnel has experienced competition from lower cost airlines some of the success of the Oresund Bridge might actually be ascribed to the growth in aviation as the bridge has improved the access to Copenhagen Airport from Sweden. But it is far from alone leisure travel or long distance travel that has ensured the success of the Oresund Bridge as the surrounding area of Copenhagen and Malmö in the southern part of Sweden has experienced a considerable integration with relocation of workplaces and places of residence that has changed travel behaviour.

The PhD work has contributed with two additional papers. The first paper is based on some of the preliminary work with the Danish Tourism Statistics (HBS) and the Danish National Travel Survey (TU). This work is updated and included in part I of the thesis and consequently not included separately in the thesis:

Knudsen, M. Aa. (2010). "Vurdering af lange rejser" (in Danish). *Presented at the Annual Transport Conference at Aalborg University.*

The second paper is a description of the air transport model for Greenland. The model system generates and optimises the air travel network of Greenland. The optimisation of the route network is based on the characteristics of the runway capacity and the characteristics of planes in an iterative process with route network assignment. This model system was applied for scenario analyses of different improvements of some of the central airports in Greenland. The paper is not included in the thesis as the focus of the paper is on model development and the applied tourism module is based on rather simple projections of travel demand.

Nielsen, O. A., Rich, J., Knudsen, M. Aa. (2007). "A combined air transport and optimisation model for Greenland". *Presented at the TRISTAN conference, Phuket, Thailand.*

PART I

TRAVEL BEHAVIOUR & MOBILITY SURVEYS

ANALYSING AND VALIDATING DANISH TRAVEL SURVEYS

Chapter 1

TRAVEL BEHAVIOUR AND MOBILITY SURVEYS

INTRODUCTION TO PART I

The main objective of part I of this thesis is to provide an overall description of the empirical knowledge on Danish travel behaviour, travel trends, and general travel characteristics. Special focus is put on long distance travel or infrequent travel types in particular. The different travel surveys analysed in the following chapters however also provide an input to a general discussion of travel survey methodologies and the difficulties in describing long distance travel. This has resulted in a general list of recommendations regarding the design of tailored travel surveys with focus on infrequent travel activities.

The study is based on the analysis of two continuous Danish travel surveys that register daily mobility and multiday mobility, respectively, throughout the latest decades with a few reference points dating back to the 1970s and 1980s. The Danish National Travel Survey (TU) is a daily mobility survey that provides information on daily travel behaviour in

Denmark[1]. TU is presented in Chapter 2 with a general description of Danish daily travel behaviour and the overall trends in domestic travelling. The Holiday and Business Survey (HBS), is the Danish version of the European tourism statistics that register travel with overnight stay during the previous three months. The HBS is presented in Chapter 3 and works as base information on Danish multiday travel behaviour. Together these two surveys are considered representative for the overall picture of Danish travel behaviour and are summarised in Chapter 4.

From 2010-2011 TU was extended with a parallel travel survey focusing on multiday travel behaviour. The TU overnight survey consists of two parts; a two-weeks survey that register the main activities during 14 consecutive days, and a retrospective survey that register travel activities with an overnight stay three months back. The retrospective survey part is supplemented by questions about long duration travel, registered one year back.

If a respondent starts the day at a different location than the home address, but returns back home during the survey day, the newest version of TU furthermore register the number of nights the respondent has been away. Altogether the three travel surveys have facilitated four possible estimates of Danish travel with overnight stay(s) that serve as validation of the different travel survey methodologies. This comparison is included in Chapter 3 to first of all validate the HBS, but also to outline and discuss the differences in the survey methodologies applied to describe multiday travel behaviour.

The comparison of travel surveys as well as the description of travel survey uncertainties is inspired by Kuhnimhof and Last (2009) and Denstadli and Lian (1998). But in contrary to these previous studies, focus in this comparison is on travels with overnight stay(s) rather than travel distances. The remaining of Chapter 1 includes a short description of the general trends in European travel and furthermore outlines some trends in tailored long distance travel surveys. First of all, the definitions of the applied travel units are described in the following section.

[1] International travel is possible to describe from TU in terms of destinations, but travel details are only registered until Danish borders.

1.1 DEFINITIONS

Throughout this thesis, daily travel and multiday travel are described and analysed. The definitions of travel units might however vary between the two travel types and might additionally vary between different studies. Due to different definitions and different intuitive perceptions in particular, the applied travel units throughout this thesis are defined and described in the following. The definitions applied are generally based on the definitions found in TU which have proven possible to transfer to the multiday travel activities from the HBS.

TU classifies the travel activities into three main travel units: stages, trips, and journeys as exemplified in Figure 2. The definition of travel units and travel characteristics applied in this thesis is summarised in Table 1. A trip is defined as the travel movement between two activities, and stages are each single travel movement with a single transport mode as illustrated in Figure 2a. Most trips including public transport have an additional access and egress mode and often consist of at least three travel stages.

The series of trips undertaken from the base location of the day to a temporary location and back to the base location is defined as a journey. One journey needs to be finished, before a second journey is registered. People completing a high series of trips during the day without attending the base location during the day, is consequently registered with one rather complex journey. A journey might however consist of sub tours that origin from temporary bases as illustrated in Figure 2c. This example might e.g. be a commuting journey, with a business tour during the working day whereas the example in Figure 2b might describe an errand on the way to work. A tour is in theory also a journey, but the base location is a temporary location. The tours are in TU registered as secondary travel activities and not separate journeys, but their travel distances are included in the total travel distance.

This definition of journeys in a daily mobility survey leaves out a series of trips not starting or ending at the same location during 24 hours. These are defined as outbound and homebound journeys depending on the origin of the day. This might e.g. be commuting with night duty work, parties, concerts etc. that ends after 3 A.M, but it might also be people having several homes, i.e. couples living apart and it might be people going on vacation, business travel etc. that includes overnight stay(s).

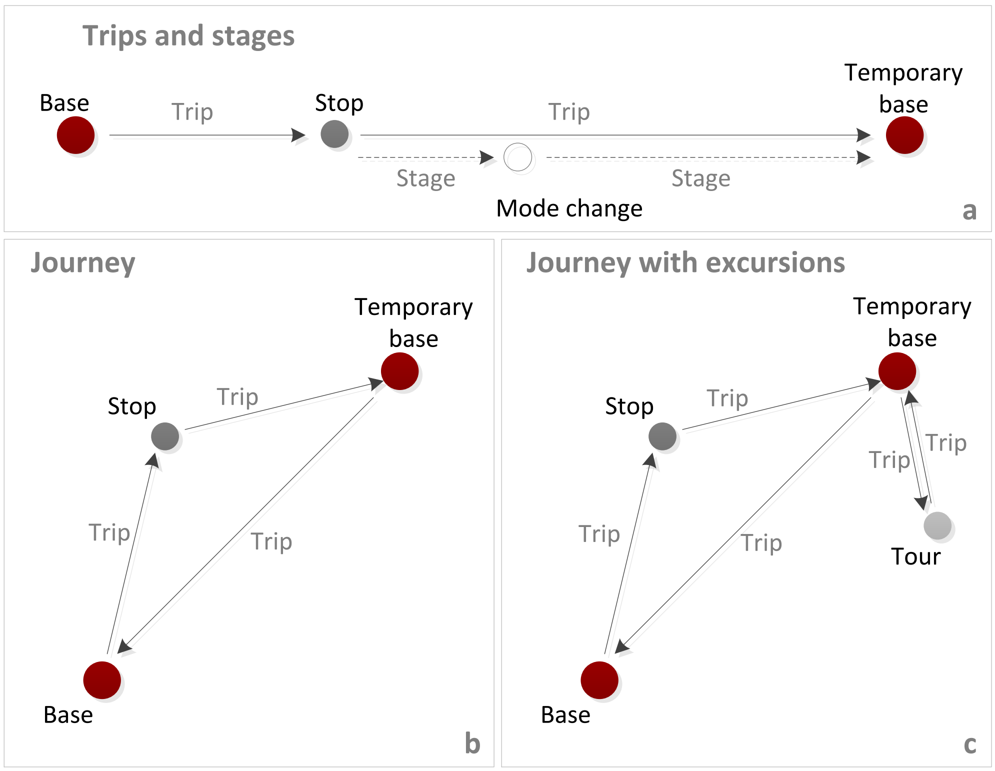

FIGURE 2: DEFINITION OF JOURNEYS, EXCURSIONS, TRIPS AND STAGES APPLIED THROUGHOUT THE THESIS

It is generally possible to transfer these travel units to multiday travel. Multiday travel is however often registered at a higher aggregated level hence stops, trips, and stages are not considered. Neither are tours during the overall journey. The only travel unit considered in the HBS is the main stay of a travel activity with an overnight stay. In this study it is consequently defined that one travel activity is the journey from home to the main destination and back home as in TU. This simplifies the travel activity to two identical travel movements with one possible temporary base location even though the respondent actually only registers one travel movement.

These applied travel units seem to correspond with the most commonly applied travel units and to the definitions described in (Axhausen, 2003a). The illustrative definitions from the DATELINE project (Brög et al., 2003) and the description from the resent KITE project (Kuhnimhof et al., 2007) suggest that journeys are two-way activities as also defined throughout this thesis. Tours are in the DATELINE project defined as excursions (Brög et al., 2003), which seems more intuitive especially regarding leisure activities completed during a multiday journey. But regarding a business activity completed during the workday, a tour might be more appropriate. The definition of journeys is however not consistent in literature and might in some cases refer to one-way movements where round-trip journeys refer to the complete travel activity from home and back home (Ortúzar and Willumsen, 2001; Abramowski and Holmström, 2007).

TABLE 1: DESCRIPTION OF TRAVEL TERMS APPLIED THROUGHOUT THE THESIS

Term	Description
Base	The origin of the journey, which is most often the home
Crow fly travel distance	- Daily travel: The crow fly distance between the base of the journey and the location furthest away during the journey - Multiday travel: The crow fly distance between the home and the main destination
Duration	The duration of the stay - Daily travel: the duration of the main activity (excl. travel time) - Multiday travel: the duration of the whole journey
Homebound	A series of trips to a base location registered in TU, which are not completed due to the one-day reporting period
Journey	The complete outbound and homebound series of trips to and from the same base
Mode change	A change of travel mode during a trip
Outbound journey	A series of trips to a temporary location registered in TU, which are not completed due to the one-day reporting period
Purpose	The purpose of the activity of the main stay
Round-trip journey	A multiday journey with a series of stops with overnight stay(s)
Stage	A travel movement with one specific transport mode
Stop	A temporary stop during a journey that might be of varying duration, hence also with overnight stay as part of a round-trip journey
Temporary base	The main destination of a journey
Tour	The same definition as journeys, however with a temporary location as the base. For multiday travel this would often correspond to the more intuitive "excursions"
Trip	A series of stages between two activities

No matter the decided definition it is possible to sketch insufficient borderline cases that are difficult to fit into the simplified travel definitions. In terms of multiday travel, the simplification of a holiday journey with several base locations with overnight stay(s) to one common journey is a rather coarse assumption that neglects a unique travel experience to a more traditional travel type. This might be difficult to accept and understand by the respondent and might also be misleading in terms of travelled kilometres. The simplification is in theory not that different from reducing complex daily series of trips to one overall journey and then apply the crow fly distance of the destination farthest away. The main difference is that all travel movements are registered in TU hence all information is available, whereas it is a necessary simplification in the HBS to maintain a simple survey design where the majority of travel activities fits into.

The travel distances registered in TU are the stated total travel length of each single travel movement that are summarised as the total route length of the travel activity. These are in the recent versions of TU simultaneously processed with respect to the least possible travel distances. Crow fly distances are for the journeys in TU registered as the crow fly distance to the destination furthest away and not the main activity of the day. The duration of the journey is on the contrary based on the duration of the main stay of the journey.

1.2 TRAVEL TRENDS

The national travel surveys that have been completed throughout many European countries for several years have provided detailed information on the development in daily travel behaviour. If estimating the average level of travelling per person, the overall trends are similar across countries: The travel time spent on travelling, and the numbers of trips completed have generally stayed constant. The constant levels are furthermore similar across countries. An average person completes around 3 trips per day and travels approximately 60-70 minutes per day (Kuhnimhof, 2008). The growth observed in travelled kilometres is consequently explained by the shift to faster transport modes that increase travel speed hence also the overall activity space of individuals and consequently also the travel distances of the single trips (Scheiner, 2010; Schafer and Victor 2000). Some of this is driven by increasing economy hence also increasing car ownership.

From the constancy of travel time and travel frequency, Metz (2008) argues that travel time savings historically have increased the activity space of an individual, rather than reducing the time spent on travelling. He furthermore claims that this is particular the case for less replicable destinations. A few years later Metz (2010) additionally outlines a peak travel theory from an approaching level of stagnation in domestic UK travel distances. This is discussed as a possible level of saturation in domestic personal travelling which suggests that people generally have reached an optimal activity space with a suitable number of relevant destinations to choose from.

An approaching maximum level of travel distances relative to the development in GDP is presented for several industrialised countries in (Millard-Ball and Schipper, 2011). This obvious trend suggests that the strong coupling between transport and economy has changed, which might have substantial impacts on the discussion of reducing emissions from transportation (Schroten et al., 2011). These relations are however also questioned due to the absence of international travel (Frändberg and Vilhelmson, 2011; Schroten et al., 2011; Schafer and Victor, 2000). For example, Frändberg and Vilhelmson (2011) describe an increase in international travel from Sweden on the expense of growth in domestic travel.

Decoupling of transport is central in the discussion of decarbonising transportation without additionally decelerating economy (Ballingall et al., 2003; Schroten et al., 2011). From the discussion of decoupling of transport from economy, (Schroten et al., 2011) also discusses the significant importance of including international travel. They find globalisation a significant driver of long distance travel and that the increasing trend of international travel seems to more than counterbalance the decoupling of domestic travel. This thesis is limited to only consider passenger travel activities even though the stagnation of domestic travel might be partly influenced by behavioural changes that have increased trade-based transportation. This could stem from e.g. increased internet shopping, increased import of IT equipment as a result of increasing work from home, or web-conferences (Schroten et al., 2011; Tight et al., 2004).

The existence of a travel time budget is a logical outcome of a number of inherent daily time constraints regarding a relatively fixed number of hours reserved for e.g. sleeping and working during an average day. The summary of travel activities during an average day leaves out a little more than 1 hour for travelling as discussed in Schafer (2000). This corresponds to the approximately 375 hours per person per year found in UK throughout more than thirty years (Metz, 2010). But even though several travel indicators are found constant at an aggregated level, it is generally recognised that this is not necessarily the case at the individual level (Mokhtarian and Chen, 2004; Dargay and Hanly, 2007; Schafer, 2000), which stresses the considerable variety of the population. The apparent aggregated travel budget is nevertheless in many studies considered as an overall travel restriction that is central for the overall development in personal travel behaviour.

1.3 Travel surveys

One of the significant problems and limitations related to analysing long distance travel behaviour is the lack of sufficient data. Most European countries have conducted national daily mobility surveys that have now been completed throughout several years. Some date back to the seventies as is the case for e.g. UK and Sweden. The national travel surveys are relatively similar and comparable across countries (Kuhnimhof et al., 2009). One of the newest cross country comparisons is found in the SHANTI collaboration (Armoogum et al., 2013).

In a daily mobility survey, the majority of the registered travel activities have destinations in the local or regional surrounding areas and many are completed on a daily basis. These travel activities are consequently described in great detail and supply researchers with rich information on travel behaviour at a highly disaggregated level. The more infrequent travel activities are also registered during an average day, but are by nature described from a smaller sample.

To describe the total spectrum of travelling in detail, supplementary surveys tailored the infrequent travel activities are often applied as an extension of the daily mobility surveys or completed in parallel. The tailored long distance travel modules are challenged by the high variety in travel characteristics and destinations as well as the low travel frequencies. The tailored surveys consequently require a large sample of registered travel activities to analyse the trends in travelling into greater detail. To increase the sample size of travel activities, the survey horizon is often extended instead of increasing the sample of respondents. This increases the probability of the respondent having a travel activity to register and additionally facilitates an identification of frequent long distance travellers (Madre et al., 2007).

Increasing the survey horizon however enforces a reduction of the number of travel details possible to require from the respondents to ensure a reasonable workload. But an increased survey horizon is also related to increasing probability of non-response and hence also significant survey uncertainties. This could be both recall errors due to longer time horizons, or response fatigue from the high workload demanded by the respondents (Denstadli and Lian, 1998; Schlich et al., 2004; Kuhnimhof et al., 2009). These relations generally complicate an optimal survey design.

To minimise the impacts of non-response, the design of a tailored long distance travel survey needs to consider the probability of the respondent having a journey to report during the surveys horizon against the uncertainties related to recall effects as the survey horizon increases. These trade-offs are further complicated by the uneven distribution of long distance trip-making in the population (Axhausen, 2003a). As is also the case in daily travel surveys, the travel frequency varies considerable across the population and some people have a high share of journeys to register. These respondents are assigned higher work load and might be affected by fatigue bias. But the respondents might furthermore have higher probability of not recalling all travel details or not recalling all the travel activities actually completed.

1.3.1 Tailored travel surveys

The combination of daily mobility surveys and tailored travel surveys that describe the less frequent travel activities is widely implemented throughout Europe, but methods and definitions vary somewhat between the surveys (Madre et al., 2007). A commonly applied distinction between frequent and infrequent travel activities is defined from a distance threshold that varies between 75 and 100 kilometres and might be crow fly distance or stated travel distance (Kuhnimhof and Last, 2009). The 100 kilometres crow fly distance corresponds to the Eurostat definitions and follows the string of European research programmes focussing on long distance travel, in e.g. the MEST projects (Axhausen and Youssefzadeh, 2003), and DATELINE (Brög et al., 2003). The recent KITE project defined a threshold of 75 kilometres crow fly distance registered during eight weeks (Frei et al. (2010); Frei and Axhausen, 2009b). The distance threshold included allows for setting the actual threshold afterwards and most likely includes both long crow fly distances as well as long route distances.

From the overview of travel surveys in (Madre et al., 2007), Czech Republic, Finland, Germany, Italy, Norway, Spain, Sweden, UK, and Switzerland are highlighted as European countries with relative up-to-date measures of long distance travel. The Swedish National travel survey is e.g. extended by a four-week reporting period of travelling above 100 kilometres and an eight-week reporting period of travelling above 300 kilometres (Widlert, 2002). The Norwegian survey registers travelling above 100 kilometres one month retrospectively (Kunert et al., 2002). The UK national travel survey registers travelling above 50 miles during 4 weeks (Dargay and Clark, 2012). The national travel surveys from Switzerland and Germany on the contrary focus on travel duration (Kuhnimhof et al., 2009).

The study of long distance travel surveys in MEST (Axhausen, 2003b) concluded that a 12-week reporting period might be too long and found eight weeks acceptable. This is also the survey length recommended in the newest European study of long distance travel surveys in the KITE project (Frei and Axhausen, 2009b). The study of (Denstadli and Lian, 1998) however found remarkable memory effects of the second retrospective survey month, whereas (Axhausen et al., 2002) did not detect drop out or fatigue effects during a six weeks period. From literature it consequently appears that a four to eight week survey period is optimal.

TABLE 2: THREE GROUPS OF TRAVEL SURVEYS WITH STRENGTHS AND WEAKENESSES FROM (KUHNIMHOF AND LAST, 2009)

	Strengths	Weaknesses
Mobility diary surveys	Negligible recall error Comparable data Easy-to-use multipurpose data Up-to-date surveys	Often insufficient sample size No frequent traveller identification Insufficient capturing of journeys with overnight stays
Single-protocol LDT surveys	Sufficient sample size Identification of frequent travellers Flexible and cost efficient survey instrument Easy-to-use data Up-to-date surveys	Non negligible recall error Not comparable across countries
Multi-protocol LDT surveys	Sufficient sample size Identification of frequent travellers Reliable representation of LDT	Complex survey set-up Complex data set Little data availability

Kuhnimhof and Last (2009) categorise the European surveys with information on long distance travel into three groups and discuss some of the strengths and weaknesses of different survey methodologies. These are listed in Table 2. The national travel surveys and their different tailored extensions belong to the category of mobility diary surveys and single-protocol long distance surveys. The former focusses on daily travel, but also registers some long distance travel activities whereas the latter focusses specifically on long distance travel, with a single type of questionnaire for all respondents. Most of the tailored long distance surveys are retrospective and vary regarding definition of travel units and survey methods. The surveys are consequently difficult to compare. The multi-protocol surveys are new approaches aiming at a higher quality of the representation of long distance travel in all distance segments.

The German INVERMO and the European KITE (completed in Portugal, Switzerland, and the Czech Republic) are two examples of multi-protocol surveys. The 'multi-protocol' refers to a differentiation of travellers according to their registered travel frequencies at the topmost survey stage and tailored questions at the lowermost level (Frei and Axhausen, 2009a).

As illustrated in the table, half of the strengths regarding the mobility diary surveys appear as weaknesses in the single-protocol surveys. On the contrary the weaknesses of the mobility diary survey appear as strengths in both single- and multi-protocol surveys. Recall errors are as the table also states non negligible for single-protocol surveys. These are reduced when introducing multi-protocol surveys which on the contrary add considerable complexities to data and the survey set-up.

The total level of travelling found from different European travel surveys are compared in (Kuhnimhof et al., 2009). The comparisons show that the daily mobility surveys describe the travel activities below 200 kilometres sufficiently and that the uncertainties from the tailored surveys more than counterbalance the uncertainties related to the limited sample present in daily mobility surveys. They furthermore find that the tailored surveys become superior for distances above 400 kilometres. In (Kuhnimhof and Last, 2009) these comparisons are extended with the two multi-protocol surveys; INVERMO and KITE. Kuhnimhof and Last (2009) find that the multi-protocol approach estimates the whole travel spectrum of long distance travel sufficiently.

The European tourism statistics are another source of information on especially international travel. These have been completed in parallel since the 1970s in many European countries. It is however generally the case that the national travel surveys and the European tourism statistics are conducted by different institutions (Madre et al., 2007). The tourism statistics furthermore focus on other parameters that might reduce their application in behavioural analyses. The Danish tourism statistics are applied in this general assessment of Danish travel behaviour as it is the only available source of information on

Danish long distance travel completed through longer periods of time. The survey is however affected by obvious uncertainties and is in particular found insufficient in terms of the level of details by which the travel destinations are registered. It has nevertheless been possible to describe some overall trends in especially international travel that supports the change from domestic to international travel as also found in Sweden (Frändberg and Vilhelmson, 2011). The survey has furthermore proven sufficient for aggregated measures of holiday demand in paper#2.

1.3.2 DANISH TRAVEL SURVEYS

Three Danish travel surveys are available and describe Danish long distance travel in different ways and represent different survey methodologies:

- The Danish National Travel Survey (TU)
- The Danish Tourism Statistics present in the Holiday and Business Survey (HBS)
- The Danish overnight survey (TU overnight)

These three travel surveys are described and applied throughout the following three chapters and provide an overall description of Danish travel behaviour and the overall trends throughout the latest 20 years with references back to the 1970s and 1980s. The three survey types more or less fit into the survey categories listed in Table 2:

- TU is a daily mobility survey that contains a large sample of daily travel activities, but a limited sample of infrequent travel activities. Compared with other European daily mobility surveys TU however comprises information on travels with overnight stay(s) due to a simple additional survey question.
- The HBS is a single-protocol survey with focus on travels with overnight stay(s). The retrospective survey period ensures sufficient sample sizes, but consequently adds higher survey uncertainties. The survey is not designed for behavioural analyses and consequently focusses on other variables than traditionally considered in travel surveys
- The TU overnight survey does to some extent falls into the category of multi-protocol surveys. The retrospective multiday survey part registers the multiday travel frequencies of individuals at the topmost level with possible prioritised selection of the additional questions on travel details. It is however revealed and discussed in Chapter 3 that the survey design could most likely gain from further

differentiation of the travellers which could improve the survey and additionally reduce the survey uncertainties.

Chapter 2

DAILY DANISH TRAVEL ACTIVITIES

TRAVEL TRENDS AND CHARACTERISTICS FROM TU 1993-2011

The Danish National travel survey (TU) is a daily mobility survey that describes Danish travel activities during 24 hours. The survey is web-based with follow-up phone calls. The purpose of this chapter is first of all to outline the overall picture of Danish travel activities and the presence and relevance of long distance travel in a Danish context. Secondly TU has been completed through several years and it provides a good picture of the overall trends in Danish domestic travel behaviour. Thirdly, comparisons across the whole survey period have not been presented in several years. The following description and assessment of the structure and history of TU is based on (Christiansen, 2012; Christensen, 2004; Christiansen and Skougaard, 2013). The analyses are only completed at an aggregated level, whereas individual travel behaviour is considered in paper#2.

As a continuous survey, TU dates back to August 1992. But the survey is affected by some changes in methods during the years (especially before 2002) and unfortunately also a break from January 2004 to May 2006 due to withdrawal of financing. TU exists as three survey generations: The first generation of TU is three single surveys that describe travelling in 1975, 1981, and 1986, where the 1975 survey only registers weekday travel and the 1986 survey is considered insufficient for comparison (Christiansen, 2012). The second generation survey describes the period from September 1992 to December 2003, and finally the current survey that covers from May 2006 until today. The second and third generation TU is analysed in this chapter[2] and the totals from 1981 described in (DSB, 1983) is furthermore included to reveal possible long-term relations.

With a few data restrictions, the two continuous survey generations are relatively comparable and describe the overall trends in travelling during the latest 20 years. Yearly variations and impacts of method changes during the second generation survey influence however the overall picture as discussed in section 2.1. Section 2.2 outlines the overall trends in domestic daily travel activities from 1993 to 2012 with a reference point back to 1981. Danish travel behaviour registered from 2007 to 2012 is analysed more thoroughly in section 2.3.

2.1 The Danish National Travel Survey, TU

Every year since 2006, 0.3% of the Danish population between 10 and 84 has participated in TU[3]. The sample of respondents is drawn as a representative sample from the Danish civil registration system (CPR). The respondents register each travel movement during the previous day from 3 AM to 3 AM. Each respondent furthermore registers a broad sample of socio-economic information and household characteristics. TU represents a comprehensive picture of everyday travel, but also holds information on the more infrequent travel activities. From 1992-2000 TU included a long distance module that registered travel activities of at least 100 kilometres during the last month. In its present design TU registers the number of nights away from home, when the travel activities of the day include a

[2] The second generation data is applied from the dataset (9209v1) and the third generation data is applied from the data set (0612v1).

[3] During a normal year the targeted sample is 20,000 respondents, i.e. approximately 1,000 successful interviews per month with a 56-65% response rate from 2007-2011 (Christiansen, 2012). From June 2009 to July 2011, the sample was enlarged due to the development of the Danish National Transport Model and the survey represents 0.5% of the population in 2010.

homebound journey, but not an outbound journey[4]. Outbound travel is likely to be underrepresented as the respondents register travel activities during the previous day and are consequently less likely to participate in the survey while being away. Homebound travel is on the contrary likely to be overrepresented as the respondents being away when they are supposed to participate are contacted during the following days and the probability of registering homebound travel consequently increases. The information on an overnight stay is not considered throughout this chapter as these biases should be taken into account in the data processing. Travels with an overnight stay registered in TU are however considered in Chapter 3. In its present form, international travel activities are also registered, but travel details are only registered until the Danish borders[5].

2.1.1 Data preparation

The survey design and sample of respondents have varied across the years, hence some data processing is necessary to achieve a comparable sample across the years. To complete the trend analysis in section 2.2 only the respondents between 16 and 74 years old are included. During various periods, the survey includes respondents from 10 to 84 years old. In this study no adjustments are however made to the person weights applied. From the latest generation of TU, the person weights are estimated relative to respondent age and not relative to age groups, hence the applied person weights are unaffected by only including a subsample. From the person weights in the second generation survey the applied person weights are however estimated based on rather coarse assumptions and it is difficult to evaluate the actual impacts of only including subsamples in the analysis. The survey from 1998-2001 also register respondents from 10-16 and 74-84 years, hence these years are affected by only including 16-74 year olds in the applied subsample. These years are however also the years generally affected the most by uncertainties and are generally disregarded in the overall trend analyses.

As the international travel activities are not registered with complete travel details, these are excluded from the sample analysed. Travel times and travel distances are only registered until the Danish borders and are consequently not representative for the actual

[4] i.e. origin and destination of the day is not at the same address

[5] International destinations are registered at nuts 3 level, and crow fly distances are consequently possible to estimate.

activity. This naturally underestimates travel frequencies, but when comparing the average travel frequencies with and without international trips, the results are very similar.

It is additionally decided to remove business trips having transportation as travel purpose e.g. truck drivers, taxi drivers, police officers on patrol etc. These trips contribute to a considerable share of total travelled kilometres, but are not representative in terms of individual travel behaviour.

The latest surveys from May 2006 to December 2012 are considered homogeneous in method and comparable across years. However, 2006 only covers 8 month from May to December and is additionally affected by some start-up difficulties. It is decided not to include 2006, as scaling to a complete year is affected by further uncertainties. For the same reason; the four months from 1992 are neither included.

2.1.2 Comparison of TU across the years

The share of respondents without a travel activity during the day is often used as a quality indicator of travel diary surveys (Madre et al., 2007). These travellers are in literature often referred to as immobile which might give intuitive wrong associations why they are described as non-travellers in the following. From a sample of 401 travel surveys from 1974-2002 Madre et al. (2007) find the average share of non-travellers to be 14% for surveys covering the whole week. They furthermore discuss some upper and lower limits of 4% based on weekday surveys. This corresponds to the share found in many other European studies (Kuhnimhof, 2008), and also corresponds sufficiently with the share of non-travellers found in TU. In the majority of years, the share of respondents registering travel activities is 85% as illustrated in Figure 3. The variation of non-travellers registered in TU very much outlines the troubles related to time series analysis of the survey:

- Before 1996, trips below 300 meters were not registered, which explains some of the higher shares of non-travellers during these years.
- The increasing share of non-travellers from 1998-2001 can be explained by changed survey methodology in 1998 and increasing problems with the quality of the interview field work (Christensen, 2006).

These relations are furthermore obvious from the subsamples of travellers also illustrated in Figure 3. When removing short distance trips from the survey (trips below 1 kilometre) and especially when removing non-motorised trips, the variation is significantly reduced and the share of travellers becomes relatively similar across the years. This corresponds to observed characteristics of non-reported trips being generally shorter and non-motorised (Richardson et al., 1995). If the survey years before 1996 and from 1998-2001 are affected more by under-reported short distance trips or non-motorised trips, a group of respondents with few trips might then occur as non-travellers. This is supported by the development illustrated in Figure 3.

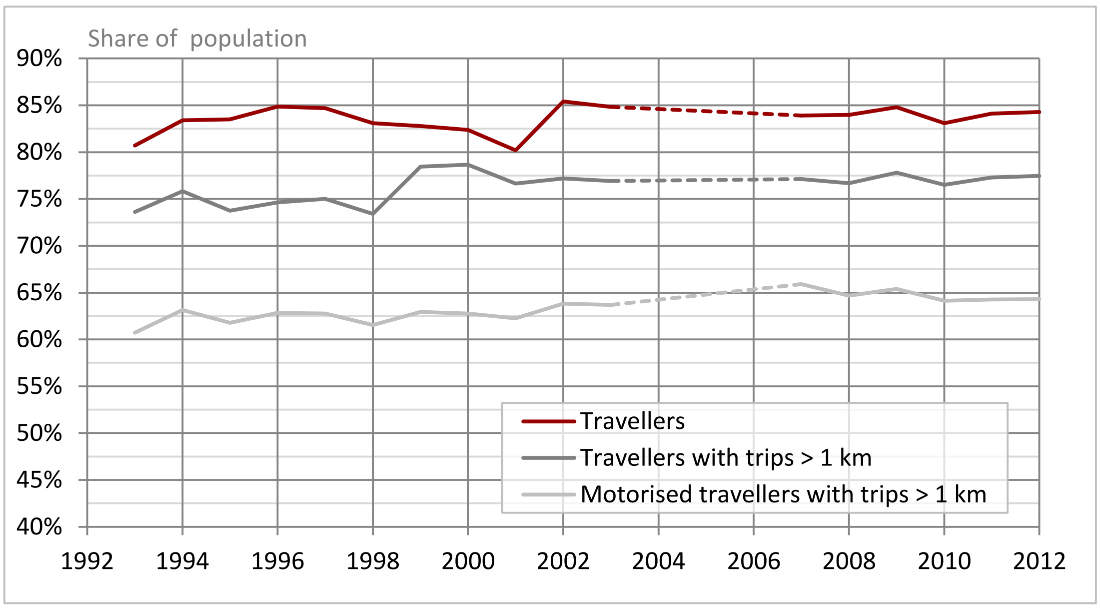

FIGURE 3: SHARE OF TRAVELLERS ACROSS THE SURVEY YEARS AND SHARE OF TRAVELLERS WITH TRIPS ABOVE 1 KILOMETRE AND MOTORISED TRIPS.

The share of travellers with trips above 50 kilometres and 100 kilometres is illustrated in Figure 4. Together with the variation observed in Figure 3 and as also described in Christensen (2004), the higher share of non-travellers in 1998-2001 is not alone related to short distance travel or non-motorised travel. The share of longer distance travellers is also found lower from 1998-2001 which supports the comprehensive uncertainties discussed in (Christensen, 2006; Christensen, 2004).

If not considering the uncertainties of 1998-2001, the general development additionally suggests two levels of travelling before and after 2002. It is however more likely that the overall level of travellers with trips above 50 kilometres increases throughout the whole time span. The figure additionally shows that the level of travelling after 2007 is influenced by the worldwide finance crisis approaching around 2007-2008, but also that travelling above 50 kilometres seems to have recovered in 2011 and continues the growth from 2011-2012.

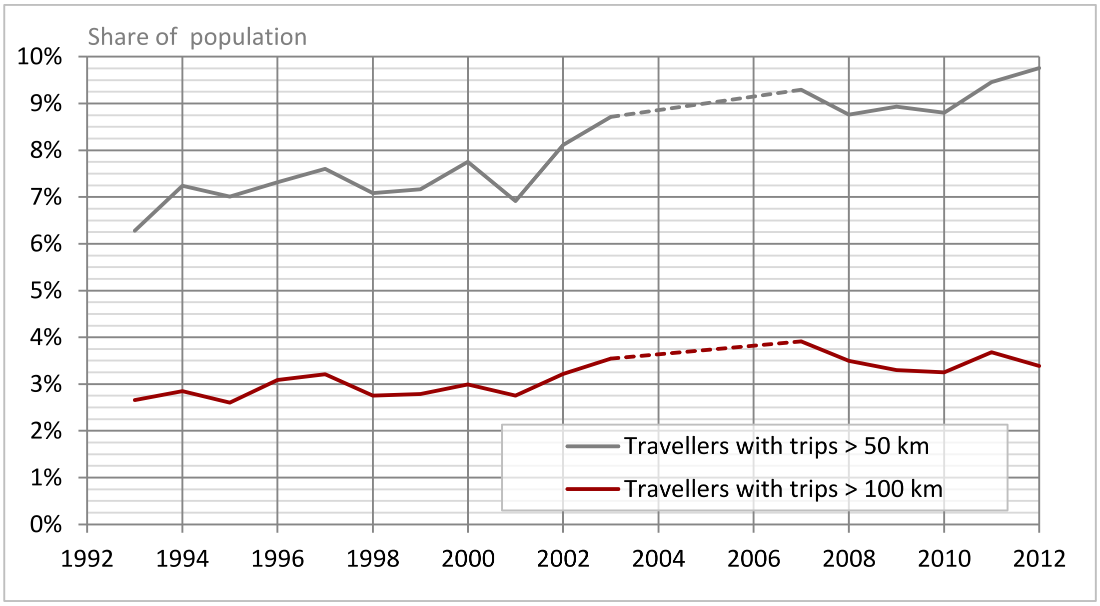

FIGURE 4: SHARE OF PERSONS WITH TRIPS ABOVE 50 AND 100 KILOMETRES

To summarise the overall validation of the two generation of TU, it is reasonable to assume the share of non-travellers to be constant, when taking the survey uncertainties into account. This works as a quality indicator of the survey, but this has also revealed a considerable number of years with survey problems. In addition to this, the overall increasing share of respondents with longer travel distances in Figure 4 also corresponds to the general assumption of increasing travel distances. TU is generally found reliable, but it is however necessary to keep in mind the complications in especially 1993 and 1998-2001 when comparing Danish travel behaviour across the years.

A way to avoid the transferred impacts of the higher share of non-travellers is to estimate the level of travelling per traveller instead of the whole population as also decided in (Armoogum et al., 2013). From the processing of TU, the biases observed in Figure 3 and Figure 4 has however been transferred to both the average level of travelling per Dane and per traveller. It is due to this mainly the survey years with a share of travellers around 85% that are considered in the following.

2.2 TRAVEL TRENDS 1993-2012

The main travel indicators are described in the following section to reveal the overall trend in Danish travel behaviour based on TU. The reference point in 1981 is applied where the information is available (DSB, 1983). Figure 5, Figure 6, and Figure 7 show the development in average travel frequency, travel time, and travel length. From all three figures it is apparent how the survey difficulties outlined in the previous section are transferred to the average level of travelling no matter if they are estimated per Dane or per traveller. It is due to this mainly the averages of 1996, 2002, 2008, and 2011 that are comparable.

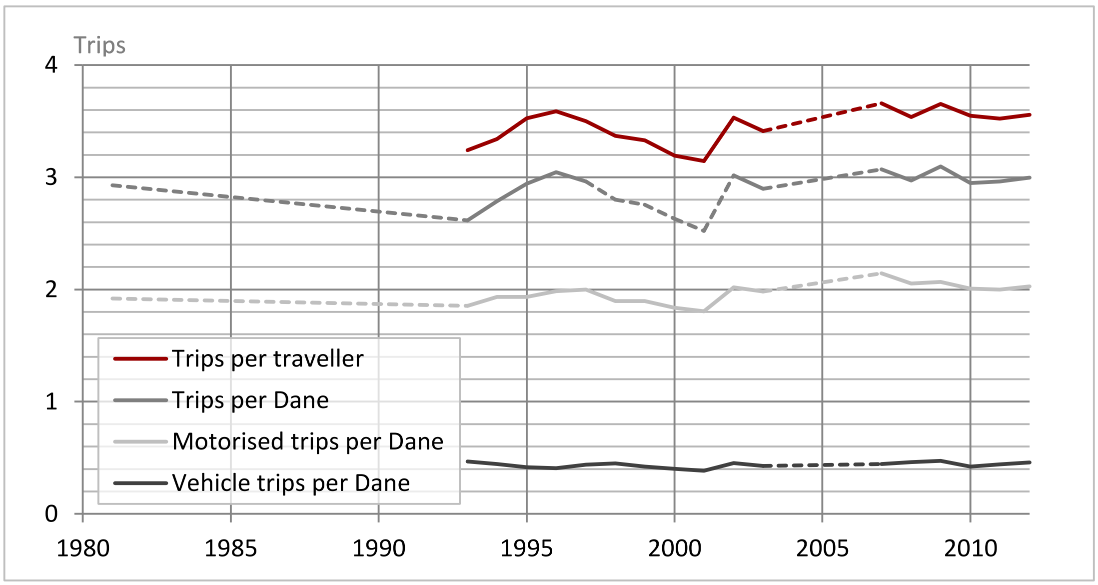

FIGURE 5: AVERAGE TRAVEL FREQUENCIES OF 15-74 YEAR OLDS IN TU

If disregarding the problematic survey years, an average Dane completes 3.0 trips per day and an average traveller completes 3.5 trips per day as illustrated in Figure 5. The travel frequency has stayed relatively constant throughout all the years with approximately 85% travellers. The travel frequency of 3 trips per day furthermore corresponds to the average in 1981 and are supported by the constancy found in other European countries: Metz (2010) finds 1000 trips per person per year (or 2.7 per day) in UK from 1972-2008 and the average in Norway varies between 3.1-3.3 trips per day from 1982 to 2009 (Vågane et al., 2011; Schafer, 2000). The travel frequency per traveller also corresponds to the findings in the

SHANTI project, where the travel frequency is between 3.5 and 3.6 per traveller in Finland, France and the Netherlands (Armoogum et al., 2013).

Figure 5 furthermore shows the development in trips per Dane when only including motorised trips and additionally only including vehicle trips, i.e. motorised travel without public transport. When considering the frequency of vehicle trips, the survey uncertainties are certainly reduced and the constancy is obvious. This further supports the assumption of not only too many non-travellers, but also an underrepresentation of non-motorised trips as well as trips by public transport.

Even though the overall level is relatively constant, a minor yearly variation is also apparent and might be related to the variation in working days during the different years. This variation is further transferred to the average travel times and travel distances described in the following.

2.2.1 TRAVEL TIME

The average travel time budget per day illustrated in Figure 6 suggests two levels of travel time; from 1994-2001 and also in 1981, the level of travel time is between 45 and 50 minutes per Dane per day. From 2002-2012 the travel time budget is just below 60 minutes per person per day. The figure also reveals a level change for vehicle travel time which suggests that the difference is not alone assigned insufficient registered non-motorised travel from 1998-2001. The difference might however reveal a general improvement in the travel survey.

If comparing the average travel times with other European studies, the Danish estimates after 2002 are found approximately 10 minutes lower than in most other countries (Armoogum et al., 2013; Kuhnimhof, 2008; Schafer, 2000; Christensen and Sobrino Vázquez, 2013). From the distribution of mode choice described in Armoogum et al. (2013) it is possible that this difference is related to a lower share of trips completed by foot and lower shares of long distance travel. Both travel types influence travel times considerably. Some of the differences might be explained by survey issues or different travel behaviour by Danes that involve more biking and less walking. But it might also be related to not including international travel as well as the shorter possible travel distances due to the Danish Geography.

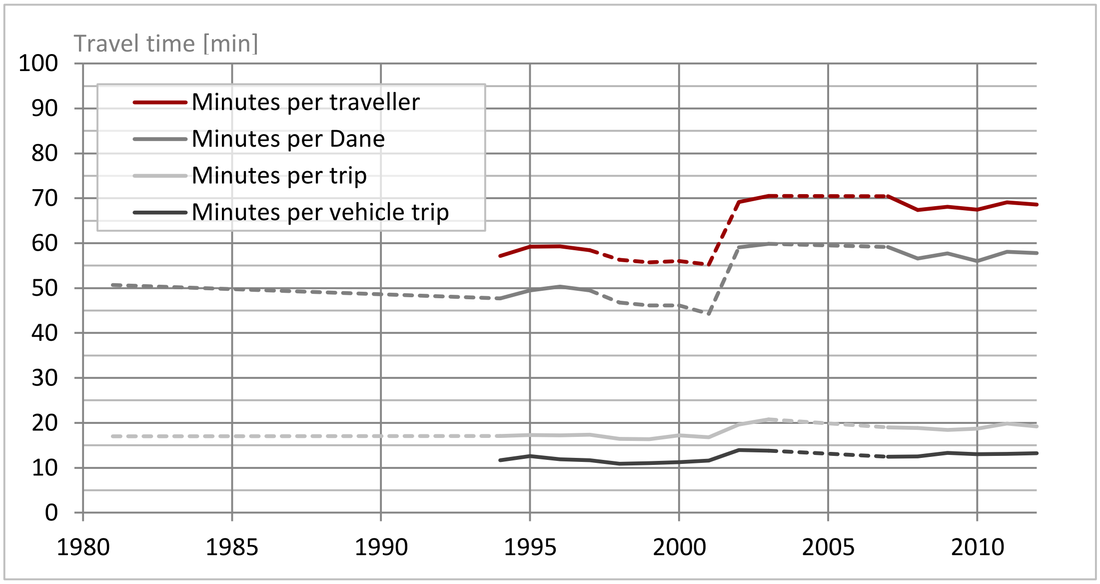

FIGURE 6: AVERAGE TRAVEL TIME PER DANE AND TRAVELLER FROM 1981 TO 2012.

2.2.2 TRAVEL LENGTH

The development in travel distances illustrated in Figure 7 suggests an overall growth in travel distances from 25 kilometres per Dane in 1981, 35 kilometres per Dane in 1996, and 41 kilometres per Dane in 2012. This development is however evidently affected by the difficulties in 1998-2001, the survey break from 2003-2007, and the economic development after 2007. The significant growth during the break from 2003 to 2007 corresponds to the overall trend since 1981 and finds a yearly growth rate in travel distances of 1.7% p.a.

The development in trip length is similar to the development in average travel distance per day which corresponds with constant travel frequencies. The average trip length has increased from 10 to 14 kilometres from 1981 to 2012.

The average travel distance per traveller is approximately 7 kilometres higher than the average per Dane. The travel distance of 46-49 kilometres per traveller corresponds to the level found in especially Norway and the Netherlands (Armoogum et al., 2013). The share of kilometres from long distance trips is however lower for Denmark, which is partly caused by not including international travel, but compared with e.g. Norway it is furthermore related to a more dense population and smaller possible domestic travel distances. The increasing trend in travelled kilometres also corresponds with other European trends: The summary of the Norwegian travel trends shows an increase from 10.3 kilometres per trip in 1992 to 12.0 in 2009 or 32.1 kilometres per day in 1992 to 42.1 in 2009 (Vågane et al., 2011; Schafer, 2000). The trend in daily mobility by Swedes is 9.5-14.3 kilometres per trip and 39-42 kilometres per person per day from 1978 to 2006 (Frändberg and Vilhelmson, 2011).

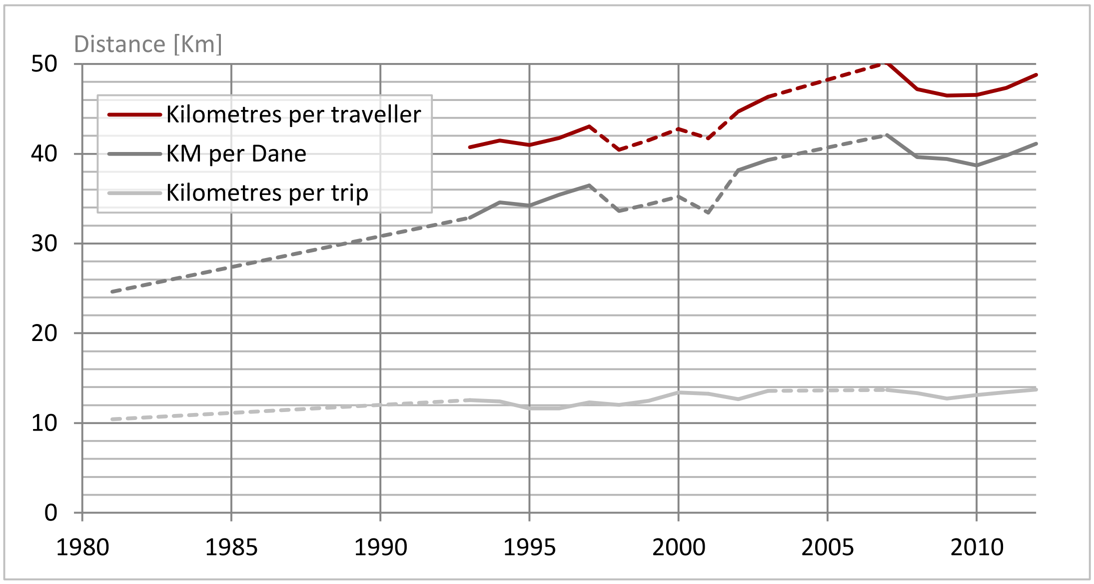

FIGURE 7: DEVELOPMENT IN AVERAGE TRAVEL DISTANCES PER DAY AND PER TRIP UNDERTAKEN BY DANES BETWEEN 16 AND 74 YEARS

Figure 8 illustrates the average travel length per year relative to GDP per capita. The figure is similar to the figures presented in (Millard-Ball and Schipper, 2011) for eight industrialised countries. If disregarding the problematic survey years in 1998-2001, the relation between transport and economy has increased from 1981 to 2007. This illustrates the strong relation between transport and economy. Tapio (2005) defines decoupling of transport from economy as the ratio between the change in transport volume and the change in GDP. From the relations illustrated in Figure 8, travel distances have increased 1.1 times faster than economy from 1981-2012 and 1.2 times the economy from 1981-2007. This relation suggests a significant coupling between Danish travel distances and economy which is furthermore supported by the contradicting impacts of the economic changes from 2007-2010 where travel distances decreased 1.3 times the decrease in economy.

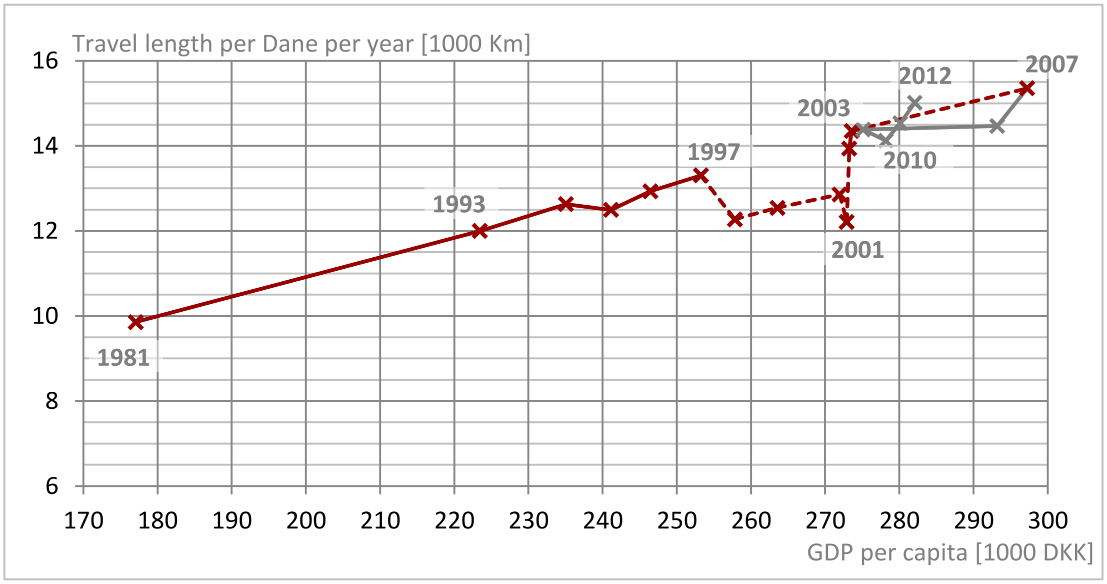

FIGURE 8: AVERAGE TRAVEL LENGTH PER DANE PER YEAR RELATIVE TO GDP PER CAPITA IN 2005 PRICES. THE SURVEY YEAR FROM 1998-2001 IS CONSIDERABLY BIASED FROM SURVEY UNCERTAINTIES, WHICH EXPLAINS THE LOVER TRAVEL DISTANCES.

The development from 2007 to 2012 suggests some apparent changes in the relation between transport and economy:

- 2007-2008 shows a drop in economy as well as in travel distances, but the drop in travel distance might also be influenced by the slightly higher travel frequencies found in 2007.
- 2008-2009 has constant travel lengths regardless the significant drop in economy.
- 2009-2010 finds a decrease in transport even though GDP is increasing. This might be related to a phasing-in period of changes in economy, but also a local drop from 3.1 to 2.9 trips per person per day.
- 2010-2012 shows increasing travel length and increasing economy. The relation however seems even stronger than found during the whole period. This trend might however also be influenced by general fluctuation reaching a new level of equilibrium after the exogenous shock in economy.

Figure 8 generally finds a positive correlation between transport and economy. It furthermore suggests a phasing-in delay of significant changes in economy. From future development it will however be interesting to analyse if this local 'loop' from 2003-2012 represents a level of saturation around 14.5 thousand kilometres per Dane per year inside

Denmark or just a local break in the general development due to recession. It is notable that the level of travel in 2012 is almost back at the level of 2007 even though economy has not completely recovered. This corresponds to the recovering also observed by Copenhagen Airport in Figure 1.

The break in TU from 2003 to 2007 is unfortunate and problematic. These years are affected by substantial growth in GDP and fall in-between two periods of stagnation and decreasing GDP. The trend from 2003-2007 however follows the overall trend from 1981-2003 if disregarding the survey issues in 1998-2001. The financial situation after 2007 has considerable impact on travel length in particular, but the overall trend from 2007-2012 suggests a temporary displacement due to the exogenous changes in the economy rather than a general level of stagnation or saturation in national travelling as suggested for UK in (Metz, 2010). One explanation of the difference might be a slower development in Danish car ownership due to higher taxation and that Danish motorisation has not yet reached its maximum.

2.2.3 Long distance travel

As illustrated in Figure 7, the average trip length found in TU is around 12-14 kilometres. This relatively short travel distance is related to the highly asymmetric distribution of trip lengths. Approximately 50% of all trips are below 5 kilometres and the share has stayed more or less constant during all the survey years as found in Figure 9. This logically influences the average trip length and diminishes the overall impact of longer distance trips. But as also illustrated in Figure 9, the picture is somewhat different when considering travelled kilometres. The limited share of 3-4% trips above 100 kilometres correspond to 20-25% of the total travelled kilometres. The magnitude of travel activities above 50 kilometres has generally increased throughout the survey years, but this development has been slowing down due to the changes after 2007. In total, the figure illustrates the increasing magnitude of longer distance travel activities when focus is on travelled kilometres instead of the number of trips. The figure only holds domestic travel hence the share of long distance kilometres is in fact higher.

The asymmetric distribution of trips and kilometres are visualised in Figure 10. Even though the sample is based on a common sample from 2007-2012, the sample size in each distance band is limited when exceeding 100 kilometres. The figure also illustrates the uncertainties related to stated travel distances due to rounding-off numbers. It is obvious from the figure that registering a 100 kilometre trip is somewhat more frequent than 95 kilometres[6]. When deciding on a distance threshold for long distance travel this impact of round numbers also need to be considered. This is of remarkable magnitude when adding a long distance threshold why some survey designs actually include a buffer and apply a 75 kilometre threshold rather than 100 kilometres as (Axhausen, 2003a).

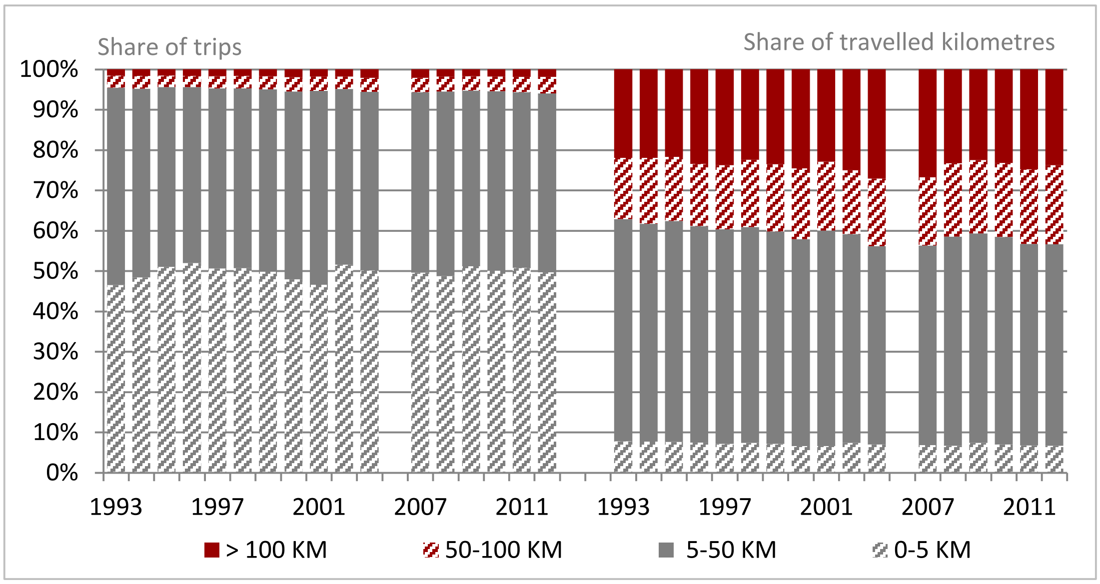

FIGURE 9: SHARE OF TRIPS AND TRAVELLED KILOMETRES IN DIFFERENT DISTANCE BANDS

The high share of trips below 5 kilometres reduces the average travel distances significantly and the possible trends in long distance travel diminish. When isolating trips above 50 kilometres and above 100 kilometres, it is found that more persons complete longer distance trips, and that the share of kilometres from long distance travel has increased. It however also appears that long distance travel has been affected the most by the economic recession from 2007-2009. The share of long distance trips decreased from 2.1% to 1.8% during these years even though the share of kilometres increased from 17.0% to 18.1%

[6] From 0-110 kilometres, the distance bands are 5 kilometre intervals and due to smaller samples, the distance bands are increased to 10, 25, 50 and 100 kilometres which explain the less distinct asymptotic trend of travelled kilometres above 100 kilometres.

during the same years. Regarding the long distance trips analysed, one have to keep in mind the limited sample of trips.

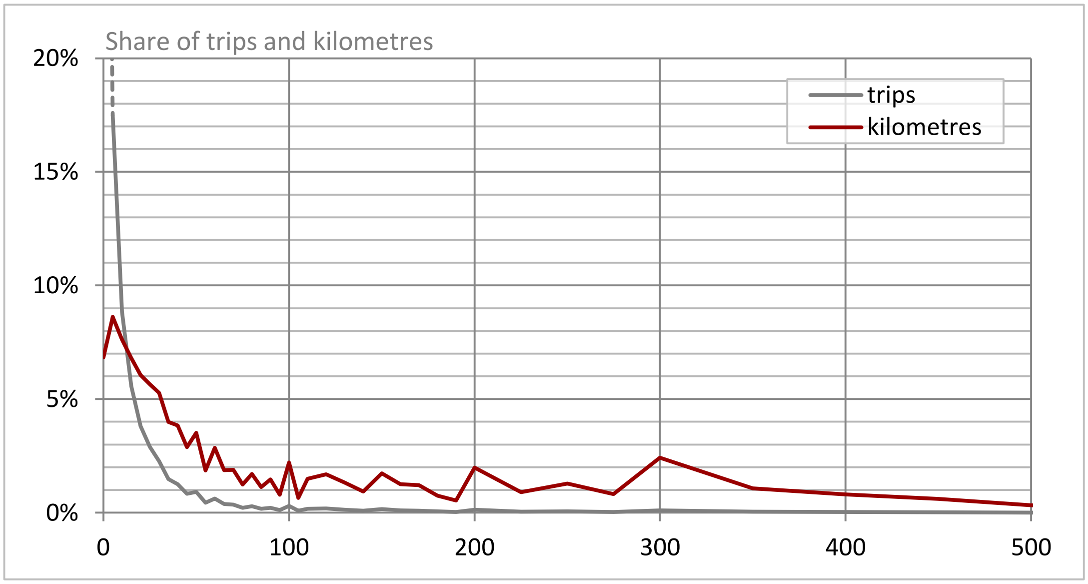

FIGURE 10: SHARE OF TRIPS AND TRAVELLED KILOMETRES WITH INCREASING TRAVEL DISTANCES

2.3 CHARACTERISTICS OF DAILY TRAVEL ACTIVITIES

In the following sections, the third generation TU is analysed into more details to reveal some of the characteristics in long distance travelling from 2007-2012. In this section journeys are analysed rather than trips (see section 1.1), the sample of respondents includes all respondents of 15-84 years[7], and finally crow fly distances are analysed rather than registered travel distances. The differences compared to the previous sections are motivated by the purpose of comparing daily travel activities with journeys with overnight stay(s), analysed from the Business and Holiday Survey (HBS) in Chapter 3.

The purpose of this section is to analyse travel characteristics in order to discuss a sufficient definition of long distance travel activities. This is motivated by the assumption that other characteristics might be relevant when dividing journeys into frequent and infrequent travel

[7] Compared with the subsample of 16-74 year olds applied in the previous section due to differences across the survey years.

activities. The following analysis disaggregates the journeys into different travel characteristics, which requires higher samples than available in TU per year. Due to this, the samples from 2007 to 2012 are pooled into one common sample weighted relatively to the interview year. Seen in isolation, these years do not represent major changes in travelling and the common survey describes a representative average picture of travelling during the second half of the 2000s. Even though six years of data are grouped as one common sample, the sample size of long distance travel is still only 1,900 observations when applying a 100 kilometres threshold. Detailed disaggregation into travel purpose, destination etc. might consequently be insufficient. The sample of outbound or homebound journeys that might include an overnight stay consists of 6,700 journeys, from where 1,200 journeys are above 100 kilometres. All outbound and homebound journeys are in the following assigned a common duration of 24 hours. The possible underrepresentation of outbound journeys and the overrepresentation of homebound journeys are not taken into account. These journeys are journeys not completed during the 24 hour limits from 3 AM to 3 AM, which might be travelling with overnight stay, couples living apart, hence having two natural home addresses, and work with night duty. But it might also be journeys that just finish during the night such as parties, concerts, visits etc.

The journeys are throughout this section grouped into the four main travel purposes; commuting, errands, leisure travel and business travel (Christiansen and Skougaard, 2013):

- **Commuting:** travelling between home and work place or the place of study.
- **Errands:** bring or pick up persons or things, shopping, social or health visits, and other errands.
- **Leisure:** Visiting friends and relatives, sport activities, entertainment, vacation homes and allotment gardens, walk, bike, run or drive, where the movement is the purpose itself, holiday, excursions, private meetings, and other leisure activities.
- **Business:** Meetings, conferences, customer visit, trade service, business trip, and other business-related transport.

	Frequent	Infrequent
Private	Errands	Leisure
Professional	Commuting	Business

FIGURE 11: ACTIVITY MATRIX

These four main travel purposes are placed in an activity matrix that distinguishes between private and professional activities, and the expected travel frequency as illustrated in Figure 11. The four overall travel purposes are expected to vary in travel profile, though having some vertical and horizontal similarities.

2.3.1 Underestimation of travel distances

When applying crow fly distances instead of the registered travel length, the total travel length of the population is significantly underestimated. This underestimation is twofold; i) the difference between the actual chosen route and the crow fly distance, and ii) the travel length from the sub trips and other stops during the journeys.

Applying crow fly distances rather than route distances however removes the uncertainties related to the stated travel distances as the crow fly distances are based on coordinates. But due to Danish geography travelling across country might enforce substantial detours and in some cases crow fly distances might be misleading, see Figure 12.

If selecting only the two-trip journeys, most journeys are assumed to follow the most direct route allowed by the network. Hence analysing two-trip journeys determines a level of underestimation caused by route relative to crow fly distance alone (i). The additional errors related to sub-trips (ii) are determined when including all the registered journeys in the estimations. Table 3 shows the level of underestimation when only considering two-trip journeys and when including journeys with several stops during the journey. The journeys are further grouped into 50 kilometre crow fly distance bands.

Table 3: Average underestimate per journey when applying crow fly distances rather than route distances. The journeys are further grouped into 50 kilometres crow fly distances.

	2 trips per journey		All journeys	
	Km	%	Km	%
0-50 km	4.80	28%	7.36	31%
50-100 km	35.19	21%	46.86	25%
100-150 km	61.29	23%	73.87	26%
>150 km	113.91	29%	125.72	32%
All journeys	6.67	28%	10.17	31%

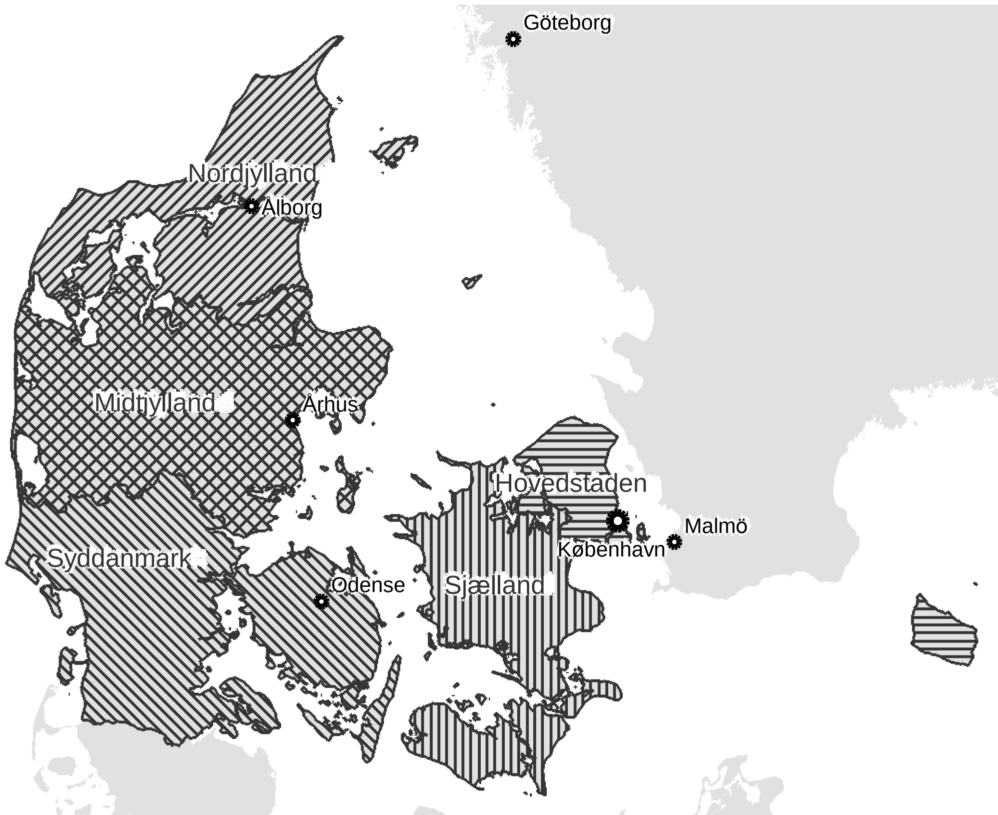

FIGURE 12: MAP OF THE FIVE DANISH OFFICIAL REGIONS. SOURCE: THE DATA- AND MODELCENTER AT DTU TRANSPORT.

From the sample of two-trip journeys, an average journey distance is underestimated by almost 7 kilometres corresponding to 28%. When further dividing the journeys into 50 kilometres distance bands, it appears that the highest relative underestimation is found from the high number of short distance journeys, but also in the limited sample of journeys above 150 kilometres. The latter is most likely due to geographically necessary detours. When further including journeys with several stops during the journey, the difference is found a few percentages higher. On average the journey distances are underestimated by 10 kilometres or 31%. The 21%-29% underestimation related to detours corresponds to the German detour factor of 1.28 and the 1.22 in Great Britain (Kuhnimhof et al., 2009; Chalasani et al., 2005).

From 2007-2012 6.2 million journeys were completed during an average day which corresponds to 1.2 journeys per person and 1.5 journeys per traveller as listed in Table 4. An average journey has a crow fly distance of 12 kilometres compared with a travel length of 18 kilometres. In total, when summarising crow fly distances, the level of travelling per day is 109 million kilometres, which is 60 million kilometres lower than the level found when summarising the stated travel length. These comparisons clearly illustrate how the definition of travel distances influences the estimated level of travelling. The main contribution actually originates from the difference between route choice and crow fly distance, whereas additionally 3-4% points originates from the structure of complex journeys with several stops.

TABLE 4: TOTAL NUMBER OF JOURNEYS AND TRAVELLED KILOMETRES PER DAY ESTIMATED FROM ROUTE DISTANCES AND CROW FLY DISTANCES.

	Journeys	Stated travel length	Total crow fly distance[A]
Total travel	5.4 million	168.8 million	109.4 million[A]
Average per journey	1	17.9[C]	12.0[B]
Per person	1.2	38.2	25.7[A]
Per traveller	1.5	46.6	31.4[A]

[A] Twice the crow fly distance when the journey is completed and crow fly distance for out- and homebound journeys

[B] Crow fly distance

[C] Half the stated travel length when journeys are completed and travel length for out- and homebound travel

Regardless the significant underestimation, applying crow fly distances has some advantages in terms of uncertainties. In this Ph.D. study, the most important advantage is the parallel to travel distances of international travel, which are rarely registered as stated route distances. Another important difference is the uncertainties related to stated distances, which most likely varies across individuals and travel activities. As regards Danish geography, some of the differences are a natural consequence of the boundaries from crossing of several straits when travelling across the country. But some of the differences might additionally originate from less awareness of the exact travel distances, when undertaking the more infrequent journeys. Finally the respondents are more likely to register distances of 100 kilometres rather than 95 or 105 kilometres, as also illustrated in Figure 10.

In some cases it might be reasonable to assume that travel distances are perceived as a radial range unaffected by the available routes. Intuitively this could in particular be the case for international travel activities, where an exact distance is most likely not known in advantage of the choice of travelling. This corresponds to the assumption of destinations rather than distances being determinants of long distance travel as discussed in Rich et al. (2010). Regarding international travels, the travel time, travel duration, travel type, or travel costs might also be suitable determinants of infrequent travel activities which correspond to the variables often included when modelling tourism demand see e.g. (Divisekera, 2003; Witt and Witt, 1995; Li et al., 2005; Song and Li, 2008).

2.3.2 Average level of travelling

An average Dane completes 1.2 journeys per day with a crow fly distance around 12 kilometres per journey. In the following sections, the similarities and differences in errands, commuting, leisure, and business travel are outlined. The travel purposes are compared according to the activity matrix from Figure 11 on page 41.

Table 5: Crow fly distance per journey (one-way), share of journeys and share of total travelled kilometres (two times crow fly distance) grouped into the four main travel purposes

		Crow fly distance per journey [KM]		Share of journeys		Share of kilometres	
Errands	Leisure	5.5	14.9	31%	37%	14%	46%
Commute	Business	13.5	36.0	30%	3%	33%	7%

The journey length, the share of journeys, and the share of travelled kilometres are listed in Table 5. The diagonal relation of errands being shortest and business travel longest is most apparent. Leisure travel is on average only found a little longer than commuting. The high share of leisure travel differs from the assumption of leisure travel being an infrequent travel type as suggested by the activity matrix. This is due to the relatively wide definition of leisure travel. When including leisure travel as a common travel purpose, leisure is actually the most frequent travel activity representing 37% of all journeys and 46% of the travelled kilometres. The definition of business travel holds similar variety in sub-purposes, whereas errands and commuting are more distinctly defined travel types. If considering trips rather than journeys, the share of errands actually increases to 35% and the share of commuting is reduced to 25%. The share of leisure and business travel however remains.

The two private travel purposes, errands and leisure travel, represent more than two thirds of all journeys registered in TU. The magnitude is even higher when considering travelled kilometres. Commuting represents 30% and business travel only 3%.

Table 6 shows the average crow fly distances of six leisure sub-purposes. The variety in leisure travel distances and frequency is obvious when considering leisure as disaggregated travel purposes. The table illustrates that the main part of leisure travel is visiting friends and relatives and 'other' leisure purposes such as sports and private business. Vacation homes and holiday travels are as infrequent as business travel, whereas entertainment is semi frequent. The high share of short distance leisure travel activities are grouped as 'other' leisure purposes and generally reduce the overall average of leisure travel distance. The average crow fly distance of holiday travel and journeys to vacation homes is still only around 50 kilometres. This certainly stresses the dominance of shorter distance travel activities and the absence of international travel. But an average of 52 kilometres suggests that a notable share of activities is also likely to be excursions completed during holidays and weekends.

TABLE 6: AVERAGE CROW FLY DISTANCE OF LEISURE TRAVEL AND THE MAGNITUDE OF THE SUB-PURPOSES.

	Crow fly distance per journey	Share of leisure journeys	Share of leisure kilometres
Visiting friends and relatives	20.1	39%	53%
Entertainment	13.2	16%	14%
Vacation home	41.9	3%	8%
Holiday and excursions	51.7	3%	10%
Home	30.1	1%	2%
Other[1]	5.4	39%	14%
Leisure	14.9	100%	100%

[1] Include doing sport, going for a walk, private meetings in private settings etc.

Business travel is grouped into four sub-purposes as listed in Table 7. The sub-purpose 'business travel' is defined as longer business travel and is in fact a combination of the other sub-purposes. The purpose only represents 4% of the business journeys and is hence based on a limited sample of only 93 observations. As also described in the following section 2.3.3.2, the characteristics of these business journeys differ considerably from the others, which is also obvious from the average crow fly distance of 109 kilometres. Business service and trade have the shortest crow fly distances, whereas the deviation in crow fly distances is somewhat higher for meetings and conferences.

TABLE 7: AVERAGE CROW FLY DISTANCE OF BUSINESS TRAVEL AND THE MAGNITUDE OF THE SUB-PURPOSES.

	Crow fly distance per journey	Share of business journeys	Share of business kilometres
Meetings and conferences	39.5	41%	45%
Costumer or client visits	34.1	29%	27%
Business service and trade	22.3	27%	16%
Business travel[1]	109.0	4%	12%
Business	36.0	100%	100%

[1] Defined as longer business travel often in combination of the other three business purposes

2.3.3 DISTANCE AND DURATION PROFILES

In the following, the journeys are analysed based on frequency plots of journeys relative to distance and duration. The frequency plots illustrate the deviation of travelling in a two-dimensional surface of time use and distance.

In the third generation TU, the duration of the stay is estimated as a part of the official available data set. The duration of the whole journey and the duration of each single travel movement is also available in data. The duration of the whole journey includes travel times, which are correlated with the travel distances and transport mode, whereas the duration of the main stay is of higher interest as it indicates something about the purpose of the journey. It is decided to use the duration of the main stay even though the duration of all stops in some cases might be more representative for the journey:

- If considering the example of a commuting journey that includes a two hour business journey during the work day, the duration of the commuting journey might only figure as e.g. a six hours journey rather than eight hours.
- If on the other hand an eight hour work day includes a one hour stop for shopping on the way home, the eight hours are more representative for the main purpose of the journey.

The journeys are grouped into four crow fly distance bands of: 0-50 km, 50-100 km, 100-150 km, and above 150 km. The sample of journeys above 100 kilometres only represents 2% of all the journeys, but it is disaggregated into two distance bands anyhow. The journeys are further grouped into six duration bands, with four three-hour bands from 0 to 12 hours, one 12 hour band (from 12-24 hours), and one representing a possible overnight stay (above 24 hours). The 24 hour band holds all the outbound and homebound journeys assuming they all include minimum one overnight stay even though some of the journeys might represent journeys ending or beginning after 3 AM. Finally the journeys are grouped into the four main travel purposes. In total the journeys are divided into 96 groups as illustrated in Table 8.

TABLE 8: NUMBER OF OBSERVATIONS IN EACH GROUP OF PURPOSES; HORIZONTALLY DISTRIBUTED INTO DURATION BANDS [HOURS] AND VERTICALLY DISTRIBUTED INTO DISTANCE BANDS [KM].

Time band	Crow fly distance band [Km]				Crow fly distance band [Km]			
[hours]	0-50	50-100	100-150	>150	0-50	50-100	100-150	>150
0-3	31,396	209	42	14	22,691	252	37	14
3-6	892	62	12	4	7,215	402	100	21
6-9	171	20	6	2	22,071	229	79	26
9-12	24	5	2	0	449	68	20	8
12-24	6	0	0	0	71	8	4	1
>24	146	13	3	4	3,584	758	465	497
0-3	2,222	72	18	5	909	87	34	14
3-6	6,169	186	26	7	457	65	36	26
6-9	15,799	538	66	24	429	81	25	19
9-12	3,654	180	19	2	101	16	5	2
12-24	436	17	0	0	16	4	1	0
>24	930	81	32	37	54	29	32	83

Table 8 holds the number of observations in each of the 96 groups emphasising the dominance of especially short distance travel and to some extend also short duration travel. Furthermore it reveals the limited sample of travelling above 100 kilometres for all four travel purposes and generally a limited sample of business travel. Another interesting relation is the deviation in the travel distance of the out- and homebound journeys (>24 hours). This stresses that a significant number of journeys with possible overnight stay does not necessary have long travel distances. The table holds 105 thousand observations from 2007-2012 that correspond to 5.4 million journeys registered per day per 15-84 year old Dane.

Figure 13 shows the observations from Table 8 in a distance-duration profile plot of journeys completed during an average day. The journeys with a possible overnight stay are not included in the figure, as the duration is set to 24 hours no matter the actual duration and is consequently assigned high frequencies as also illustrated in Figure 14 and Figure 15.

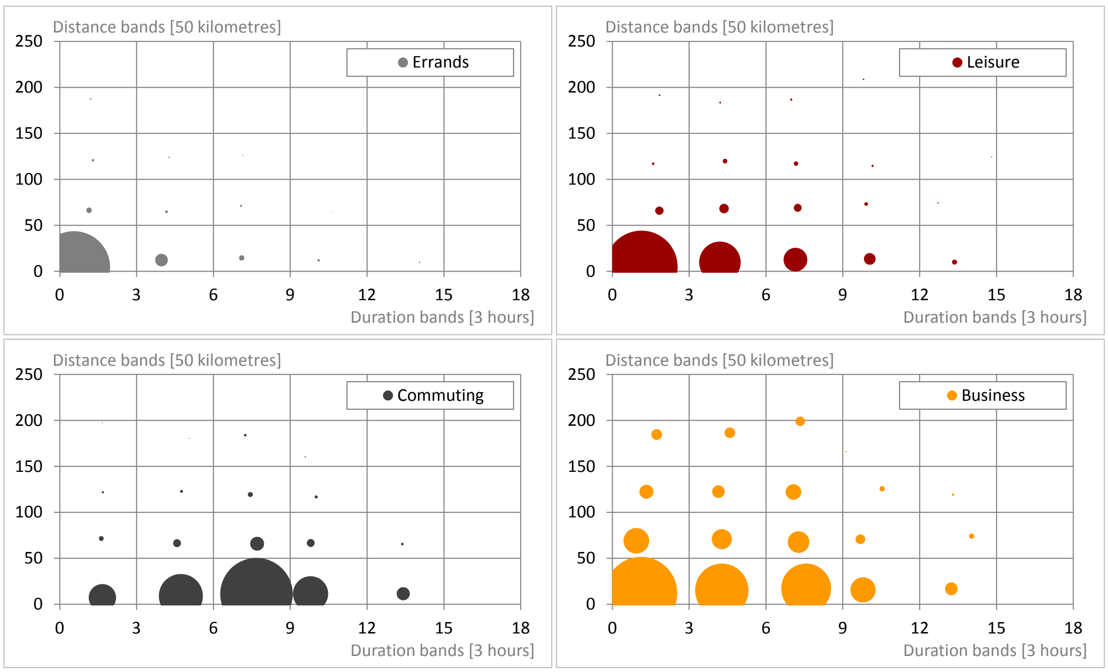

FIGURE 13: DISTANCE-DURATION PROFILES OF JOURNEYS COMPLETED DURING 24 HOURS DIVIDED INTO MAIN TRAVEL PURPOSES. THE SIZES OF THE BUBBLES REPRESENT THE SHARE OF JOURNEYS INSIDE THE DISTANCE-DURATION BAND CENTRED AT THE AVERAGE TRAVEL DISTANCE AND DURATION OF THIS GROUP OF JOURNEYS. THE AREA OF ALL BUBBLES IN EACH FIGURE SUMS TO 100%.

The sizes of the bubbles in Figure 13 correspond to the frequency of the journeys in each of the specific distance-duration bands and the centre of the bubbles corresponds to the average crow fly distance and average travel duration. The area of the bubbles summarises to 100%. The profiles show the frequency of journeys relative to distance and duration, and illustrate the ‘activity space’ of the different travel purposes. All four travel purposes are centralised below 50 kilometres, however with varying deviation. Regarding travel duration the concentration of journeys deviates somewhat more between the travel purposes.

Errands are highly concentrated in the lower left corner: 95% of all errands have distances between 0 and 50 kilometres and less than 3 hours duration. On average these 95% of the errands have 0.5 hour’s duration and 4.4 kilometres’ crow fly distance.

Leisure travel also has the majority of journeys in the 0-50 kilometres and 0-3 hour's distance-duration band. 57% of all leisure journeys have on average 1.1 hour's duration and 4.8 kilometre's crow fly distance. The deviation in travel distances and travel duration however varies more and indicates a slightly relation of increasing duration of the stay with increasing travel distances.

Commuting is concentrated around an average work day of 6-9 hours. 96% of all the journeys range below 50 kilometres. This actually stresses the limited magnitude of long distance travel especially when considering everyday activities. Business travel has the highest variation, especially in relation to crow fly distances, but also duration. 21% of the business journeys have distances above 50 kilometres. The 'activity space' of business travel is the most disperse of the four travel purposes and it seems that the duration of the journey is more or less unaffected by distances. This reveals some of the possible drivers of travel demand and travel distances that differ between private and professional purposes.

As also listed in Table 9, the majority of the journeys are daily journeys below 100 kilometres. Only 0.5% of the errands are not completed before 3 AM or include an overnight stay. 4% of the commuting journeys are possibly people working on night duty or people with two addresses, 8% of the business journeys and 14% of the leisure journeys might include an overnight stay or be finished after 3 AM. From the 14% leisure journeys, the 12% are journeys below 100 kilometres, where the 8% business journeys are more evenly distributed above and below 100 kilometres.

Another relevant parameter is the travel mode. The high share of business travel above 100 kilometres during one day might be completed by air. Air travel reduces the travel time significantly, and one-day travel might be more beneficial than staying a night away from home.

TABLE 9: SHARE OF JOURNEYS ABOVE AND BELOW 100 CROW FLY KILOMETRES SEPARATED INTO DAILY AND MULTIDAY JOURNEYS FROM TU

	Errands		Commuting		Leisure		Business	
	< 100km	≥ 100km	< 100km	≥ 100km	< 100km	≥ 100km	< 100km	≥ 100km
Daily	99%	0.2%	96%	1%	85%	1%	86%	6%
Multiday	0.5%	0.02%	3%	0.2%	12%	2%	3%	4%

2.3.3.1 Leisure travel

Even though the sample sizes become relatively small, distance-duration profiles are constructed for four sub-leisure purposes, i.e. Visiting friends and relatives, Entertainment[8], Vacation homes, and Holiday and excursions in Figure 14. Journeys with an overnight stay are included in the figure to outline the magnitude of overnight stays compared with the daily activities.

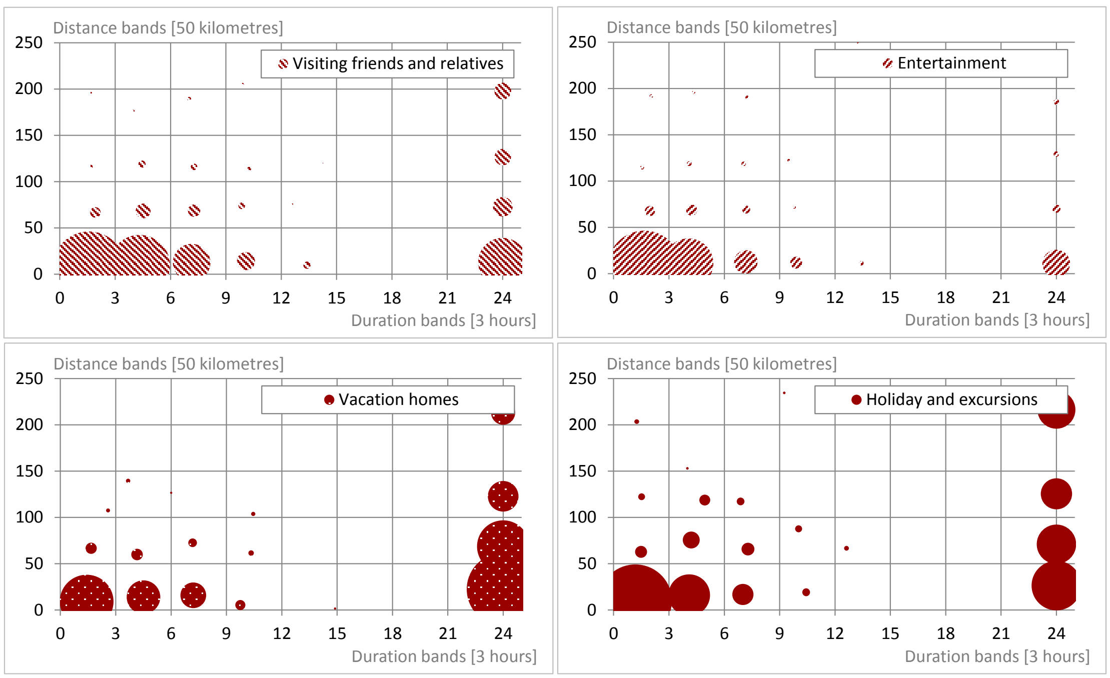

Figure 14: Distance-duration profile of sub leisure purposes

The overall share of the different travel purposes is listed in Table 6. The frequency of entertainment with an overnight stay is limited and this travel purpose is concentrated around a crow fly distance between 0 and 50 kilometres. The profile of visiting friends and relatives on the other hand shows a high variety, especially regarding duration. Most of the activities are however still inside the range of 50 kilometres.

The majority of holiday journeys and journeys to vacation homes often include an overnight stay. This is intuitively, but the figure also shows that the destinations are not necessarily

[8] Includes cinema, café, restaurants, sport events, church attendance etc.

located far away. The daily journeys are most likely excursions. The purpose of going to vacation homes also includes allotment gardens, which does not necessarily have an overnight stay.

2.3.3.2 Business travel

The same disaggregation is completed for business travel even though the samples are very limited. As illustrated in Figure 15 business travel holds an even higher variation between the sub-purposes. The most apparent relation is the evidently increasing share of 'business travel' journeys with an overnight stay when the travel distances increases. 28% of 'business travel' has an average of 205 kilometres crow fly distance and have an overnight stay.

Compared with the profiles of leisure travel, the magnitude of long distance travel is somewhat higher for business travel. A considerable share of business journeys has crow fly distances above 100 kilometres even though the duration of the stay is only of a few hours.

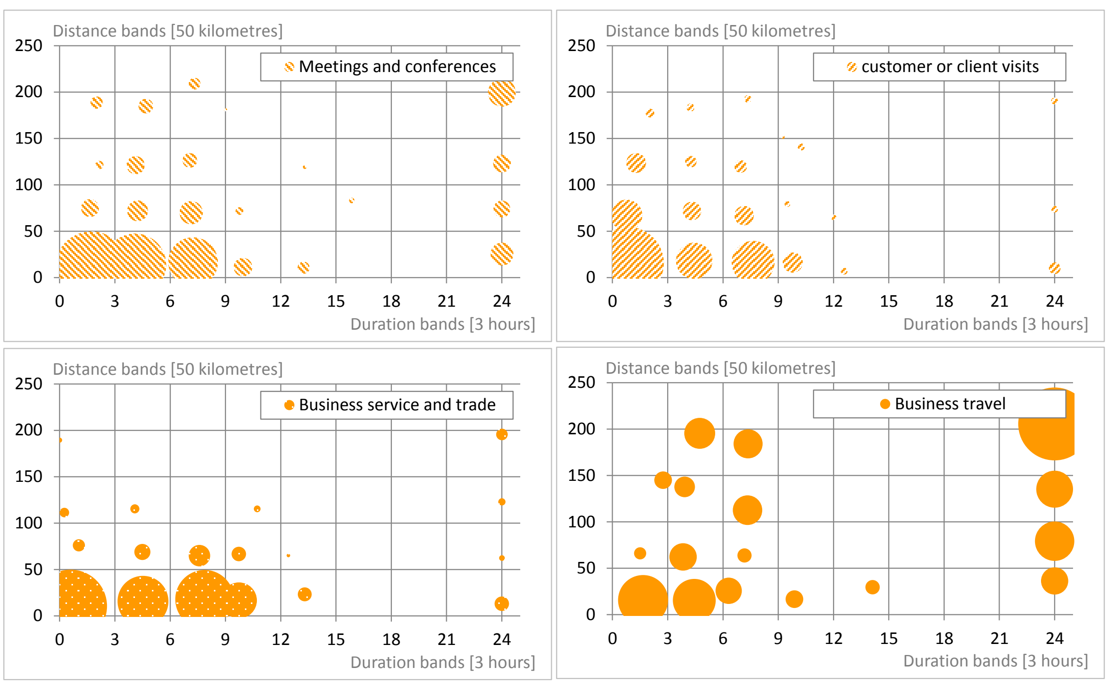

Figure 15: Distance-duration profiles of business journeys

From the distance duration plots in Figure 13 it is possible to outline some overall differences between the four travel purposes based on the concentration of journeys as well as the deviation in the interface of travel distance and travel duration of the journeys. Generally the high share of journeys below 50 kilometres emphasises the limited impact of long distance travel in daily travelling rather than outlining differentiated characteristics of long distance travel. However, together with Figure 14 and Figure 15 where leisure and business travel are disaggregated into sub-purposes, it is possible to illustrate more significant trends regarding long distance travel.

The frequent travel purposes of errands and commuting have the most definite interfaces, which is related to the more distinct defined travel purposes. Errands are characterised as journeys with very short distances and very short duration. If the distance is longer, the duration is often very limited and if the duration is longer, the distance is often limited. This relation is related to the combinination of shopping which are considered short distance travel, and collecting or bringing things or persons which are short duration purposes.

In the case of commuting, the journeys are logically centralised around an average working day. Some of the variation in the duration of commuting is influenced by the grouping of commuting and eductaion travel and others might be part time workers as well as work, including business activities, at other locations. The crow fly distances are generally not considered as long distances.

The interface of the more infrequent travel types, leisure and business travel, is more disperse due to the diversity in the definition of the travel purposes. Both travel types are centralised around short distance and short duration travel. But both travel types also include a considerable share of journeys with a possible overnight stay and distances above 100 kilometres. The most evident difference between the two purposes is higher variation in business travel especially for short duration journeys with longer travel distances.

Due to the deviation in Figure 15, business travel is certainly interesting if focussing both on travel above 100 kilometres and travel with an overnight stay. It seems that travel distances are perceived differently than the other purposes as long distance travel is also completed for short duration purposes. Business travel is driven by market factors that differ significantly from the personal characteristics that are most likely central drivers of leisure travel. Leisure travel does however also vary considerably, especially when also considering leisure travel with an overnight stay. It is consequently assumed that leisure travel plays an important role regarding infrequent travel activities with significant impacts on the total level of travelling performed by individuals.

2.4 SUMMARY

This assessment of the Danish National Travel survey (TU) describes the extent of Danish travel behaviour and how it has developed during the previous 19 years with a likely long term trend dating back to 1981. The descriptive analysis of travel characteristics has illustrated significant differences in the four main travel purposes regarding travel distance and travel duration that might be relevant before deciding on a definition of long distance travel. Travel purpose or sub-purposes seem more descriptive than travel distances, but are not alone suitable for defining long distance travel due to the considerable magnitude of short distance travel present in each of the travel purposes. The trend analysis has generally found similar trends to those found throughout Europe, but nothing suggests that Danish domestic travel distances have approached a general level of stagnation.

Most travel activities are below 50 kilometres and 50% of all trips are actually below 5 kilometres. Longer distance travel activities are hence of minor magnitude regarding the overall share of travel activities, but somewhat more significant in terms of travelled kilometres. The development in TU however suggests an increasing share of respondents travelling more than 50 kilometres. The majority of longer ranging travel activities are leisure travel and business travel. However even when disaggregating travel activities into more narrowly defined travel purposes, a significant share of the activities is still shorter than 50 kilometres in crow fly distance.

Previously commuting has gained high focus in transport research due to the significant impact on peak hour traffic and consequently the high relevance for dimensioning the road network and analysing congestion problems (Vickerman, 1972; Axhausen et al., 2002). Even though commuting represents a high share of everyday travelled kilometres, it is still of minor importance when considering long distance travel. Non-work activities actually dominate everyday travel activities in terms of travel frequencies and travelled kilometres. From the summary of journeys in section 2.3 it appears that the private travel purposes represent 68% of all journeys and 60% of all travelled kilometres. A notable share of these activities is errands such as shopping and bringing or picking up things or persons. But errands are generally short distance travel activities with an average travel distance of 5.5

kilometres. Leisure travel has an average travel distance of 14.9 kilometres and represents alone 46% of all domestically travelled kilometres.

Based on the discussion of decoupling of transport from economy and generally reducing the emission from transportation, leisure travel is pointed out as a travel activity possible to reduce without additionally ceasing economy (Schroten et al., 2011). Leisure travel is however also a complex travel activity to fully understand as it is characterised by fewer constraints than e.g. commuting travel and found more flexible as it is embedded into other daily travel activities and included as a part of larger trip chains (Schlich et al., 2004). But leisure travel is also often pleasure motivated and the drivers of leisure travel might differ from the drivers of other travel activities, especially when also including holiday travels.

The definition of travel purposes has not been as distinctly defined throughout all the survey years, but with a few adjustments of the survey years before 2003, it is possible to describe the development in travel purposes back to 1998 and less differentiated back to 1994. Even though the years from 1998-2001 are clearly affected by survey uncertainties, the distribution of travel purposes has stayed relatively constant, with no significantly increasing trend. The average number of leisure travel activities per Dane has stayed constant around 1 leisure trip per day per Dane since 1994 and the average leisure travel length has additionally stayed constant around 16 kilometres per Dane. When only considering domestic travel, nothing from TU suggests that particular growth is present in leisure travel.

Chapter 3

DANISH MULTIDAY TRAVEL ACTIVITIES

TRAVEL TRENDS AND TRAVEL CHARACTERISTICS FROM THE HOLIDAY AND BUSINESS SURVEY

The study of Danish multiday travel behaviour is based on the Danish Holiday and Business survey (HBS) that is managed by Statistics Denmark. The survey is a three month retrospective survey that has registered Danish tourism statistics continuously since 1996 with four additional summaries dating back to 1972[9]. The survey is affected by significant survey changes and Statistics Denmark recommends that the survey is not applied for time series analyses (Statistics Denmark, 2011). The survey is nevertheless the only survey available that describes holiday travel and international holiday travel in particular during a longer time horizon. It has therefore been decided to outline and evaluate the development in multiday travel from the HBS anyhow. This has however required comprehensive data preparation and validation before outlining any possible trends in travel activities. When keeping all the survey changes in mind, the processing and validation of the survey have

[9] The interviews are telephone interviews that register tourism statistics as a part of the European Tourism survey that fulfills the EU directive 95/57/EF

succeeded in outlining a number of reliable trends in Danish multiday travel which are not available elsewhere. It is assumed that the HBS and TU together more or less describes the whole spectrum of Danish travel activities, however with a little overlap and some considerable differences in travel details.

From 2009 TU has included an additional question about the number of overnight stays if a respondent registers a homebound journey. In 2010 and 2011 DTU Transport furthermore completed the TU overnight survey with special focus on multiday travel. These two TU surveys facilitate an evaluation of the level of multiday travel estimated from the HBS. But they furthermore facilitate a comparison of different survey methodologies applied to register travel with an overnight stay.

The main objectives of this chapter are to describe Danish multiday travel behaviour and to reveal the overall trends in multiday traveling. An additional purpose is to validate the information on travels with an overnight stay found in the HBS, TU, and the TU overnight survey. As each survey is affected by different survey uncertainties, this comparison is furthermore an evaluation of different survey methodologies and survey designs. Finally this section works as a general validation of the HBS as it is not designed for behavioural analyses.

Section 3.1 includes a general introduction to the HBS regarding survey design and survey history. Due to the extensive work of preparing the survey for analyses, the processing and validation of data is described in section 3.2. From the processed data, some overall trends are presented in section 3.3. The total level of multiday travel in 2010 described from the three different travel surveys is presented and evaluated in section 3.4. The different survey methodologies are discussed in section 3.5 and the overall findings of the chapter are summarised in section 3.6.

3.1 THE HOLIDAY AND BUSINESS SURVEY

The holiday and business survey (HBS) describes Danish travel activities with one or more overnight stays. The survey is a three month retrospective survey that has been completed continuously since 1996, though with some significant survey changes that reduce the possible applications of the survey for comparison across the years. This chapter only considers the survey from 1997-2011 due to incomplete samples in 1996 and 2012. The sample of respondents includes Danes of 15 years or older, but this study only consider respondents between 15 and 84 years for comparisons with TU. The survey was furthermore completed in 1972, 1976, 1980 and 1985. These results are only available in the published summaries from Statistics Denmark (Statistics Denmark, 1974; Statistics Denmark, 1978; Statistics Denmark, 1981; Statistics Denmark, 1987).

The processing of data has outlined two obvious changes in the travel survey with significant changes in the overall level of travellers and travelling. These changes are supported by the description of survey changes (Statistics Denmark, 2005; Statistics Denmark, 2009). Consequently, the survey is grouped into three overall survey periods; before May 2004, from May 2004 until May 2008, and after May 2008.

The HBS is affected most significantly by the change in the survey design introduced in May 2008. The difficulties can be assigned to two different changes:

- A change in the definition of the three main travel categories registered
- A reduction in the number of travel activities registered with travel details from five to three.

Before May 2008, the travel activities were grouped into the three main travel types; long duration travel with four or more overnight stays, short duration travel with 1-3 overnight stays, and business travel with overnight stay. The total number of long duration journeys was registered one year back whereas short duration and business travel were registered three month back[10]. Up to five journeys per category were registered with complete travel details. From 2004-2008 the latest five journeys during the latest three months were registered with details, and before 2004 it was the five 'most important' journeys.

Since May 2008 the three main journey types have been holiday travels, visits, and business journeys. As a common travel purpose, visits include visits at friends and relatives (VFR) and staying in own or borrowed vacation homes, but not in rented vacation homes which are registered as holiday travels. All journey types are registered three month back and only the three latest journeys are registered with details. It is possible from the registered travel

[10] From 2004-2008 details about long duration journeys were only registered three month back

details before and after 2008 to group the travel categories into five similar categories as illustrated in Figure 16.

The redefinition of the three main travel types introduced in May 2008 has complicated an overall trend analysis in two ways: First of all the introduction of visits as a separate travel purpose has illustrated that high frequent domestic visits with few overnights stay was insufficiently described before 2008. The processing of data has shown that the difference mainly influences VFR and it is found highly likely that the perceived relevance of VFR differs between the respondents and might additionally differ between the interviewers. Secondly the reduction to only register details about the latest three travel activities has resulted in higher importance of journey weights required to scale the journeys with travel details to fit the stated totals.

The survey period from 2004-2008 is furthermore affected by other survey issues that have been difficult to fully explain. It is found highly likely that these survey years are biased from response fatigue related to a high level of travel details requested from the respondents. This might have resulted in respondents not registering all their travel activities. From the data processing it seems obvious that the number of travellers is affected in 2004 and 2005, but also that some of the problems are corrected in 2006.

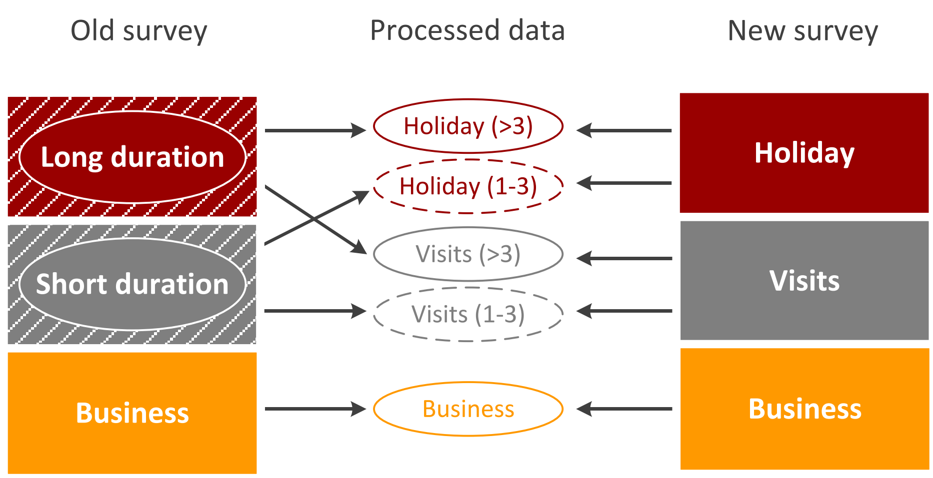

FIGURE 16: DEFINITION OF THE THREE TRAVEL TYPES IN THE HBS BEFORE AND AFTER MAY 2008 WITH THE CORRESPONDING FIVE SUBDIVISIONS OF TRAVEL TYPES.

The preparation of a comparable sample from 1997 to 2011 is achieved by adapting the data from before May 2008 to the newest data structure. This has first of all resulted in a segmentation of journeys into the five categories in Figure 16. This segmentation includes some uncertainties as it is based on registered travel purpose and accommodation which has changed definitions during the survey years. It is for instance not completely clear whether a holiday at friends and relatives would be registered as a holiday or as visiting friends and relatives if the respondent at the topmost level should distinguish between visits and holiday travels as it is the case in the newest version.

3.2 DATA PROCESSING AND VALIDATION

Some of the variations in the estimates are related to variations in sample sizes. The level of travelling is from 1997 to 2003 described based on approximately 4,000 respondents per year, whereas the samples from 2005 to 2007 are above 9,000 and the newest versions are based on 5,000-6,000 respondents as also listed in Table 10. When comparing with the original samples selected to participate in the survey, the response rates are between 66% and 72% for most survey years. The response rates during years with survey changes differ a little, with only 57% responses in 2004. But the response rates are not significantly different during the rest of the problematic years from 2005-2007.

TABLE 10: NUMBER OF OBSERVATIONS AND TRAVELLERS PER YEAR IN THE DIFFERENT SURVEY PERIODS. 2004 AND 2008 ARE NOT GROUPED WITH OTHER SURVEY YEARS AS THEY ILLUSTRATE THE IMPACTS OF CHANGES BETWEEN TWO SURVEY GENERATIONS.

	1997-2003	2004	2005-2007	2008	2009-2011
Respondents	4,000	6,400	9,200	7,000	5,800
Respondents with travel activities	1,600	2,500	3,900	3,300	3,400
Share of travellers	40%	39%	42%	47%	59%

The survey design requires an estimation of two types of data weights to scale data to the total level of traveling; a journey weight and a person weight:

- For high frequent travellers only a limited share of the travel activities is registered with details. These travel activities are scaled to the total stated number of travel activities by assigning a journey weight which in this case is estimated separately per individual. I.e. each travel activity registered with details is scaled proportionally to the stated total of the specific travel type. Some travel types might be more likely to be repeated than others, but this is not considered in the estimated journey weights. Each journey with details is assumed representative for the travel behaviour of the individual.

- Each respondent is furthermore scaled to fit the population from a person weight. This person weight is estimated relative to the travel month with the first possible travel activity[11] not relative to each of the three relevant calendar months. This makes a difference in the total level of travelling if the sample sizes change significantly between two calendar months. The simplification has been necessary because of incomplete knowledge of all three survey months and exact interview date.

Person weights are available in the survey before 2008, but new weights are in this study estimated for all survey years to ensure comparability. The method applied is an iterative proportion fitting approach stratified relative to age, gender, family type, place of residence, interview month, and interview year. The journey weights are also estimated as a part of processing data and the totals presented in this thesis consequently differs slightly from the totals published by Statistics Denmark.

From the survey years before 2008, it is only a few respondents that register a total number of travel activities above five. Consequently only few respondents are applied a journey weight. Long duration journeys completed more than three month back are removed from the survey, and the totals are adjusted. This modification adds some uncertainties to the stated totals, but does on the contrary also reduce the impacts of memory loss from the 12 month retrospective survey period.

The journey weights have substantial impacts on the total level of travelling in the newest survey. In 2010 the journey weights represents 270,000 journeys per month or 25% of the total level of travelling with overnight stay(s). The impacts are significantly higher for visits, where a considerable share of the respondents registers more than three visits with an overnight stay during three months. But it also influences business and holiday travels.

Figure 17 illustrates the share of travellers per quarter, when the survey before 2008 has been adapted to the new survey design with visits and holiday travels. From 1997 to 2007

[11] Before May 2008 this corresponds to the month before the interview month, and from May 2008 it is the same as the interview month.

the overall share of travellers stayed more or less constant around 40%-45%, but from 2007-2010 the share of travellers has increased to 60%. It is obvious from the distribution of respondents with visits, that this change is related to the introduction of visits as a separate travel purpose. If only considering the share of travellers with holiday activities, the share of travellers has steadily increased from 23% to 33% across all survey years and nothing indicates that this travel segment is evidently influenced by the survey changes.

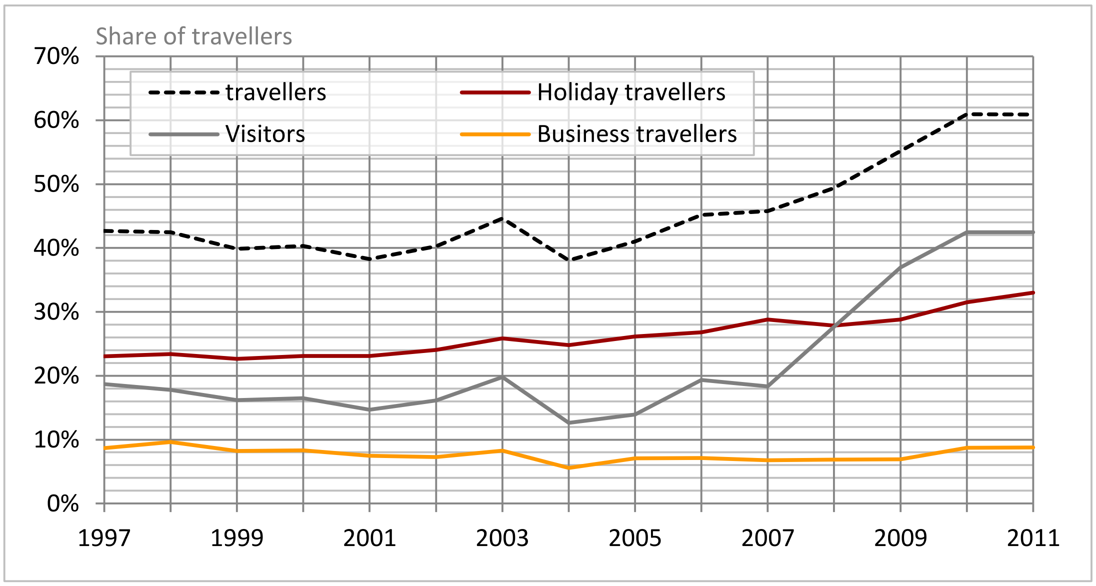

FIGURE 17: SHARE OF TRAVELLERS PER QUARTER AND TRAVELLERS HAVING AT LEAST ONE HOLIDAY, VISIT, OR BUSINESS JOURNEYS DURING THREE MONTH

The variation in travellers from 1997-2007 insinuates some additional survey uncertainties during these years. 2003 and 2004 are considerably affected by the survey change from a quarterly to a monthly survey in May 2004 and the additional change in sample sizes (Statistics Denmark, 2004) together with the person weights being estimated relative to the interview month. 2004-2007 furthermore holds some survey problems that have influenced the share of respondents with visits the most. It is found highly likely that this drop in travellers is related to the high work load required from the survey design from 2004 to 2008 that have resulted in increased response fatigue. This might have affected short duration travel and business travel the most as the hierarchy of the questionnaire has registered long duration travel at first, then short duration travel, and finally business travel. It appears from the share of travellers that some of these survey issues were corrected in

2006. In Figure 18 it is furthermore clear how this bias is mainly related to journeys to vacation homes. It is plausible that the biases are also related to insufficient definition of travel purpose and accommodation which changed definitions during these years and that some journeys to vacation homes for some reason are not registered.

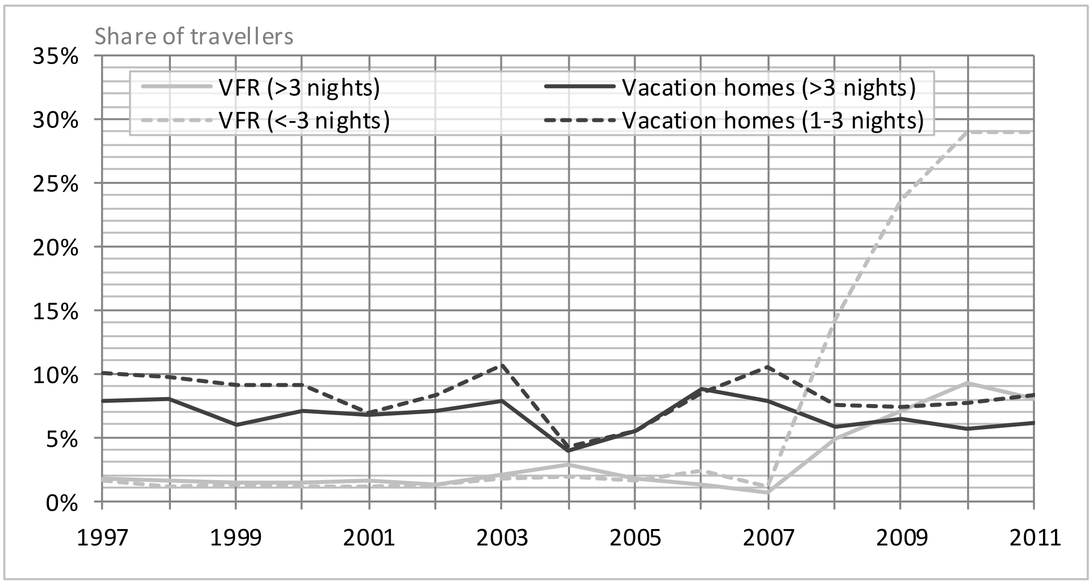

FIGURE 18: DISTRIBUTIONS OF TRAVELLERS WITH VISITS SEGREGATED INTO VFR AND VACATION HOMES OF SHORT OR LONG DURATION.

2009 is the first complete year with the newest survey design, but the growth in travellers is also present from 2009 to 2010 as illustrated in Figure 17 and Figure 18. This difference suggest either a longer phasing-in period of the new survey design or impacts from the recovering after the financial drop in 2007-2009 as also observed from TU and from the passenger statistics from Copenhagen Airport in Figure 1.

Due to the more or less continuously increasing share of holiday travellers and the relatively constant share of business travellers these two travel purposes are considered reliable and it is likely that the survey difficulties have mainly influenced the description of visits. Even though the development in the share of travellers is found reliable, the survey problems with too comprehensive questionnaires in 2004-2008 might also have reduced the number of journeys registered with details and consequently the total level of travelling if the stated totals are adjusted to match the number of journeys registered with details.

Despite the uncertainties related to the segmentation into the two travel types, it is clear from Figure 18 that it is in particular VFR that was not registered before 2008 and it furthermore stresses the significant magnitude of VFR with a few nights' stay. Visits are probably more likely to occur during all survey months, which might additionally have increased the sample of travellers.

3.2.1 VALIDATING DATA

The estimated journey and person weights are first of all validated relative to the total level of travel published in the yearly statistics from Statistics Denmark. Most of the variation across the survey years can be explained by method changes and these changes also figures from the totals published by Statistics Denmark. Secondly the level of air travelling is validated relative to air travel statistics.

Business travel is not affected by the change in definition of the main travel types and should consequently be comparable with the totals published by Statistics Denmark. Before 2008, the present study generally estimates the level of business travel 1-6% higher than the published totals, but 10-16% higher after 2008. Besides the different person weights and journey weights, a reasonable explanation to the overestimation is likely to be a different handling of outliers. If removing the most frequent travellers from the survey or truncating their stated totals to reduce the impact of extreme travel activities, it has proven possible to approach the total level of travelling published by Statistics Denmark.

Similar differences are found for the other travel types. Journeys with four or more overnight stays registered before 2004 are however estimated 14-17% higher than the published values. This higher difference stems from the uncertainties related to memory loss in retrospective surveys as the estimates from Statistics Denmark are based on the stated total travel activities per year, whereas this study scales the three month survey to the yearly total. After 2008 the total level of visits and holiday travels are in this study overestimated by 4-6% compared to Statistics Denmark (Statistics Denmark, 2012; Statistics Denmark, 2011).

The validation generally supports the estimated person and journey weights applied in this study, but most travel activities are overestimated compared with the totals published by Statistics Denmark. It is generally found that this difference is most likely caused by the handling of outliers, which furthermore seems to be of higher importance after 2008 due to the higher impact of high frequent travellers. It is found that some respondents register a very high number of activities with overnight stay and are assigned high relative importance.

From 2002-2012, air travels are furthermore possible to validate from the air travel database based on the Sabre database and the Danish airport database from the Danish Transport Authority that is constructed in Christensen (2014). The modified database holds the approximated origin-destination air travel flows by Danes. The total number of journeys completed by air from the HBS and the air travel database are listed in Table 11. The estimates are based on two survey years to increase the number of observations to be able to compare the data sources at country level.

TABLE 11: JOURNEYS PER YEAR FOUND IN THE HBS AND THE AIR TRAVEL DATABASE

One-way air travel	2002/03	2006/07	2009/10
HBS	3,009,860	3,884,842	4,704,808
Air travel database	3,370,679	5,110,370	5,203,010
Underestimation from the HBS	11%	24%	10%

The comparison certainly supports the concern related to the survey years from 2004-2007. Based on the 2002/03 and 2009/10 samples, it is reasonable to assume that the HBS underestimate the total level of air travel activities by 10 to 11% compared with the air travel database. The HBS survey however finds a level that is 24% lower in 2006/07. According to the air travel database, the number of departures has increased 2% from 2006/07 to 2009/10, which also corresponds to the overall trends illustrated from the passenger statistics in Figure 1. The HBS however finds air travel to increase with 21% during the same years. If instead imputing this difference from the air travel database to the HBS, the total number of journeys completed by air should have been 4.6 million in 2006/07. This suggests that the total level of air travel in 2006/07 is underestimated by more than 700.000 or 16% in the HBS.

The overall difference of 10-11% might reflect the level of underestimation related to memory loss, but might also be influenced by missing one day travels in the HBS and the uncertainties related to the modification of the air travel database. From a questionnaire completed in Copenhagen Airport it is found that one day air travels represented 7% of all departures in the first half of 2008 and 2009 (Copenhagen Airport, 2009). One day air travels seem to explain the majority of the difference and generally supports the level of travelling found in the HBS. The survey is however expected to be significantly influenced by memory loss due to the retrospective survey design which contradicts the similarity with the air travel database. This nevertheless supports the assumption of a general overestimation in the processed HBS data that seems to counterbalance the magnitude of memory loss.

When furthermore comparing the most popular destinations, the HBS is found representative for the most frequently visited destinations. In 2009/10, the number of journeys going to Spain by air is 5% lower than found in the air travel database and journeys to UK are 5% higher. Even though two survey years are combined, the number of information is still limited and the totals vary somewhat more between other destinations. Travels to Sweden by air are e.g. underestimated by 16%, based on 77 observations and travels to France overestimated by 16% based on 165 observations.

3.2.2 Summing up data processing and validation

The comparison with the totals published by Statistics Denmark supports the data processing, but finds that the processed data applied in this study overestimate the level of traveling compared with statistics Denmark. This overestimation is influenced by less restrict considerations regarding outliers and in relation to this, higher journey weights that in particular influences the totals after 2008. The comparison with the air travel database nevertheless supports the total level of travelling found in the HBS. The air travel database furthermore supports the assumption of survey problems from 2004 to 2007.

Response fatigue is likely to explain some of the difficulties present in 2004-2007 due to high required work load. It is assumed that this in particular influences short duration travel and business travel as these activities are registered as the second and third travel type. This will in particular influence domestic travels as a significant share of the short duration travel activities, is domestic travelling. This is also evident from the significant drop in travellers with visits during three months as illustrated in Figure 18. But the impact of response fatigue cannot be completely rejected for holiday travel either.

The samples of holiday travels and international travel activities are however found reliable and comparable across the years, when keeping the problems in 2004-2007 in mind. Due to this it has been decided to mainly focus on holiday travel and international travel in the following section. The survey holds among others information on travel month, number of overnight stays, size of travel group, main transport mode, travel purpose, accommodation, and a fairly aggregated destination. For domestic travel, the destinations are based on the official grouping of Danish municipalities into 16 counties before January 2007 and five regions after 2007. International travel destinations are only registered at country level. The definition of travel details such as travel purpose and accommodation additionally varies across the survey designs. Due to the aggregated travel destinations, the estimation of travel distances are a simple approximation of crow fly distances to the capitals of the registered countries and the average distances between the municipality of the residence and the capital of the destination regions. The applied travel distances and the total level of travelled kilometres are consequently affected by uncertainties.

3.3 Travel trends 1997-2011

As discussed in the previous sections, variation across the years is affected by changes in survey methods and changes in sample sizes. When estimating total travelling per year, the journeys registered with details are first of all scaled to the stated total number of journeys during three months. Secondly these journeys are scaled to a whole year. And finally the journeys are scaled to fit the population by person weight. Any larger conclusions from small changes in the level of travelling are consequently uncertain. It is nevertheless possible to view some overall trends during the period from 1997 to 2011, taking the variations in survey methods and travel definitions into account.

Figure 19 shows the overall development in holiday travel with overnight stays completed by Danes from 1997-2011. The adjusted total presented in Figure 19 illustrates the potential level of travelling in 2004-2007 when assuming the 16% underestimation found in the air travel database representative for all travel types. Holiday travels are divided into domestic destinations and international destinations which are further divided into European destinations and destinations outside Europe. From the development in the figure it is reasonable to assume that the overall level of holiday travels has increased considerably during the 15 years. Some of the growth is however also related to the general increase in holiday travellers as illustrated in Figure 17.

The survey change of the HBS in 2008 is generally presented as a source of level changes in travel activities due to the introduction of visits and additionally the higher journey weights. But these changes influence visits the most and the total level of holiday travel in 2008 is actually found lower than in 2007. This trend corresponds to the impacts of the worldwide economic recession that also appeared from the travel distances in TU and from the passenger statistics from Copenhagen Airport in Figure 1. When comparing the overall development in Figure 19 with Figure 1 it is actually possible that the drop in 2008 should have been even higher, but is influenced by the survey biases from 2004-2007. The adjusted totals in Figure 19 support this assumption and the overall development suggest that the trends in travelling should mainly be discussed from the difference in travelling before 2004 and after 2008. In the following sections, focus is consequently put on the cross sectional differences between 1998 and 2010.

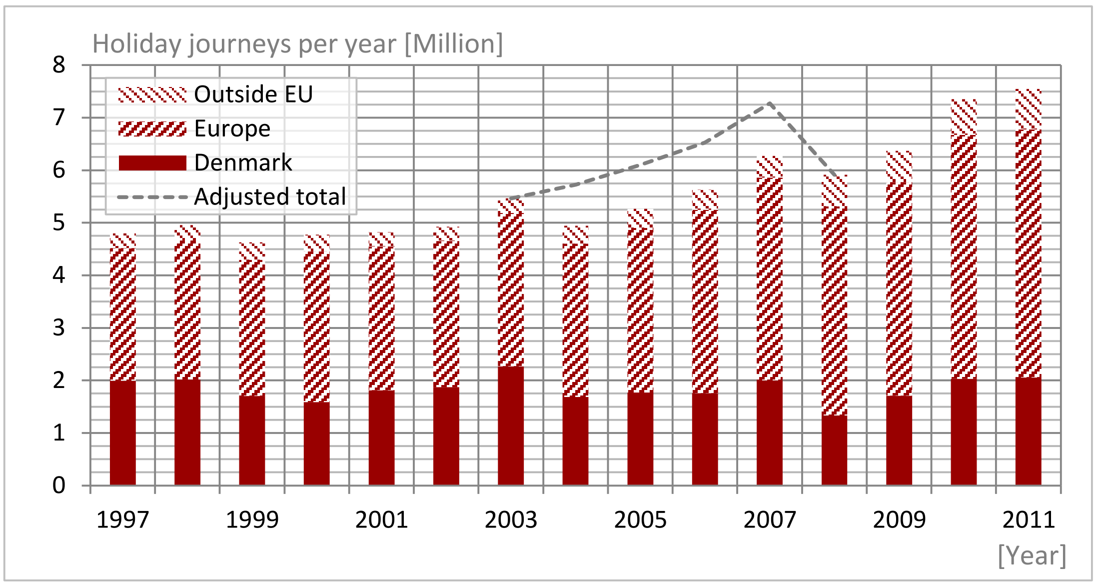

FIGURE 19: TOTAL NUMBER OF HOLIDAYS JOURNEYS PER YEAR COMPLETED BY DANES BETWEEN 15-84 YEARS. THE ADJUSTED TOTAL FROM 2004-2007 ILLUSTRATES THE POSSIBLE 16% UNDERESTIMATION FOUND FROM AIR TRAVELS.

As illustrated in the figure, Europe represents a significant share of Danish holiday destinations and the number of domestic holiday activities has stayed approximately constant at 2 million journeys. In 1997 the 2 million domestic journeys represented 42% of all holiday activities, whereas the 2 million journeys only represented 28% of all holiday activities in 2010. This decreasing market share is supported by reference points from the yearly statistics that finds domestic travel representing 60% in 1972, 63% in 1976, 58% in 1980 and 50% in 1985 (Statistics Denmark, 1974; Statistics Denmark, 1978; Statistics Denmark, 1981; Statistics Denmark, 1987). A linear regression from 60% in 1972 to 27% in 2011 shows a reduction in market shares of 1% p.a. The share of domestic travel in 1972, 1976, 1980, and 1985 is however only based on journeys with four or more nights' duration. Short duration travel was not registered before 1985. In 1985 short duration travel actually increased the share of domestic travel from 50% to 55% and it is in fact possible that the actual decrease in the share of domestic travel has been even higher when also including journeys with 1-3 nights' duration.

Table 12 shows the cross sectional summaries of journeys in 1998, 2002, 2006 and 2010. The relatively constant level of travelling from 1998 to 2006 is mainly influenced by the survey problems from 2004-2007, but also the stagnation in economy from 2000-2003. The survey problems are mainly assumed to influence short duration travel and business travel, which is also supported by the drop from 2.60 million business journeys per year in 2002 to 2.15 in 2006 or from 0.60 business journeys per Dane per year to 0.49 as listed in Table 13.

TABLE 12: POPULATION OF DANES BETWEEN 15 AND 84 YEARS AND MILLION JOURNEYS PER YEAR WITHOUT VFR

	1998	2002	2006	2010
Danes between 15 and 84 years	4.34	4.36	4.41	4.53
Holiday travels per year	4.95	4.92	5.62	7.35
Journeys to vacation homes per year	4.57	3.69	4.16	5.42
Business journeys per year	3.16	2.60	2.15	3.23
Total journeys per year	12.67	11.22	11.93	16.00

When disregarding VFR, the Danes produced almost 13 million journeys in 1998 and 16 million journeys in 2010 which correspond to an average change from 2.92 to 3.53 journeys per Dane per year as listed in Table 13. Table 12 and Table 13 also present estimates based on different subsamples of travel activities. The relative importance of travelling to vacation homes is obvious from the tables: Journeys to vacation homes have actually represented approximately one third of the total number of journeys in all four survey years. And the average number of domestic journeys to vacation homes per Dane has increased 1.7% p.a. from 1998 to 2010.

Only a limited share of the Danes has destinations outside Europe, but holiday travel and business travel outside Europe have both doubled from 1998 to 2010. This relation correspond fine with some of the trends observed from the air travel database, where travels to the US, Thailand, and Egypt have increased by more than 100% from 2002/03 to 2009/10.

TABLE 13: JOURNEYS PER DANE PER YEAR WITHOUT VFR AND THE AVERAGE YEARLY INCREASE FROM 1998 TO 2010. VACATION HOMES OUTSIDE EUROPE IS EXCLUDED DUE TO VERY SMALL SAMPLES.

	1998	2002	2006	2010	1998-2010[B)]
Population	**4.34**	**4.36**	**4.41**	**4.53**	**0.4%**
Holiday journeys per Dane	**1.14**	**1.13**	**1.27**	**1.62**	**3.0%**
Domestic	0.46	0.43	0.40	0.45	-0.3%
European	0.61	0.64	0.79	1.02	4.4%
Non-European	0.07	0.06	0.09	0.15	7.0%
Journeys to vacation homes per Dane[A)]	**1.05**	**0.85**	**0.94**	**1.20**	**1.1%**
Domestic	0.89	0.66	0.70	1.09	1.7%
European	0.15	0.18	0.22	0.11	-2.5%
Business travel per Dane	**0.73**	**0.60**	**0.49**	**0.71**	**-0.2%**
Domestic	0.40	0.34	0.22	0.31	-2.1%
European	0.29	0.23	0.23	0.33	1.1%
Non-European	0.03	0.03	0.03	0.06	6.4%
Total travel per Dane	**2.92**	**2.57**	**2.71**	**3.53**	**1.6%**
Domestic	1.76	1.42	1.32	1.85	0.4%
European	1.05	1.05	1.24	1.47	2.8%
Non-European	0.11	0.10	0.14	0.22	5.6%

A) The sample of destinations outside Europe is too small
B) Average yearly change from 1998 to 2010

Table 14 shows the average travel frequency per Dane when including the statistical reports before 1997. From the sample of journeys with more than four nights' duration, VFR is included as these are most likely registered in the published reference points before 1998. This however results in a somewhat higher level of travelling in 2010 that is biased by the introduction of visits as a separate travel type. If disregarding the observation in 2010, the average number of journeys with more than four nights' duration has increased by 2% per Dane per year from 1972 to 2002 which corresponds to a total change of 0.5 journeys per Dane. The trend is a little higher for international travel, whereas the level of domestic travel has stayed relatively constant.

The short duration journeys were in 1985 defined as journeys of 1-3 nights' duration where respondents have paid for the accommodation. Due to this, visits are not included in the estimates from 1998 to 2010 listed in Table 14. 2010 is consequently not as highly affected by the survey change, but the totals from 1985 and 2010 nevertheless differ somewhat more than the relatively constant level from 1998-2006. This limited variation is related to the survey problems around 2006, but also the economic stagnation around 2002. This level of stagnation together with survey uncertainties however complicates any distinct conclusion on significant growth.

TABLE 14: JOURNEYS PER DANE PER YEAR, THE TOTALS BEFORE 1997 ARE BASED ON (STATISTICS DENMARK 1974, STATISTICS DENMARK 1978, STATISTICS DENMARK 1981, STATISTICS DENMARK 1987) AND 1998-2010 IS BASED ON THE PROCESSED SURVEY DATA.

	1972	1976	1980	1985	1998	2002	2006	2010[C]
Population	**3.73**	**3.90**	**4.01**	**4.09**	**4.34**	**4.36**	**4.41**	**4.53**
4 or more nights[A]	**0.69**	**0.91**	**0.87**	**0.93**	**1.24**	**1.19**	**1.41**	**2.15**
Domestic	0.41	0.58	0.50	0.47	0.50	0.43	0.43	0.99
International	0.27	0.34	0.36	0.47	0.74	0.76	0.97	1.16
1-3 nights[B]	**-**	**-**	**-**	**0.20**	**0.32**	**0.31**	**0.32**	**0.48**
Domestic	-	-	-	0.15	0.22	0.21	0.20	0.25
International	-	-	-	0.05	0.09	0.11	0.12	0.23

A) From 1998-2010, visits are included in the averages as it correspond the most to the averages published before 1997
B) Visits are not included from 1998-2010 as 1-3 nights' travel is defined as travel with paid accommodation
C) 2010 is affected by higher journey weights

These average travel frequencies are likely to be influenced by the development in economy. Figure 20 shows how the travel frequency has generally increased together with the growth in the economy. The relation between holiday travel and economy is limited from 1996 to 2002 whereas the overall development in travel frequencies has increased significantly from 2004 to 2011 even though the average GDP is similar in 2004 and 2011. Even though the economy is significantly reduced from 2007 to 2009 it is notable how the holiday frequencies continue to increase. Some of this might be influenced by the survey uncertainties in 2004-2007 where the level of travelling should ideally have been a little higher.

The development is a little different when only considering air travelling as illustrated in Figure 21. The figure illustrates the development in air travelling based on the HBS and the air travel database. The figure shows how 2004-2007 have resulted in a lower level of travelling in the HBS compared with the air travel database and how the economic setback from 2007-2009 generally reduces air travel activities. Figure 20 and Figure 21 insinuates how the economic setback might influence air travel more evidently than travel frequencies in general. This might actually suggest that an economic crisis influences travel behaviour in a way that might involve more car travel to neighbouring countries or even more domestic travels.

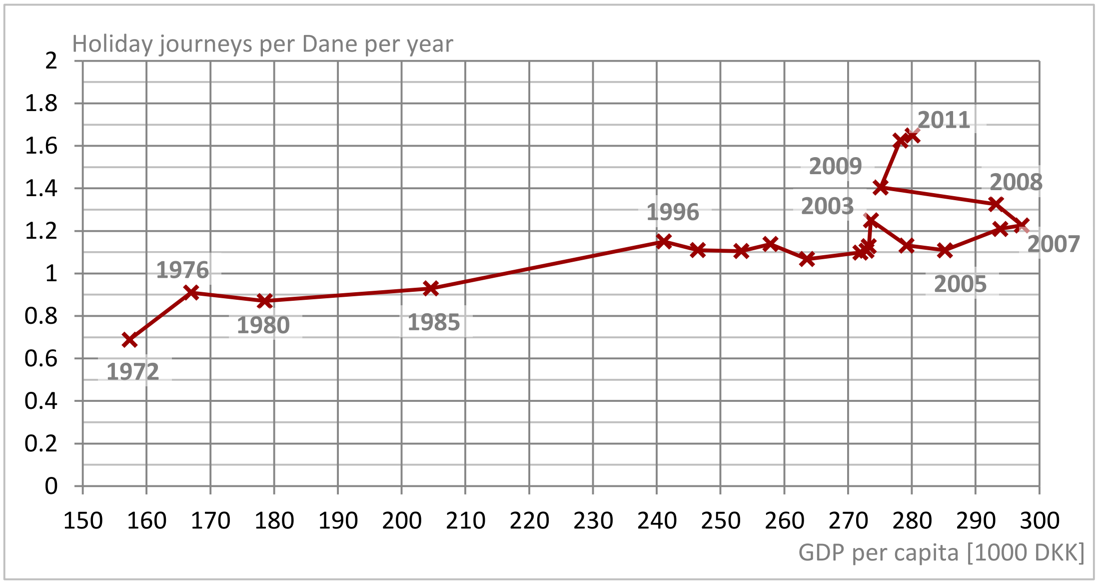

FIGURE 20: THE DEVELOPMENT IN HOLIDAY TRAVEL PER DANE BETWEEN 15 AND 84 YEARS RELATIVE TO THE DEVELOPMENT IN GDP PER CAPITA.

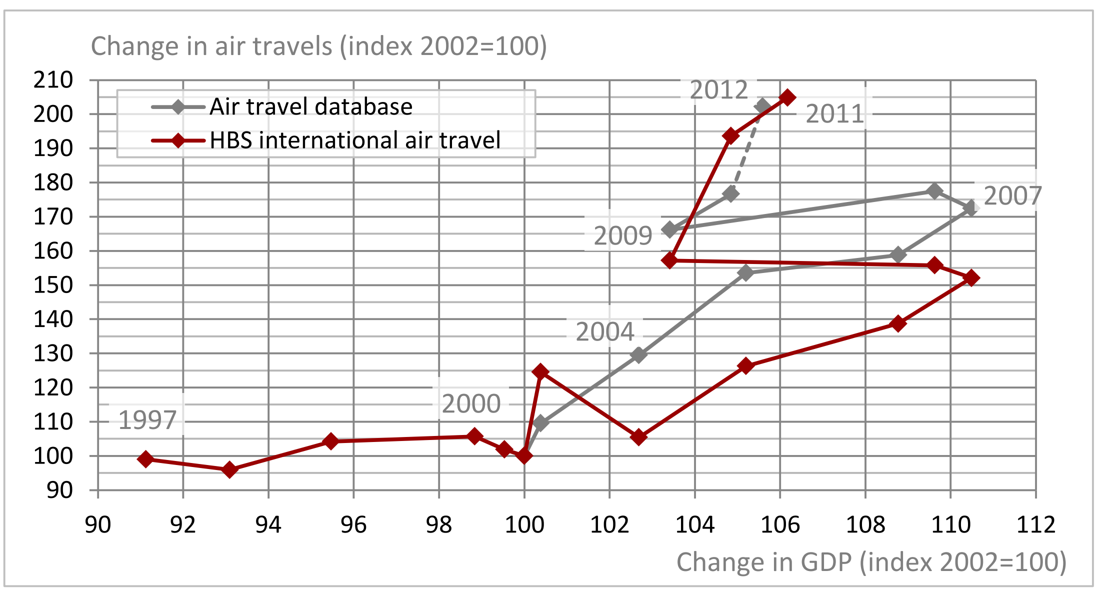

FIGURE 21: CHANGE IN AIR TRAVEL RELATIVE TO CHANGE IN GDP BASED ON THE HBS AND THE AIR TRAVEL DATABASE

3.3.1 INTERNATIONAL HOLIDAY TRAVEL

This section only considers international holiday travel and describes the relations between travel frequency, transport mode, travel duration, and travel distance bands. The transport modes are divided into air travel, car travel, and other transport modes. Four duration bands are defined: 1-3 nights representing weekend travel and extended weekends, 4-5 nights representing short duration holidays, 6-7 nights representing one week holidays, and >7 nights representing longer vacations.

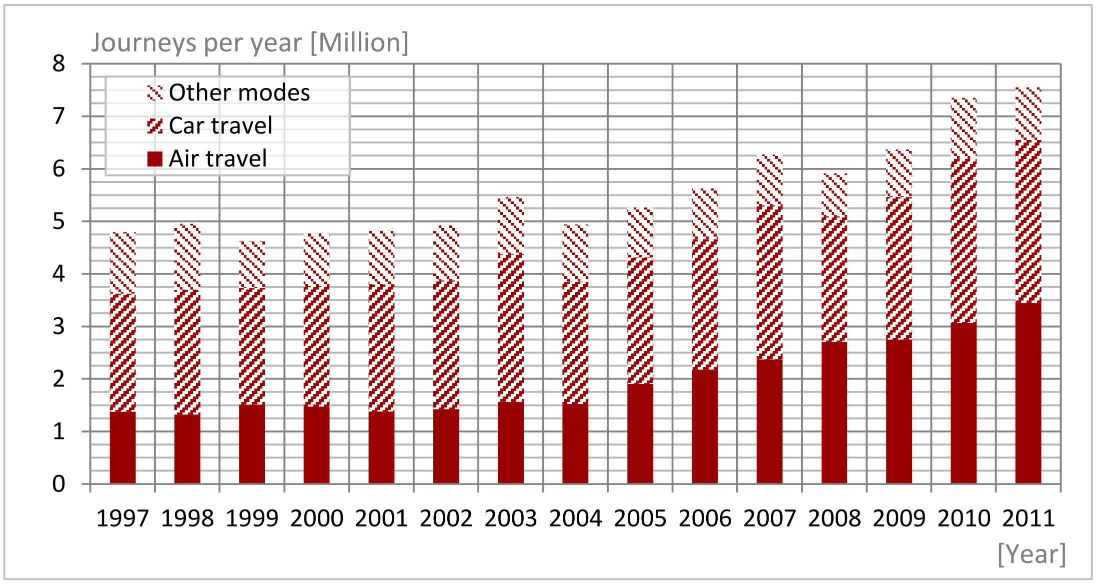

FIGURE 22: MODE SHARE FOR INTERNATIONAL HOLIDAY TRAVEL

The distance bands increases by 500 kilometres representing radials from Copenhagen to international capitals. The distance band below 500 kilometres includes the neighbouring countries Sweden, Norway and Germany even though the geographical coverage of all three countries in fact expands across several distance bands. The distance band from 500 to 1000 kilometres includes e.g. Finland, the Baltic countries, and Belarus in to the east, England to the west and Austria in the south. The 1,000-1,500 kilometres band includes e.g. Ukraine in the east, Ireland, Scotland and the Faroe Islands in the west, and France and Serbia in the south. The 1,500-2,000 kilometres band includes e.g. Russia in the east, and Italy and Bulgaria in the south. Spain, Greece, Iceland, and Turkey represent European countries in the last distance bands at destinations above 2,000 kilometres. This destination band furthermore includes destinations outside Europe.

Figure 22 shows how the growth in international travel is dominated by air travel. The share of car travel has stayed approximately constant around 25%. The share of air travel has increased from around 45-50% of all international holidays to a little more than 60% today. According to this, the share of other modes has decreased from representing around 25% of the holiday activities to 13% today. The growth from around 2004 corresponds to the obvious growth in passengers from Copenhagen airport in Figure 1, but again it is reasonable to assume that the growth from 2004-2007 should have been even higher and that the travel frequencies were actually reduced from 2007-2008. The growth from 1998-2000 and the relatively constant level from 2000-2004 also correspond sufficiently with Figure 1.

Figure 23 illustrates the relation between mode and travel distance, and how this has changed between 1998 and 2010. It is obvious that the share of air travel increases as travel distance increases. It is furthermore apparent how air travelling has become more common for travel distances between 500 and 1,500 kilometres. It is however also worth stressing that from the 5.3 million international holiday journeys completed in 2010, 38% of the journeys had destinations above 2,000 kilometres away and 29% below 500 kilometres away as listed in Table 15. Neighbouring countries are widely visited by car, and the southern parts of Europe and destinations outside Europe are mainly visited by air. The rest of Europe has however experienced an increasing number of holiday journeys by Danes and a substantial share of the journeys are air travel on the expense of other modes.

Table 15: Million journeys per year in 1998 and in 2010 without VFR

	Total	<500 km	500-1000 km	1000-1500 km	1500-2000 km	>2000 km
1998	2.94	0.82	0.40	0.41	0.29	1.02
2010	5.33	1.54	0.72	0.58	0.48	2.02
Change	82%	88%	77%	42%	65%	98%

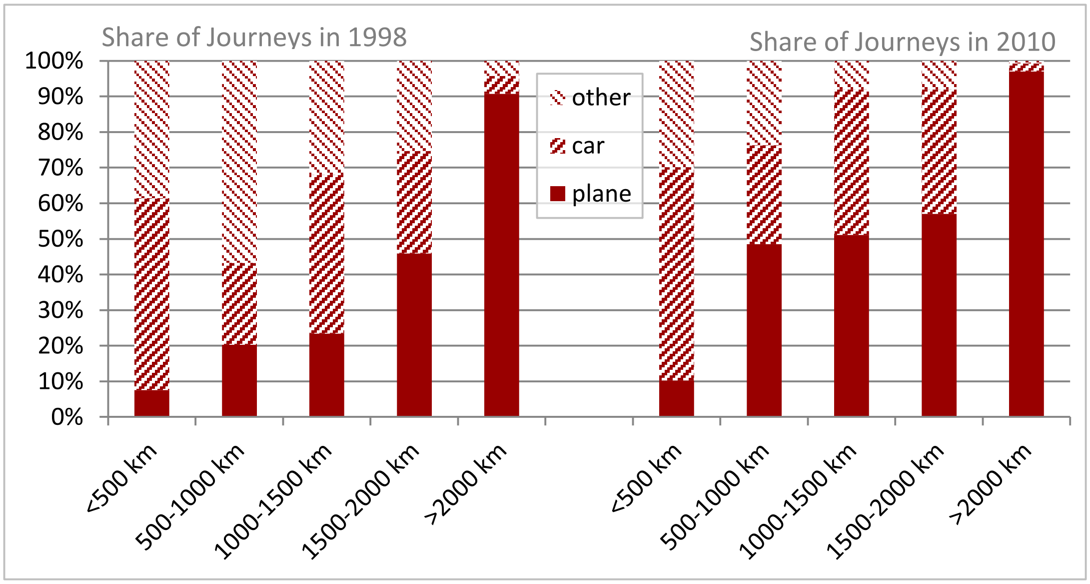

FIGURE 23: SHARE OF INTERNATIONAL HOLIDAY JOURNEYS IN 1998 AND 2010 DIVIDED INTO TRANSPORT MODE AND DISTANCE BANDS

In Figure 24 the international holiday journeys are divided into the four travel duration bands. Journeys of six or more nights' duration dominate the holiday journeys. But weekend travel and short duration travel have generally achieved increasing market shares. Weekend travel has increased from representing around 14% of all holiday activities to 20% today, and short duration travel has developed from around 14% to 18%. However, the decreasing share of journeys with six or more nights' duration does not correspond to a decrease in the actual number of journeys. But where the number of international short duration journeys with 1-3 or 4-5 nights' duration has more than doubled from 1998 to 2010, one week journeys have increased by 51% and long duration journeys by 64% as also listed in Table 16.

TABLE 16: MILLION INTERNATIONAL HOLIDAYS IN 1998 AND 2010 GROUPED INTO TRAVEL DURATION

	Total	1-3 nights	4-5 nights	6-7 nights	>7 nights
1998	2.94	0.40	0.42	1.11	1.00
2010	5.33	1.04	0.94	1.67	1.64
Change	82%	160%	131%	51%	64%

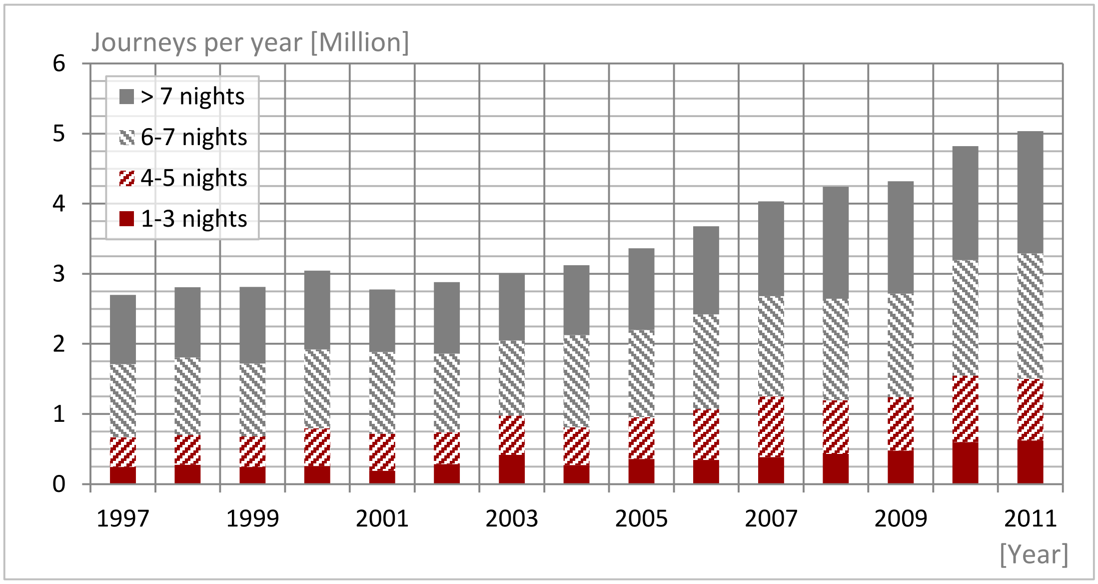

FIGURE 24: DURATION OF INTERNATIONAL HOLIDAY TRAVELS

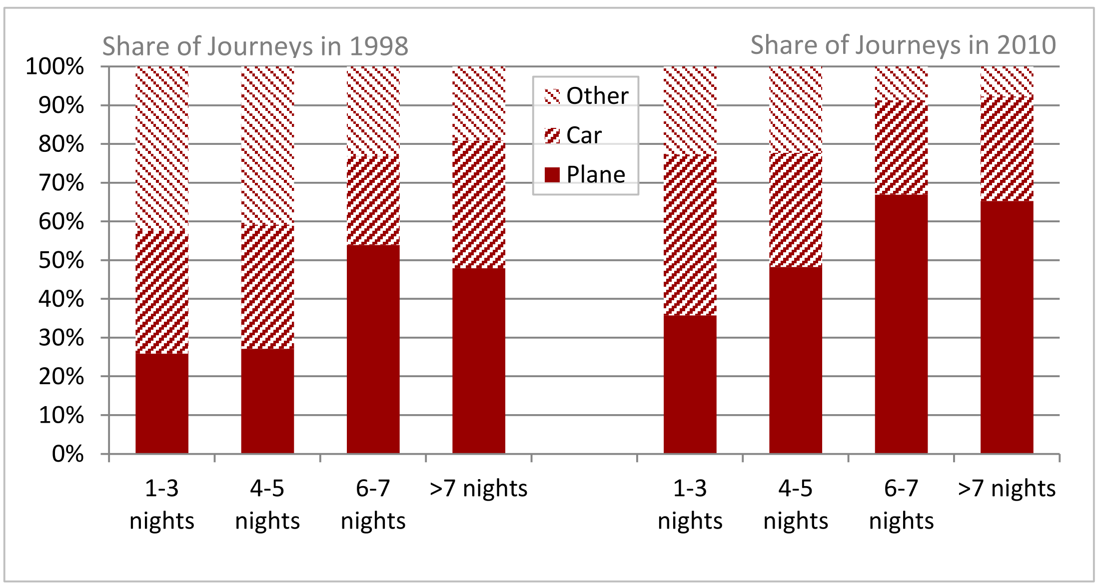

FIGURE 25: MODE AND DURATION FOR INTERNATIONAL HOLIDAY TRAVEL

Figure 25 illustrates the relation between travel duration and transport mode. The figure illustrates how air travel has increased throughout all duration bands and it also illustrates the decreasing share of other modes mainly in favour of air travel. The increasing air travel and increasing short duration travel might reflect the impacts of reduced prices for plane tickets and the following shift from charter travel to scheduled airlines. This change furthermore involves less restrictions regarding travel duration as the journeys are constructed and optimised by the individual and holiday travels do not necessarily need to last at least one week.

Finally the relation between distance and duration is illustrated in Figure 26. The duration of international holiday activities generally increases with travel distances. The increasing share of weekend travel with 1-3 nights' duration and short duration travel with 4-5 nights duration is again obvious. This is in particular the case for distances below 500 kilometres.

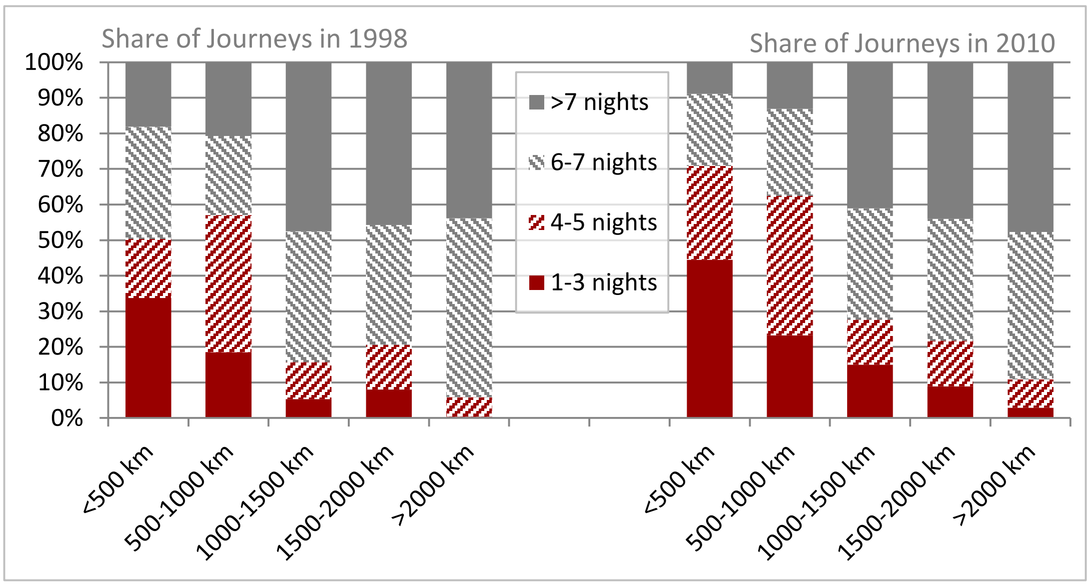

FIGURE 26: DISTANCE DURATION FOR INTERNATIONAL HOLIDAY TRAVEL

The average change in each of the 5x4 distance duration segmentations is listed in Table 17. Except for holiday travel less than 500 kilometres away with more than seven days' duration, the travel frequency has generally increased from 1998 to 2010. Weekend holiday journeys more than 2,000 kilometres away have increased the most, but are based on a limited sample. This growth in destinations more than 2,000 kilometres away is nevertheless obvious no matter travel duration. The table also illustrates how weekend holiday journeys have increased considerably in all distance bands.

TABLE 17: INCREASE IN NUMBER OF INTERNATIONAL HOLIDAY JOURNEYS IN 1998 AND 2010 GROUPED INTO TRAVEL DURATION AND DISTANCE BANDS.

	Total	1-3 nights	4-5 nights	6-7 nights	>7 nights
<500 km	88%	148%	199%	21%	-8%
500-1000 km	77%	122%	80%	96%	12%
1000-1500 km	42%	299%	73%	21%	23%
1500-2000 km	65%	82%	69%	67%	59%
>2000 km	98%	1399%	191%	63%	116%
Total	82%	160%	131%	51%	64%

The distribution of journeys into the travel distance bands depends very much on the most popular destinations. If estimating the 10 most popular holiday destinations in 1998 and 2010, the overall hierarchy has changed a little, but all 10 destinations are European countries. The different sample sizes in the two survey years are however also apparent. 1998 includes 60 different holiday destinations compared with 86 in 2010. The travel frequency of the different destinations is based on fairly limited samples. In 1998 Norway is the most frequently visited holiday destination, but it is only based on 76 observations. The second most visited destination is France, which is based on 75 observations. The third most visited destination is Spain with 72 observations.

The samples are larger in 2010 and the most frequently visited holiday destination is Germany based on 245 observations. The second most popular destination is Spain with 226 observations, and the third most popular destination is Sweden with 141 observations. The samples from 1998 are more sensitive due to the smaller sample sizes and detailed analyses are affected by uncertainties. Very few observations separate the different destinations during one year and several years should therefore be combined for more detailed analyses. The comparison of travel destinations from the samples of air travelling in the HBS and the air travel database has nevertheless revealed that the small samples actually represent the overall travel patterns in a comprehensive way.

3.3.2 TRAVEL DISTANCES

The high share of European travel naturally influences the travelled kilometres. Due to the substantial uncertainties related to travel distances the estimates should only be considered as an approximation of the magnitude of multiday travel when considering a general budget of travelled kilometres by Danes. This approximation does nevertheless correspond sufficiently with the total level of travelling represented in the air travel database. The estimates presented here include domestic travel, but do not include VFR. The total travelled kilometres to vacation homes are found considerably higher before 2008 which is assumed biased from the segmentation of holiday journeys into holiday travel, VFR, and travelling to vacation homes.

TABLE 18: MILLION KILOMETRES PER YEAR WITHOUT VFR

	1998	2002	2006	2010
Population	4.34	4.36	4.41	4.53
Holiday journeys kilometres per year	10,499	10,954	14,653	20,839
kilometres to vacation homes per year	3,034	2,774	3,751	1,596
Business journey kilometres per year	4,550	3,945	3,884	7,074
Total kilometres per year	18,083	17,674	22,288	29,509

The overall growth in journeys corresponds to an increase from around 18 billion kilometres per year in 1998 to almost 30 billion kilometres in 2010 as listed in Table 18. This corresponds to a growth from 4,200 kilometres per Dane between 15 and 84 years in 1998 to 6,500 kilometres in 2010 as listed in Table 19. This difference of a little more than 2,000 kilometres per Dane corresponds to two journeys to and from e.g. Germany or one journey to and from England per Dane per year.

TABLE 19: JOURNEY KILOMETRES PER DANE PER YEAR WITHOUT VFR

	1998	2002	2006	2010
Holiday travel kilometres per Dane	**2,418**	**2,511**	**3,321**	**4,597**
Domestic	109	106	101	115
European	1,468	1575	2,067	2,490
Non-European	840	830	1,153	1,992
Kilometres to vacation homes per Dane	**699**	**636**	**850**	**352**
Domestic	219	173	174	194
European	260	314	424	149
Non-European	220	149	252	10
Business travel kilometres per Dane	**1,048**	**904**	**880**	**1,560**
Domestic	122	107	70	96
European	474	378	376	552
Non-European	452	419	435	913
Total travelled kilometres per Dane	**4,164**	**4,051**	**5,052**	**6,509**
Domestic	450	386	345	404
European	2,202	2,267	2,866	3,191
Non-European	1,512	1,398	1,841	2,914

Table 19 shows the average travel distances estimated per person per year. The significant reduction in kilometres to vacation homes originates from fewer travel activities to international vacation homes which influences the overall average significantly. Even though the change is most likely related to the survey change in 2008, these journeys are additionally based on a relatively limited sample of respondents.

3.3.3 Summary of travel trends

Even though the HBS holds some obvious uncertainties, the previous comparisons have however outlined some significant trends and changes in travel characteristics. The Danes on average travel more and have more international destinations with a higher share of air travel. From 1998 to 2010, the average travel frequency per Dane increased from 2.9 to 3.5 journeys per year, which on average corresponds to an increase of 2.3 thousand kilometres per Dane. In 1998, 89% of the travelled kilometres were international kilometres which increased to 94% in 2010. From these significant shares of kilometres, 78% was in 1998 air travelling which increased to 84% in 2010.

The segmentation into international holiday travel has revealed an interesting trend of an increase in short duration holiday journeys and in particular those of 1-3 nights' duration that are dominated by weekend travel. This development is central as it insinuates that international travel does not necessarily have an upper limit defined by the number of weeks of vacation from work a person has during one year. The increasing travel frequencies of short duration travel found in all distance bands additionally stresses the importance of weekend travel in the total record of travelled kilometres by individuals.

Holiday journeys to destinations more than 2,000 kilometres away also increase considerably which is of high relevance regarding the overall mileage travelled. This might be increasing travel to the southern part of Europe, but also represents the growth in travelling to destinations outside Europe. Long distance journeys are also mainly long duration travel and in contrary to the weekend holidays, the number of long duration holiday journeys has a natural maximum for most respondents.

When including the published totals from 1972, 1976, 1980, and 1985, the overall change from a dominance of domestic holiday destinations to international travel is obvious. The reference points furthermore support the estimates of an increasing number of holiday journeys completed per year per Dane.

3.4 MULTIDAY TRAVEL IN 2010

The TU overnight survey was completed in 2010-2011 by DTU Transport. The main objective was to collect information on the overall travel movements across several days. The survey was designed to improve knowledge on travel with overnight stay(s) as part of the development of the Danish National Transport Model and the research project of 'Drivers and Limits' in transportation. The motivation was two-fold as the segmentation relative to overnight stay(s) first of all allows for a substitution pattern across distance bands, and secondly ensures that distances are not considered as a choice, but rather as a means that facilitates certain destination choices (Rich et al., 2010). The segmentation of travel activities into travelling with overnight stay(s) corresponds to the overall definition of tourism travel (UNWTO, 2012) and consequently also the travel activities registered in the HBS.

The TU overnight survey includes two sub-surveys; a two-week survey that registers the main activity of the day and the overnight location during at most 14 consecutive days, and a retrospective survey that registers most travel activities with overnight stay(s) during 3 months and some activities completed during 12 months. Each survey part was completed during one year, but not completely in parallel. The two-week survey was completed from December 2009 to January 2011 and was extended with the retrospective survey from August 2010 to January 2011. The retrospective survey part was continued one month later from February 2011 to August 2011 and consequently lacks interviews in January hence travel details during the latest three months from October-December. In parallel with the development of the TU overnight survey, the ordinary TU was extended to register the number of nights' duration of homebound travel activities that started outside the home and ended at the home address (see section 1.1). During 2010 and 2011, the TU surveys provided three relatively comparable measures of travel with overnight stays, however with varying sample sizes and some differences in travel types registered.

Together with the total level of travelling registered in the HBS, the TU surveys are compared and discussed in the following. The comparisons and survey validations follow up the research of (Christiansen, 2011). The structure of the comparison is based on the overall travel categories defined in the retrospective TU survey:

- Domestic travel with 1 overnight stay

- Domestic travel with 2-5 overnight stays
- Domestic travel with more than 5 overnight stays
- International travel with 1-5 overnight stays
- International travel with more than 5 overnight stays

3.4.1 TU (1 DAY)

As the ordinary TU is a daily mobility survey, it naturally only registers a limited sample of the more infrequent travel types and thereby also a limited sample of travel with overnight stay(s). As opposed to the data processing in Chapter 2, international travel is also included in this section. From TU the journeys with an overnight stay are selected from the sample of homebound journeys. The selection procedure takes the overrepresentation of homebound journeys into account by removing respondents that according to the interview day and the stated duration of the journey were away at the day the interview should ideally have taken place[12]. From this selection procedure, the sample of journeys with an overnight stay is reduced to 719 respondents and 623 when only considering leisure and business travel. Respondents that have just not completed the journey before 3 AM most likely do not register an overnight stay and are consequently not included in this sample. The summary of TU journeys is consequently based on a fairly limited sample with only 107 observations representing international travels. The selection procedure is affected by some uncertainties due to a complex design of the follow-up phone calls. This has become easier in the newest version of TU (Christiansen, 2012). From the newest release of TU that includes three years with information on travels with overnight stay(s) from 2010 to 2013, the total sample includes 2,024 journeys with overnight stay(s) and 298 international journeys.

3.4.2 TU (2 WEEKS)

The TU two-week survey was designed as a repeated daily mobility survey throughout 14 consecutive days. The first months of running the survey however revealed considerable survey costs related to the high number of necessary phone calls after 7 and 14 days to motivate respondents to complete the whole survey. This resulted in a survey change where respondents were not contacted to complete the second week of the survey if they had

[12] A respondent is assigned a day 0 to register in TU, but in many cases the survey is completed during one of the following days (Christiansen, 2012)

completed the first survey week. This has resulted in an apparent variation in survey length amongst the respondents that might be influenced by response fatigue. The respondents had 21 days to complete the survey and memory loss can consequently not be completely rejected. But most travel activities are registered with at most one month retrospective time horizon.

The survey registers the origin address of the day and the main activity of the day. From the continuous survey design it is possible to describe the overall travel movements during a series of days. The 2010 sample holds 8,345 respondents, of which 1,746 register travels with overnight stay(s). They register 2,492 journeys with overnight stay(s). 2,158 of these are leisure or business related travel activities. Even though the respondents complete a different number of survey days, this comparison includes all respondents and travel days anyhow. The person weights are adjusted relative to the survey length.

3.4.3 TU (3 MONTHS)

The design of the TU retrospective survey first of all registers the total number of travel activities in a travel matrix as illustrated in Figure 27 and secondly registers details of at most 12 journeys selected from a prioritised hierarchy of the matrix cells. In this comparison only the information from the travel matrix is applied and hence further travel details are not considered and the totals are most likely not affected by response fatigue. The survey does not register domestic one day journeys as these are more frequent travel activities and consequently difficult to register sufficiently from longer retrospective periods. These journeys are furthermore assumed sufficiently described from the two-week survey part. Travelling to own vacation homes is not registered in the travel matrix either. For some respondents these activities might also be frequently completed and less likely to be recalled sufficiently from a retrospective survey. Respondents owning a vacation home are however asked additional questions about the frequency of visiting the vacation home[13]. 23% of the respondents have access to vacation homes, 64% of these respondents visit the vacation homes during a period of three months and 25% have more than three visits. In addition to this the two-week survey finds that 47% of the journeys with overnight stay(s) are domestic one day journeys and 3.9 million journeys per year are travels to own vacation

[13] At the present time of data processing, no suitable way of including the registered journeys to vacation homes was decided.

homes. The high travel frequencies support the considerations of not including these travel activities in a retrospective travel survey.

Due to the significance of memory loss as discussed and described in e.g. (Denstadli and Lian, 1998; Frändberg, 2006; Schlich et al., 2004) only the three first survey months are considered in the following. The survey design enables segmentation into three separate one month retrospective surveys and consequently a measure of the possible impact of memory loss[14].

FIGURE 27: TRAVEL MATRIX FROM THE TU OVERNIGHT SURVEY

The overall design of the TU overnight survey enables a description of the total level of Danish travel behaviour. It registers both daily and multiday travel, but the daily activities are registered with fewer travel details than in TU. If the two survey parts were completed simultaneously, it would furthermore be possible to reveal the relation between daily and multiday travel at the individual level.

3.4.4 HBS (3 MONTHS)

Compared with the four travel categories registered during a period of three months in the TU retrospective survey, the HBS only consider the three main travel types: Holiday, Visits, and Business travel. The HBS neither divides the main travel activities into travel month at the topmost level. The 2010 HBS sample includes 3,467 respondents with travel activities and 7,500 journeys registered with travel details. Compared with the previous description of travel trends, VFR are included in this section. This travel type is assumed to be considerably affected by survey uncertainties as e.g. memory loss, but nevertheless represents a significant share of journeys with an overnight stay.

[14] The TU retrospective survey was not completed throughout one complete year why some survey months are described from smaller samples and holds higher uncertainties. This is in particular the case for December.

The sample sizes of the different travel surveys vary from 600 to almost 8,000 journeys and when furthermore divided into the five travel categories, the sample sizes become inconveniently small in some of the travel categories as listed in Table 20.

TABLE 20: OBSERVATIONS IN THE DIFFERENT TRAVEL SURVEYS. COMMUTING AND ERRANDS ARE REMOVED FROM TU AND THE TU TWO-WEEK SURVEY.

	TU 1 day	TU 2 weeks	TU 3 months	HBS
Domestic 1	284	1,012	-	1,713
Domestic 2-5	181	764	1,987	2,701
Domestic >5	47	107	515	586
International 1-5	60	152	1,322	1,221
International >5	49	122	1,626	1,279
Total observations	623	2,158	5,450	7,500
Travellers	623	1,746	4,175	3,467

3.4.5 TOTAL LEISURE AND BUSINESS TRAVEL IN 2010

Figure 28 shows the total level of travelling registered in the different surveys divided into the five travel categories defined in the retrospective TU. To construct comparable samples of journeys as registered in the retrospective surveys, only leisure travels and business travels are included from TU and the two-week survey. The retrospective TU survey is included even though it does not describe domestic one day travels and travelling to own vacation homes. From the retrospective TU, the total level of travelling in Figure 28 is estimated as an average of all three survey months and isolated when only including the journeys registered one month back. The difference illustrates the impact of memory loss from a one month retrospective survey compared with a three month retrospective survey. When comparing the totals with the other surveys, the most apparent difference is the level of domestic travel, which is logically related to the missing travels to vacation homes.

It is obvious from the figure, that the most significant difference between the HBS, the ordinary TU, and the two-week surveys is the domestic one day journeys. If not considering domestic one day journeys, the total level of travelling in the HBS falls in-between the two TU surveys. Domestic travels of 2-5 nights' duration vary the least between the three surveys with 1.07-1.25 million journeys per month, having the lowest level in the HBS. The two-week survey has the lowest level of domestic long duration travels and international travels.

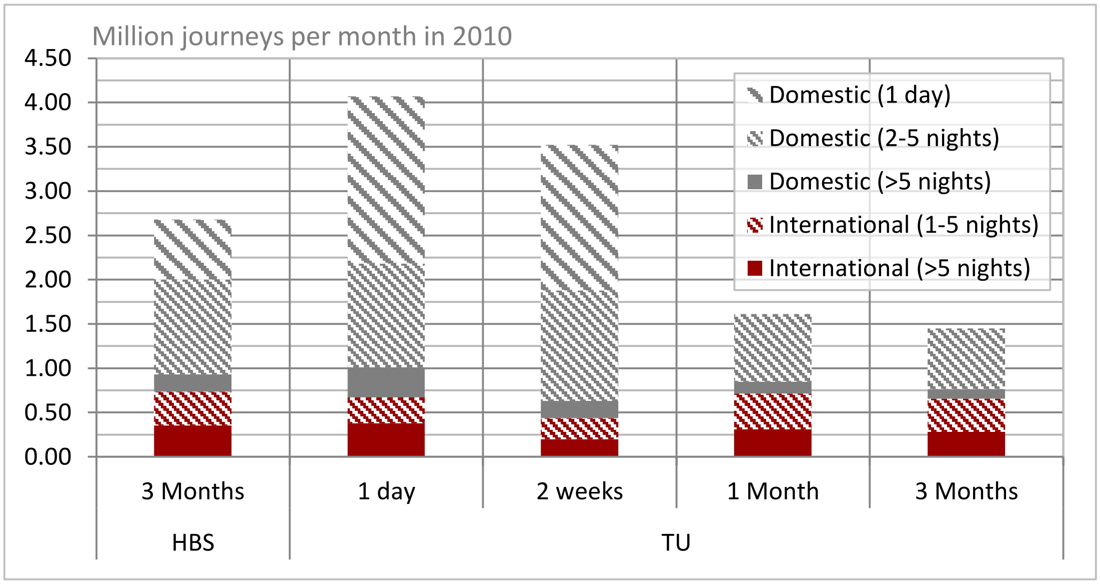

FIGURE 28: JOURNEYS WITH OVERNIGHT STAYS PER MONTH REGISTERED IN THE HBS AND THE TWO TU SURVEYS: THE ORDINARY TU AND THE TWO-WEEK SURVEY.

The total level of travelling is also listed in Table 21 where the numbers in brackets are the average share of travellers having a journey with an overnight stay during one month. When not including domestic one day travels, the similarities across the samples are notable, especially for the most infrequent travel types: 10-16% of the population has an international journey during a month and the distribution is relatively uniformly distributed between short-duration travels with 1-5 nights or long-duration travels with more than five overnight stays.

From the sample of travels with overnight stay(s), domestic short-duration travel is the most frequent travel type. The domestic one day journeys are affected by significant uncertainties as this travel type is influenced by contradicting definitions and perceptions. In the ordinary TU, the journeys considered in this analysis also include respondents with several homes. Frequently completed domestic one-day journeys of e.g. couples living apart, children with separated parents, or young respondents visiting their parents frequently are most likely not considered of relevance in the retrospective surveys, and if they are included they are likely to be affected by memory loss. This might explain the considerable difference between the 36-42% travellers with domestic one-day journey during a month in the ordinary TU and the two-week survey compared with only 15% found in the HBS.

TABLE 21: MILLION JOURNEYS WITH AN OVERNIGHT STAY PER MONTH COMPLETED BY DANES BETWEEN 15 AND 84 YEARS. THE NUMBERS IN BRACKETS CORRESPOND TO THE SHARE OF THE POPULATION HAVING A JOURNEY WITH OVERNIGHT STAY. THE TOTALS CORRESPOND TO THE TOTALS ILLUSTRATED IN FIGURE 28.

	TU 1 day	TU 2 weeks	TU 3 months	HBS 3 months
Domestic 1 day	1.89 (42%)	1.64 (36%)	-	0.68 (15%)
Domestic 2-5 days	1.17 (26%)	1.25 (28%)	0.68 (15%)	1.07 (24%)
Domestic >5 days	0.34 (7%)	0.19 (4%)	0.11 (2%)	0.19 (4%)
International 1-5 days	0.29 (6%)	0.24 (5%)	0.37 (8%)	0.38 (8%)
International >5 days	0.38 (6%)	0.20 (4%)	0.28 (6%)	0.36 (8%)
Total	4.07 (78%)	3.52 (78%)	-	2.68 (59%)
Total excl. domestic 1 day	2.18 (48%)	1.88 (42%)	1.45 (32%)	2.00 (44%)

As the magnitude of memory loss in the TU two-week survey is assumed negligible and as the estimates are only based on person weights, the TU two-week survey is generally considered less affected by recall effects than the HBS and holds a higher sample than in TU. But the overall evaluation however finds that the survey might be biased from response fatigue which results in a lower level of travelling than found in TU or missing long duration and international travelling due to the increased probability of being away and not respond the survey. When comparing the total level of travelling in TU and the two-week survey with the level found in the HBS and the retrospective TU survey, it is actually plausible that TU provides a better approximation of Danish travels with overnight stay(s) than the two-week survey. When furthermore comparing the TU estimates from 2010 with the larger sample of travel activities in 2010-2013, the distribution of travel activities is very similar. This generally supports the findings from TU even though they are based on limited samples.

If however assuming that the two-week survey underestimates international travelling this would additionally suggest that the international travel activities in the HBS are not affected considerably by memory loss as the difference between the two surveys would then be even higher. The higher level of international travelling found in the HBS could on the other hand also reflect that the respondents with more than three holiday journeys tend to register the most important holidays which favours international travel experiences. The apparent similarities found between air travels in the HBS and the air travel database does on the contrary support the level of international travelling found in the HBS. Again this supports the assumption of a general overestimation that to some extent compensates the impact of memory loss.

According to this it is reasonable to assume that Danes complete around 1.6-1.9 million domestic one day journeys per month as found in TU and the two-week survey. But this high number of journeys also describes daily travel from e.g. couples living apart and does not necessarily correspond to the definition of infrequent travel activities that contribute considerably to the total level of travelled kilometres. Otherwise it is reasonable to assume that the HBS and TU describe a sufficient spectrum of travel with overnight stay(s) completed by the Danish population of 15-84 year olds with 1.9-2.2 million journeys per month or 0.4-0.5 journeys with overnight stays per Dane per month when not considering domestic journeys with one overnight stay. The level of international travelling varies less between the surveys and suggests that Danes complete 0.7 million international journeys per month which corresponds to 1.8-2.0 international journeys per Dane per year.

3.4.6 Recall effects

Figure 29 shows the differences in the estimates of the total level of travelling registered in the retrospective TU survey when considering the three survey months separately. This study describes memory loss from the difference between the journeys registered during the latest month and the overall average of all three months as also presented in Figure 28. This approach differs from the method applied in Denstadli and Lian (1998) where the third month is compared with the first month and naturally results in higher estimates of memory loss.

The one-month retrospective survey finds a total of 1.61 million journeys per month compared to 1.45 found from the average of all three survey months. The totals are estimated from the information in the travel matrix and should consequently not be affected by response fatigue. This difference results in an 11% underestimation when including all three survey months, where the estimates of the third month alone correspond to a 16% underestimation compared with the first month.

Figure 30 illustrates the memory index when registering travel activities in a one-month, two-month, or three-month retrospective survey. The figure assumes that a one month retrospective survey represents the right level of travelling, whereas the percentage underestimation is estimated for a two-month and three-month retrospective survey i.e. the average of two and three months respectively.

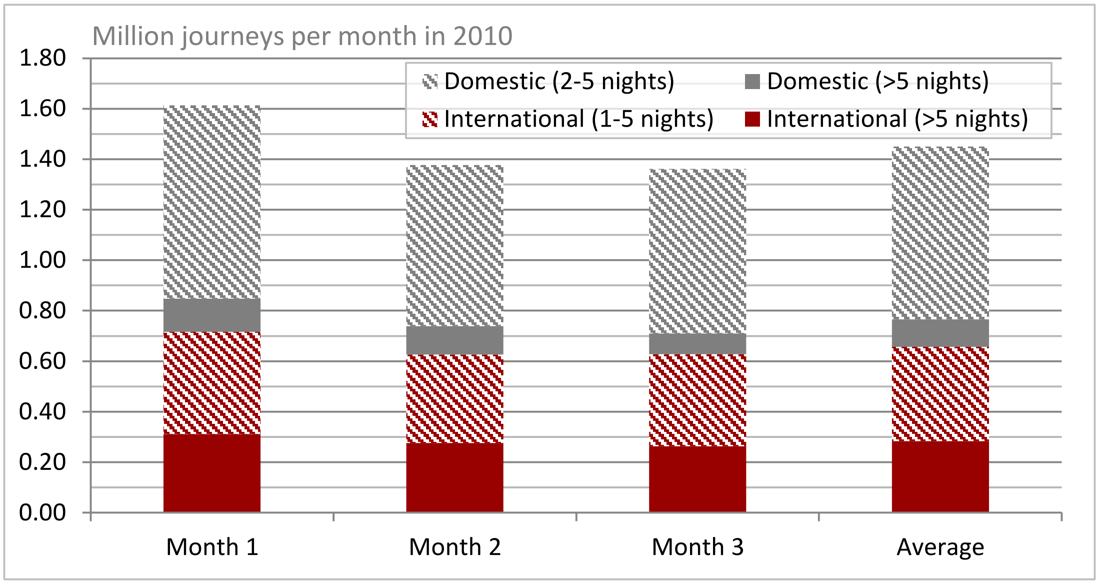

FIGURE 29: MILLION JOURNEYS WITH AN OVERNIGHT STAY REGISTERED IN THE THREE MONTH RETROSPECTIVE EXTENSION OF TU. THE TOTALS ARE ESTIMATED SEPARATELY FOR EACH SURVEY MONTH AND AS AN OVERALL AVERAGE.

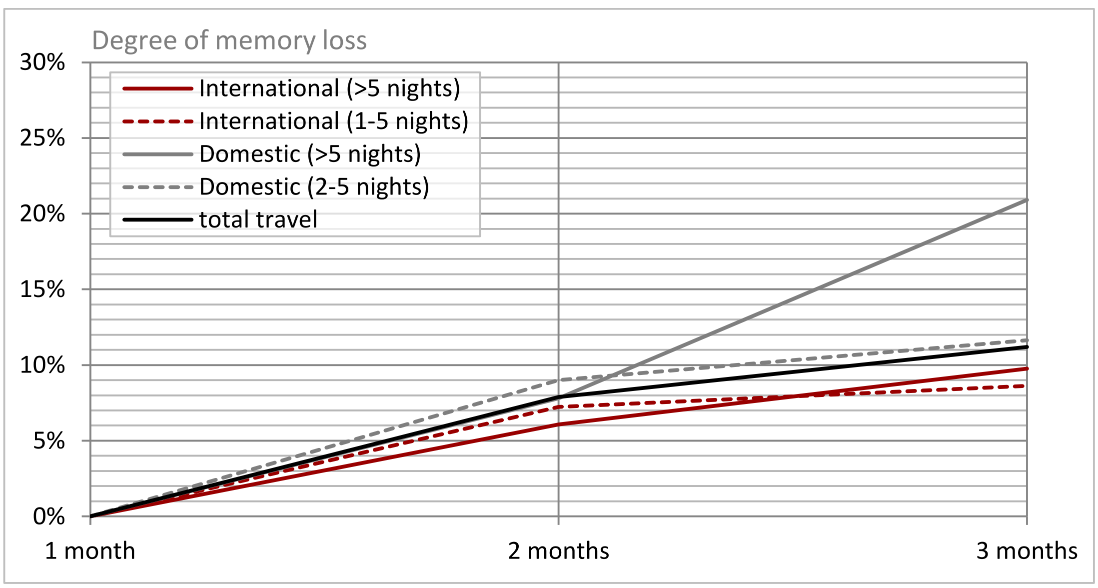

FIGURE 30: MEMORY LOSS INDEX ESTIMATED FROM THE TU 3 MONTH RETROSPECTIVE SURVEY.

The memory index of domestic long-duration travels differs considerably from the other travel segments, which is related to smaller samples. The difference is however only present for the third survey month, which also suggests that it could be related to a survey error from e.g. the lower number of observations in December. But it might also be related to a too comprehensive handling of outliers and removal of likely errors during the data processing. Otherwise a two-month retrospective survey underestimates the level of travelling by 6-9% and a three-month survey underestimates the level of travelling by 9-12%. The third survey month alone provides an underestimation of 10-16% which is somewhat lower than what was found in Denstadli and Lian (1998) who also found considerable differences between different travel type segments.

The relatively low level of memory loss found in the retrospective TU survey part might be related to differences in survey approaches, which suggests that the introduction matrix might after all have resulted in recalling more travel activities within each of the four travel types and three travel months. A higher level of memory loss might on the contrary be present in the sample of journeys registered with details which are not considered in the present study. In relation to this, it is also necessary to stress that the data set analysed here is processed and some respondents are removed due to obvious errors. One might argue that an analysis of survey troubles should be completed on data that are not corrected for errors, as some of these errors might in fact be related to memory loss. But some of the errors were on the contrary obviously related to a misinterpretation of the introduction travel matrix and inappropriate to include in the study.

The first analyses completed on the original data set however resulted in memory losses of almost double sizes and an obvious difference between travel types. On average, the sample resulted in a 22% underestimation of travels with overnight stay(s). Domestic travels were underestimated by 25-30% and international long-duration travels by only 10%. This apparent difference furthermore illustrates how the impacts of memory losses are considerably reduced from thorough data processing. Many domestic travel activities are removed from the survey which furthermore stresses the troubles related to recalling domestic travel activities in a comprehensive way.

Table 22 shows an adjustment of the estimated totals if taking memory loss into account. The estimated totals from the HBS are corrected relative to the memory loss factors found from the retrospective TU survey and listed as HBS^A. The totals of the retrospective TU survey are additionally corrected for the missing vacation homes by extracting these journeys from the HBS in 2010. In the HBS, travelling to own vacation homes corresponds to 0.35 million journey per month which is close to the 0.32 found in the two-week survey. The adjusted totals are listed as TU^B. These totals are furthermore corrected for memory loss in TU^C.

When correcting for memory loss and including vacation homes in the retrospective TU survey, the estimated totals actually match the original estimates based on the HBS. As it is very unlikely that the HBS is unaffected by memory loss, this relation also supports the assumption that high relative magnitude of journey weights and too limited restriction on outliers in the HBS have generally overestimated the total level of travelling as also discussed in the previous sections. From the comparison with the air travel database it however seems reasonable that the total level of travelling found in the HBS does not overestimate the actual level of travelling, but might however counterbalance some of the uncertainties from memory loss. From the comparison with the air travel database, the missing daily travel activities and missing travellers below 15 years and above 84 years are however also of relevance.

TABLE 22: MILLION JOURNEYS WITH AN OVERNIGHT STAY PER MONTH COMPLETED BY DANES BETWEEN 15-84 YEARS IN THE ORDINARY TU, THE TU OVERNIGHT SURVEY, AND THE HBS. THE ESTIMATES ARE FURTHERMORE CORRECTED FOR MEMORY LOSS AND MISSING REGISTERED TRAVEL TO VACATION HOMES.

	TU 1 day	TU 2 weeks	TU 3 months	TU^B 3 months	TU^C 3 months	HBS	HBS^A
Domestic 2-5	1.17	1.25	0.68	0.91	1.01	1.07	1.20
Domestic >5	0.34	0.19	0.11	0.17	0.20	0.19	0.23
International 1-5	0.29	0.24	0.37	0.39	0.43	0.38	0.42
International >5	0.38	0.20	0.28	0.30	0.32	0.36	0.39
Total	2.18	1.88	1.45	1.77	1.97	2.00	2.24

A) HBS scaled and adjusted for memory loss
B) TU 3 months including vacation homes registered in the HBS
C) TU 3 months with vacation homes adjusted for memory loss

When adjusting the HBS for memory loss, the total level of travelling is significantly higher than found in the two-week survey, but it actually approaches the level found in the ordinary TU. The HBS still finds higher shares of international travelling, which suggests that the memory loss index should have differed more between travel types than found in Figure 30 as also found in the original data before detailed data processing. It might however also reflect the uncertainties related to small samples in TU. The comparisons nevertheless suggest that the HBS generally represents a comprehensive picture of the total level of travels with overnight stay(s) when not considering domestic one day travels.

3.5 DISCUSSION OF TRAVEL SURVEYS AND SURVEY METHODOLOGIES

The validation throughout the previous section has outlined contradicting results and it is difficult to recommend one survey approach over the other. The advantages of the different survey methodologies certainly depend on the purpose of the survey. TU provides a comprehensive picture of the total level of travelling, but the estimates are based on limited samples of respondents. If combining three TU survey years, the number of respondents is similar to the sample in the two-week survey, but the TU sample has more respondents with international travel activities. This supports the overall evaluation of the two-week survey that seems to fall short in describing the most infrequent travel activities sufficiently.

The overall workload of the two-week survey is high compared with the achieved results. Together with the fact that the varying survey period between respondents additionally complicates sufficient data processing, this survey approach is not found appropriate to describe travel with overnight stay(s) into greater details without an additional retrospective survey part. In relation to this it actually seems that the considerably less cost expensive extension of the ordinary TU fulfils the purpose of describing the more frequent travel activities with overnight stay(s). It is however important to stress that the purpose of the two-week survey part was not alone to register travel activities with overnight stay(s), but also to register the variation in travel behaviour of individuals across several days.

If however requiring a larger sample of domestic short-duration travel than registered in TU, the overall design of the TU overnight survey might gain from some overall adjustments. It seems likely that one week with the repeated travel survey is appropriate to register the more frequent domestic travel activities with overnight stays and reduce the impacts of response fatigue. This is supported by the high share of travellers completing short-duration domestic travel activities with overnight stay during a month as listed in Table 21. A one-week survey might then be supplemented by an additional retrospective survey part for international travel and the infrequent domestic long-duration travel activities. The retrospective survey part might however also gain from some adjustments:

Disregarding domestic one day journeys as well as journeys to own vacation homes in the retrospective TU survey is reasonable when considering their frequent occurrence. The inclusion of these journeys might remove focus from the less trivial activities and they might additionally be difficult to recall sufficiently anyhow. It is however possible that all travel activities with overnight stay(s) could be described comprehensively from a one-month survey if not interested in too many travel details. This would on the other hand not remove the uncertainties related to domestic travels of one night's duration. From TU and the two-week survey, domestic one-day travels represent 46-47% of all travel activities with overnight stay(s), whereas the share is only 25% in the HBS. The high shares reflect the uncertainties in recalling domestic one-day travels, but also that respondents most likely perceive visits with overnight stay(s) differently or that the definition of holiday travel, visits, and business travel in the HBS is not completely exhaustive.

The structure of the retrospective extension of the TU overnight survey ensures more information about the stated number of journeys. The introduction of the travel matrix distributes the number of journeys into the retrospective month they were completed which might ideally reduce the extent of memory loss as the respondent is guided to recall each month separately. The respondents are confronted with the stated total number of journeys and might reconsider the answers if the total number of journeys is very different from the actually completed number of journeys. The respondent is on the other hand faced with several more matrix cells to consider. This complex design might have added some unintended uncertainties to the survey. It is however also found that the processing of data removes some of the uncertainties related to memory loss as the processing of data has revealed considerably inconsistencies between the travel matrix and the travel activities registered with detail. The travel matrix consequently also works as a source of validation.

As the maximum number of journeys registered with details in the retrospective TU survey is not restricted to a specific travel type as is the case for the HBS, it might actually be possible to more or less avoid journey weighs or only include journey weights for the limited number of respondents with very high travel frequencies. The travel matrix furthermore results in journey weights that can be estimated with greater details than possible in the HBS. In the HBS, this could on the other hand be accommodated by changing the sample of holiday journeys registered with travel details back to five journeys instead of only three. The response fatigue found before 2008 is assumed to be related to the high number of details required per journey and not the sample of five journeys. It does however seem necessary to modify the definition of visits if these activities should be registered in a retrospective survey. If keeping visits as a separate travel purpose, it should otherwise be considered to reduce the survey horizon. It could on the contrary also be relevant to divide the travel activities differently in the HBS, e.g. into domestic and international travelling as in the retrospective TU survey.

The actual survey design however depends on the purpose of the survey and the previous comparison has certainly outlined the trade-offs between sample sizes and survey uncertainties. The survey design of the TU overnight survey approaches the multi-protocol methodology by introducing the travel matrix, and selecting the journeys of highest importance to be registered with details if a respondent registers many travel activities. This could among others involve high prioritised international travel during all three months and giving the lowest priority to domestic travel more than one month back. A selection procedure similar to this was actually included in the survey, but with the present design most journeys were registered with details, because most respondents registered less than 12 journeys in total. With such a prioritised selection procedure, it might also be possible to include visits at own vacation homes and one-day domestic travel, but the survey horizon of three months should then be reconsidered due to memory loss.

3.6 Summary

During the latest decades, the total level of domestic travel has stayed more or less constant, whereas international holiday travel has increased. This has had a substantial impact on the total budget of travelled kilometres. The development is of considerable importance when discussing future emissions from transportation. The growth in international travel has detected two travel segments of high relevance: increasing travel to more distant destinations and increasing weekend travel with a high share of air travel as the main mode. The total development in international travel is consequently not only more holidays with destinations located further away. The first travel segment is naturally important due to increased travel distances, but the latter travel segment is on the contrary a travel type with fewer time constraints regarding the number of weeks of vacation during the year and consequently has a higher potential for further growth.

The three Danish travel surveys differ somewhat in survey methodologies and consequently work as a unique source of survey validation of the total level of travelling estimated from the HBS. The comparison of the total level of travelling in 2010 has revealed a number of contradicting relations that generally complicate the favouring of one survey approach over the other and consequently also to determine a specific point estimate of the total level of travelling with overnight stay(s).

The comparison has among others found that the limited extension of the TU questionnaire has resulted in sufficient information of the total level of travelling with overnight stay(s). The sample of travel activities is however too limited for detailed analyses. Even though the two-week survey provides a larger sample of journeys with overnight stay(s), it is still too small to describe the most infrequent travel types in a comprehensive way.

The total level of travelling found from the HBS is despite the substantial survey uncertainties found acceptable for describing the total level of multiday travel when disregarding domestic one day travel. Domestic travel of 2-5 nights' duration is also likely to be considerably biased from recall effects and the definition of visits that seems to be interpreted differently by individuals. It is however found that a retrospective survey period is required to describe long-duration domestic travel and international travel from a sufficient sample, especially if interested in travel details. The present design of the HBS is generally considered inappropriate as too much focus is put on visits that have proven difficult to recall and additionally has removed focus from holiday travels that are consequently unnecessarily biased from journey weights.

Some of these uncertainties are reduced in the design of the retrospective module of the TU overnight survey. Together with the two-week survey it is discussed that further adjustment of the survey design could most likely improve the survey to better describe the whole spectrum of travelling. This might be from a one-week mobility survey and an additional retrospective survey that mainly focuses on international travel and domestic travel of more than five nights' duration. It could however also be as an extension of the ordinary TU. The length of the retrospective survey depends on the level of details by which international travel should be described. It is however difficult to achieve samples large enough to evaluate international travel or even European travel at the country level.

Chapter 4

DANISH TRAVEL BEHAVIOUR AND TRAVEL SURVEYS

SUMMARY AND CONCLUSION OF PART I

The overall trends in European travel behaviour generally centre around the peak travel theory with the approaching maximum level of domestic travel or at least the travel budget theory with obvious constancy in travel frequency and travel time during an average day. A discussion of the importance of international travelling does however emerge. This is related to the significance of globalisation that has resulted in international travel being embedded into people’s life.

If considering infrequent travel activities as travel with overnight stay(s), three Danish travel surveys are available that together register the whole spectrum of Danish travel behaviour in 2010: The Danish National Travel Survey (TU), the tourism statistics found from the Holiday and Business survey (HBS), and the TU overnight survey. TU and the HBS furthermore include information back to the 1980s and 1970s that describe the overall trends in Danish travelling. Together with the findings in paper#2, the previous chapters have provided empirical knowledge on Danish travel behaviour and travel trends during the latest decades with focus put mainly on leisure travel including also international holiday travels.

4.1 DANISH TRAVEL BEHAVIOUR

The two previous chapters have described the overall picture of Danish travel activities during the latest decades when dividing travel activities into daily and multiday travel. The travel activities described in Chapter 2 and Chapter 3 have an overlap of domestic travel with overnight stay(s) and do not consider daily international travel activities. The processing of TU in Chapter 2 does not take the travel activities with overnight stay(s) into account, but the activities figure in the totals anyhow. To describe travel with overnight stay(s) in a comprehensive way needs some further processing of data as also described in Chapter 3.

In the following, TU is nevertheless assumed to describe all daily domestic travel activities as well as domestic travel with overnight stay(s) even though outbound and homebound activities might be biased. The HBS describes international travel with overnight stay(s). The two surveys combined describe the whole spectrum of travelling, but leave out daily travel activities across the Danish borders as these were excluded from the analysis of TU due to missing travel details.

A summary of the total level of Danish travel in 1997 and 2010 is presented and compared in the following. 1997 is found as the most suitable year for comparison given the uncertainties in TU from 1998-2001 and the insufficiencies in the HBS from 2004-2007. As the travel activities from TU in 1997 were not summarised to journeys in the available data set, the included travel frequencies are based on trips that are approximated journeys by a factor of 0.4 as an average journey consists of 2.5 trips[15]. Stated travel distance are included for domestic travel as it is considered most appropriate given the considerable detour factors of 1.2-1.3 and as crow fly distances are not available in 1997. The international crow fly distances applied in the HBS are also affected by uncertainties that might be influenced

[15] An average Dane completes 3 trips or 1.2 journeys per day which corresponds to 2.5 trips per journey.

by the presence of memory loss together with the crow fly distances being estimated for aggregated destinations and applied journey weights.

Table 23 shows the summary totals of 1997 and the totals of 2010 are listed in Table 24. An average Dane between 15 and 84 years actually completed slightly more journeys in 1997 than in 2010 which are related to more domestic travel activities or the natural variation found in the travel frequencies registered in TU. But the number of kilometres per Dane per year has increased by a little more than three thousand kilometres or 1.3% p.a. The overall distribution between private and professional travel activities has stayed relatively constant with 27-28% professional travel activities that represent 36-38% of the travelled kilometres.

TABLE 23: SUMMARY OF 1997 TRAVELLING PER YEAR PER AVERAGE DANE BETWEEN 15 AND 84 YEARS.

		Journeys	Kilometres
TU	Private domestic travel	341 (72%)	7,700 (45%)
	Professional domestic travel	129 (27%)	5,600 (33%)
HBS	Private European travel	0.73 (0.15%)	1,800 (10%)
	Private travel outside Europe	0.10 (0.02%)	1,200 (7%)
	International business travel	0.29 (0.06%)	800 (5%)
Totals	Total	472	17,100
	Total (private)	342 (73%)	10,700 (62%)
	Total (professional)	130 (27%)	6,400 (38%)

The most apparent differences between the two survey years are the increasing share of international travelled kilometres which represented 22% in 1997 and 30% in 2010. The same travel activities only represented 0.24% of the total number of journeys in 1997 and 0.37% in 2010.

TABLE 24: SUMMARY OF 2010 TRAVELLING PER YEAR PER AVERAGE DANE BETWEEN 15 AND 84 YEARS.

		Journeys	Kilometres
TU	Private domestic travel	329 (72%)	8,300 (41%)
	Professional domestic travel	126 (28%)	5,800 (29%)
HBS	Private European travel	1.13 (0.25%)	2,600 (13%)
	Private travel outside Europe	0.15 (0.03%)	2,000 (10%)
	International business travel	0.40 (0.09%)	1,500 (7%)
Totals	Total	457	20,200
	Total (private)	330 (72%)	12,900 (64%)
	Total (professional)	126 (28%)	7,300 (36%)

When considering these two cross-sectional averages, private domestic travel has in average decreased by 0.3% p.a. and domestic professional travel by 0.2%. Private domestic travel distances have increased by 0.6% p.a., whereas professional travel distances have increased by 0.3% p.a.

International travel has on the contrary experienced considerably higher growth rates above 3% p.a. The travel distances have increased by 3.2% p.a. to destinations in Europe and by 3.9% p.a. outside Europe. Business travel has increased the most by 4.6% p.a.

Besides revealing growth in international travel activities, the analyses of the HBS have certainly outlined a number of travel type segments of high relevance in the discussion of future emissions from transportation. The growth in holiday travel is in particular found from international travel, and air travel has become more common. Two travel type segments have additionally developed more: the very long distance holiday activities that are also more likely to have at least six overnight stays and short duration European travel.

The analyses of the HBS have furthermore revealed constancy in domestic holiday travel. This supports the discussion of a general change from domestic to international travel, where the share of domestic travel has decreased by 1% p.a. from 1972 to 2011. In addition to this it is revealed that travelling to vacation homes have represented approximately one third of all activities with overnight stay when not considering VFR.

Reducing transportation and the additional emissions is central in the political strategies both nationally and at the European level, but it is widely discussed in literature how the reduction in transportation should not be at the expanse of the growth in economy (se e.g. Tapio, 2005; Tight et al., 2004; Ballingall et al. 2003; Schroten et al., 201). Decoupling of transport from economy is in Tapio (2005) defined as the elasticity of transportation at the macro level, with the ratio between the change in transportation relative to the change in economy. A decoupling factor between 0.8 and 1.2 is considered as significant coupling between transport and economy. From the strong correlation between personal travel and economy as also illustrated in Figure 8, Figure 20, and Figure 21 on page 37, and page 73 respectively, it is possible to evaluate the level of decoupling present in Danish travelling.

According to the development in domestic personal kilometres in Figure 8, the overall trend in travelling still reflects a strong coupling between transport and economy with a decoupling factor of 0.82 from 1981-2007. From 2007-2009 the decoupling factor was 0.85, however estimated from the significant reduction in both transport and economy. Domestic holiday travel distances registered in the HBS indicates a trend of decoupling of transport from economy with a decoupling factor of 0.68 from 1997-2007 which also correspond to the lower income elasticities presented in paper#2. On the contrary the growth in international travel distances has more than doubled compared with the changes in economy. The decoupling factor is 2.52 for European holiday travels and 3.17 for holiday travels outside Europe. These factors also correspond to the high income elasticities found for holiday travelling in paper#2 and paper#3. The decoupling factors of holiday travel frequencies are a little different, but generally describe the same relations. Holiday travels have increased 1.61 times the economy from 1997-2007 where domestic travels have decreased by a factor of -0.11, European travels have increased by 2.86 and travelling outside Europe by 2.61.

This strong relation between transport and economy shows that the Danish development in travel behaviour has not at all reached a maximum level and that the only trend of stagnation is found for domestic holiday travel. The development in domestic travels has experienced a temporary set-back due to the economic recession, but has during recent years again experienced growth in travel distances. This might on one hand suggest growth in transport even though economy develops with slower speed than previously, but might on the other hand also reflect the recovering of the economic crisis.

International travel has experienced considerable growth and the strong relation with economy does not suggest that the problems related to increasing transportation are solved from a natural level of stagnation or saturation. Danish long distance travel and international travelling in particular represents a travel segment that continues to grow and is positively correlated the economy.

4.2 Long distance travel and travel surveys

Long distance travel is regardless the exact definition characterised as an infrequent travel activity that only represents a limited share of travel activities, but contributes to a considerable share of travelled kilometres. From the large sample of traditional weekday activities the impact of these infrequent travel activities only influences the overall averages in a limited way. Any trends in long distance travelling are consequently difficult to outline from overall averages of daily travel behaviour.

The significant variation in travelling during non-working days however seems important to better understand these infrequent travel activities that contribute significantly to the total level of travelled kilometres. In addition to this, the travel characteristics described in TU and in particular the significant trends in international holiday travel from the HBS emphasise the importance of leisure travel in the discussion of the negative externalities related to personal transportation. This is furthermore supported by the discussion of decoupling of transport from economy where private travel purposes are discussed as central if transportation should be reduced without additionally ceasing growth in economy. The significance of leisure travel outlined throughout this thesis however suggests that reducing private travelling would require substantial behavioural changes as leisure travel represents an important part of people's weekday activities and as international holiday travel represents the majority of Danish holiday activities.

Describing infrequent travel activities require tailored travel surveys to achieve comprehensive sample sizes. It is however also recognised that retrospective travel surveys include higher survey uncertainties. This relation is also supported by the comparison of the different survey methodologies throughout Chapter 3. The different survey types find similar levels of travelling however with varying uncertainties assigned.

The comparison of the different survey methodologies generally finds most domestic travel activities with few nights' stay insufficiently described in a retrospective travel survey. Domestic travel with few overnight stays is on the contrary likely to be described comprehensively from a daily mobility survey that registers overnight stays as in TU or from a continuous travel survey as the two-week travel diary survey. Due to the considerable expenses related to follow-up interviews as well as the presence of response fatigue, a seven day survey is however recommended.

When adjusting the two retrospective surveys for the obvious uncertainties, the two surveys find similar levels of travelling. The advantage of the TU overnight survey is that it is approaching a multi-protocol design with the introduction travel matrix that on one hand provides detailed information on the total level of travelling and subsequently enables a selection procedure to prioritise the journeys registered with details. This selection procedure is not as restricted as the three main travel types considered in the HBS. But the detailed travel matrix on the contrary might have been too complex and introduced other possible survey uncertainties. The design of the TU overnight survey furthermore has the advantage of describing the linkage between daily travel and multiday travel, if both survey parts are completed simultaneously. The design however seems to exaggerate as the two week period is too long to register everyday activities and too short to register infrequent international travel sufficiently. The retrospective design additionally includes a three month period that is affected by memory loss and does not register all travel types. A reduction to a seven day diary and a one-month retrospective survey seems more comprehensive and might reduce the response biases from response fatigue and memory loss. Another and related approach could be an extension of the ordinary TU that asks additional questions of the previous month that also include domestic one day travel and travelling to own vacation homes. But to achieve a comprehensive sample of international travel activities with representative destinations requires large sample of respondents or longer retrospective survey periods.

The retrospective TU survey has additionally facilitated an evaluation of the magnitude of memory loss. The overall magnitude of memory loss is an 11% underestimation from a three month survey period with relatively limited difference between the analysed travel types. This is however based on validated data and contradicts the studies from the original data set. Without removing or reducing the errors from the retrospective survey, international travel was proven somewhat easier to recall than domestic travel. This also corresponds to the significant uncertainties found in registering domestic one day travels in a retrospective survey.

The study of infrequent travel activities has mainly focussed on travel with overnight stay(s), which is in particular related to the available data sources, but has furthermore facilitated the discussion of an appropriate definition of long distance travel. As revealed from TU, respondents tend to register round numbers which influences the registered travel distances and would also influence long distance travel defined as travelling above a specific distance threshold. This problem is possible to accommodate by defining a buffer distance and register travelling above e.g. 75 kilometres. The focus on overnight stay has on the contrary revealed troubles with registering visits or domestic short duration travel in general. From the high share of travellers with domestic travel with one or 2-5 nights' duration, it is discussed that this travel segment might instead be described sufficiently in daily mobility surveys. It is consequently found that focus should in particular be put on tailored travel surveys that register international travel activities, but also domestic holidays or domestic travel with more than five nights duration.

Chapter 5

LITERATURE

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PART II

ASSESSMENT OF LONG DISTANCE TRAVEL

PAPERS

PAPER #1

HOUSEHOLD AND INCOME BIAS IN TRANSPORT SURVEYS

Working paper

HOUSEHOLD AND INCOME BIASES IN TRANSPORT SURVEYS

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ABSTRACT

Income is a fundamental driver behind many transport activities. As a result much attention has been given to demand sensitivity with respect to income. This paper focuses on survey biases and their impact on demand elasticities. The analyses apply a simple car ownership model as a case study based on the Danish National Travel Survey (TU). The survey is joined with register data that ensure homogeneous defined variables that minimises the biases from measurement errors. It furthermore enables the evaluation of non-response rates.

Three sources of bias are analysed. First of all the difference between a household-based survey and an individual-based survey is analysed and shows that applying individual-based surveys for estimation of car ownership, which is considered as a household decision, underestimate income elasticities. Secondly it is found that the response biases present in the survey reduce income elasticities from 0.20 to 0.09 as low income households and single-family households are underrepresented. Thirdly the bias related to registering sufficient and homogeneously defined incomes is analysed and it is found that this measurement error strongly reduced income elasticities to only 0.03. A selection procedure and weighted estimates that account for response bias are additionally tested and it is found that it is possible to accommodate some of the impacts from response biases.

Keyword: Response bias, Measurement error, Car Ownership, Income elasticity, Transport surveys

1 INTRODUCTION

It is generally acknowledged that surveys are not necessarily representative for the population (Christensen & Sobrino Vázquez, 2013; A. Richardson & Meyburg, 2003; Richardson et al., 1995) and might be measured with errors (Bound et al., 2001). The work of this paper is inspired by the findings of (Madsen & Mulalic, 2012). They analysed a measurement error related to stated income in the Danish National Travel Survey (TU). Madsen and Mulalic (2012) have shown that a measurement error in an explanatory variable can bias parameter estimates considerably. The following analyses evaluate the impacts of both sample bias and measurement errors exemplified by using a simple binary discrete choice model of car ownership. Being aware of the improvements found from dynamic models for car ownership (Jong et al., 2004), the static choice model is applied as it has a simple and transparent model structure. Furthermore, it is important to stress that the purpose of the study is to reveal the impacts of survey biases and not the actual demand for car ownership.

TU works as a key source of knowledge on Danish daily travel behaviour. Besides estimating the total level of Danish travel activities, it is applied for many different modelling and research purposes. Survey biases can be taken into account by estimated person weights when scaling the survey to fit the population, but these biases are often disregarded when applying data for model purposes. This paper analyses the possible impacts of survey biases.

TU is an individual-based travel survey that focuses on individual travel behaviour. As car ownership is generally considered as a household decision, the survey biases are first of all discussed relative to the natural difference between individual-based surveys and household-based surveys. In addition to this, the impacts of response biases present in TU are analysed. The sample issues involve non-response bias and may be caused by difficulties in reaching various groups of respondents (Christensen, 2004; Verhoeven et al., 2008). Another reason for non-response or incomplete responses could be due to unwillingness to share information such as e.g. income or unwillingness to spend time participating in surveys (Groves et al., 2013). It is also worth noticing that the possible unwillingness to share information is usually heterogeneously distributed across the population with biases related to e.g. age, low and high income groups, high and low education (Dixon, 2002; Richardson et al., 1995; Verhoeven et al., 2008) or as proven in Hurst et al. (2010) that self-employed systematically underreport their income. Another survey bias considered is measurement errors related to the difficulties in collecting comprehensive information on income.

The paper is structured with some descriptive statistics of the applied data in section 2. The model specification is outlined in section 3 and the results are presented in section 4 with the three sets of biases presented separately. First of all the difference between individual-based surveys and household-based surveys is revealed, secondly the response biases from TU are analysed and evaluated. Thirdly the impacts of measurement errors in income are presented. Section 5 includes the summary and conclusions.

2 DATA

TU is an individual-based travel survey, where the respondents are selected randomly from the Danish Civil Registry (CPR)[1]. The sample is stratified relative to age, gender and municipality (Christiansen, 2012). Three samples of TU are analysed throughout this work: 'TU sample' refers to the total sample selected to participate in TU, 'TU non-response' refers to the samples of respondents not responding the survey and 'TU response' is the respondents completing the survey in a comprehensive way. These samples leave out a smaller sample of respondents that complete the survey, but do not provide sufficient informations of income.

TU can be enriched with register data from Statistics Denmark which enables an identification of non-response and provide a larger sample of background information based on the personal identification codes of the respondents. Register data also provide information not registered in the survey and ensure homogeneous defined variables that furthermore enable evaluation of measurement errors.

Several measures of personal income are available in register data which stresses the complexities in registering personal income. The focus in this study is on gross income which is assessed as: all personal incomes inclusive special income, but not share income and rent subsidies.

2.1 SAMPLE BIAS AND INCOME DISTRIBUTIONS

The difference between individual-based and household-based surveys is in particular evident regarding incomes. The average yearly household income of the 4.0 million Danes between 18 and 84 years is 464 thousand DKK[2], whereas the 2.7 million Danish households

[1] The Danish Civil Registry represents both Danish citizens, but also international residents who's stay in Denmark has been officially approved

[2] €1=7.45 DKK in 2009 (www.statistikbanken.dk, accessed the 10th of January 2014)

have an average household income of 404 thousand DKK as also listed in Table 1. In an individual-based survey, the household income of couples is included twice: both as personal income and as the income of the partner. The difference from 464 to 404 further insinuates that the personal income of people living as couples is on average higher than people living in single-families. This difference is strongly related to age as incomes are generally lower for the youngest and eldest parts of the population who also have a higher probability of living as single-families.

From the average level of income listed in Table 1 it appears that the overall TU sample is slightly, but not distinctively affected by selection bias. The difference relative to the sample of responses and non-responses however reveals the impact of response biases. The average household income of the non-response sample is 422 thousand DKK and the average is 528 thousand DKK from the sample of responses. These differences suggest that higher income households are generally more likely to participate in the travel survey.

TABLE 1: AVERAGE PERSONAL GROSS INCOME IN 2000 PRICES FROM TU SAMPLES AND IN THE POPULATION.

	Observations	Personal income		Household income	
		Average	Median	Average	Median
TU sample[a)]	26,589[3]	271	242	479	423
TU non-response[b)]	11,235	251	210	422	339
TU response[c)]	11,578	294	273	528	503
Danish population (18-84 years)	4.0 million	265	236	464	403
Danish households (18-84 years)	2.7 million	-	-	404	320

a) Original sample of respondents selected to participate in TU
b) Sample of respondents not participating in the survey
c) Sample of respondents completing the survey

Even though the differences in household income might also relate to the age of the respondents, the differences are in Table 2 outlined relative to family types. Amongst the 4 million Danes, the share of single-family households is 34%, but from the 2.7 million Danish households 51% of all households are single-family households. Because TU is an individual-based survey, the ideal share of single-family households is 34%. The share of 32% in the TU

[3] The remaining 3776 TU respondents participate in the survey, but do not report all the necessary details, which is mainly income.

sample, together with an average household income a few percentages above the population is reasonable. What is most apparent in Table 2 is that single-family households are more likely not to participate in the survey and that these in particular are respondents with lower income. The responses among couples suggest similar trends i.e. that lower income groups are less likely to complete the survey. In total these response biases provide a sample of TU respondents with lower shares of single-family households and a higher level of household income than found in the population.

TABLE 2: HOUSEHOLD INCOME IN 1000 DKK PER YEAR AND SHARE OF SINGLE FAMILIES AND COUPLES PRESENT IN TU COMPARED WITH THE POPULATION

	Singles family households			Households of couples		
	Share	Household income		Share	Household income	
		Average	Median		Average	Median
TU sample	32%	230	195	68%	596	556
TU non-response	41%	212	171	59%	566	514
TU Response	26%	260	238	74%	623	594
Danish population	34%	228	191	66%	585	544
Danish households	51%	228	191	49%	584	544

The comparisons are made relative to the sample of 4 million Danes, but when comparing with the averages of Danish households, the sample of TU responses becomes even less representative. The 26% single-family households are far from the 51% single-families found from the 2.7 million Danish households. Even though respondents with lower income are more likely not to participate in the survey, this limited share of single-family household naturally results in general overestimate of average household income in the sample of TU responses.

To accommodate this difference, three household-based samples are constructed from the TU samples. The selection procedure includes 50% of the respondents living together as couples. This stratification only considers the bias between individual-based and household-based samples and the response bias is consequently still present in the constructed TU samples. Two 10% samples of Danes and Danish households are additionally constructed from register data. This results in a test setup with eight samples of the population as listed in Table 3.

The two samples selected from register data are constructed from a 10% sample of the Danish population between 18 and 84 years and a 10% sample from the corresponding Danish households. The model specification in (1) includes the socio economic variables of household income, the age of the one or two adults living in the household, and age squared. For households owning at least one car, the income is corrected for car user costs by the constant $r = 36/1.197$ in 1000 DKK per car which is the unit user cost of car ownership also applied in the Danish National Transport Model. The original TU sample includes 26,612 respondents, which is reduced to 17,617 when constructing the household-based sample. The TU non-response sample includes 42% of the respondents from the original TU sample, and the TU response sample includes 44% of the respondents. The remaining 14% is the share of respondents responding to the survey, but not including all the information required for the following analyses. This sample has been analysed separately, but are not included in this study. 13% of these respondents do not report income. All samples are based on 2009 data.

TABLE 3: NUMBER OF OBSERVATIONS PRESENT IN THE EIGHT SAMPLES ANALYSED

	Household-based survey	Individual-based survey
10% of the population (18-84 years)	264,733	394,486
TU sample	17,617	26,612
TU non-response	7,920	11,235
TU response	7,343	11,578

3 MODEL SPECIFICATION

Car ownership is modelled from a simple binary logistic model. The model specification presented in (1) estimates the probability of having one or more cars in a household, i, given household income $I_{house,i}$ that is corrected for car user $cost$ from the relation in (2). The model specification furthermore includes a number of socio economic variables and a vector of k correction factors relative to household type and place of residence, $X_{i,k}$.

$$V_i^{car} = \alpha + \beta_{inc} \ln\left(I_{House,i} - cost\right) + \sum_k \beta_k X_{i,k} + \varepsilon_i \qquad (1)$$

Where:

$$\text{cost} = \begin{cases} 0 & if\ car = 0 \\ r & if\ car = 1 \\ 2r & if\ car > 1 \end{cases} \tag{2}$$

The correction factors correct for family structure by distinguishing between single males and single females relative to couples, and one or several children relative to no children. Finally the specification controls for geography by eight regions relative to the capital (the municipality of Copenhagen and Frederiksberg).

The marginal effects, $m_{car,i}$, and income elasticities, $E_{car,i}$, of car ownership are shown in (3) and (4), respectively (see also Train (2003))

$$m_{car,i} = \frac{\partial P_{car,i}}{\partial z_i} = \frac{\partial V_{car,i}}{\partial z_i} P_{car,i}(1 - P_{car,i}) \tag{3}$$

$$E_{car,i} = \frac{\beta_{inc}}{\mathrm{I}_{\mathrm{House,i}} - \mathrm{cost}}(1 - P_{car,i})\mathrm{I}_{\mathrm{House}} \approx \beta_{inc}(1 - P_{car,i}) \tag{4}$$

4 MODEL ESTIMATION AND MODEL RESULTS

The empirical section is divided into three separate parts. At first the difference between individual-based samples and household-based samples of the population is analysed in section 4.1. This is based on the two 10% samples selected from register data. This comparison is supplemented by the six samples of TU respondents as outlined in Table 3. These comparisons are presented as the impacts of response bias in section 4.2. Finally the impacts of measurement errors related to stated income in the TU responses are presented in section 4.3.

4.1 INCOME EFFECTS OF CAR OWNERSHIP FROM DANISH HOUSEHOLDS

The model specification in (1) and (2) is applied on the 10% sample of Danish households and the 10% sample of the population. All parameters are estimated precisely and with plausible magnitudes (see Table 4). The representativeness of the 10% samples was tested by different stratification criteria as well as a comparison of 100 repeated trials of 1%

samples. Both tests resulted in robust estimates, but from the 1% samples it appeared that the most uncertain parameter estimates were the correction of single-family homes and the age and age squared of the partner. This corresponds to the findings when applying the smaller samples from TU.

TABLE 4: CAR OWNERSHIP PARAMETER ESTIMATES AND 95% CONFIDENCE INTERVAL OF MODEL ESTIMATION BASED ON A 10% STRATIFIED SAMPLE OF THE POPULATION (AGE SCALED BY FACTOR 10)

	10% of the Danish households		10% of the Danish individuals	
	Estimate	95% Confidence	Estimate	95% Confidence
Constant	-7.01***	[-7.18 ; -6.85]	-6.77***	[-6.89 ; -6.65]
Income	0.63***	[0.61 ; 0.64]	0.58***	[0.57 ; 0.60]
Single male	-0.42***	[-0.58 ; -0.26]	-0.50***	[-0.62 ; -0.38]
Single female	-0.72***	[-0.89 ; -0.56]	-0.79***	[-0.92 ; -0.67]
One child	0.60***	[0.57 ; 0.64]	0.59***	[0.56 ; 0.61]
Two or more children	0.80***	[0.80 ; 0.87]	0.85***	[0.83 ; 0.88]
Age (person A)	1.05***	[1.01 ; 1.09]	1.06***	[1.02 ; 1.10]
Age (person B)	0.30***	[0.24 ; 0.37]	0.26***	[0.21 ; 0.31]
Age squared (person A)	-0.09***	[-0.09 ; -0.09]	-0.09***	[-0.10 ; -0.09]
Age squared (person B)	-0.02***	[-0.03 ; -0.02]	-0.02***	[-0.02 ; -0.01]
Greater Copenhagen	0.74***	[0.70 ; 0.78]	0.79***	[0.76 ; 0.82]
Outer Copenhagen	1.10***	[1.06 ; 1.14]	1.12***	[1.09 ; 1.15]
South Zealand	1.28***	[1.24 ; 1.32]	1.34***	[1.30 ; 1.37]
Funen and Bornholm	1.20***	[1.16 ; 1.24]	1.25***	[1.22 ; 1.29]
South Jutland	1.41***	[1.37 ; 1.46]	1.49***	[1.46 ; 1.53]
West Jutland	1.33***	[1.29 ; 1.37]	1.40***	[1.36 ; 1.44]
East Jutland (incl. Århus)	1.18***	[1.15 ; 1.22]	1.26***	[1.23 ; 1.28]
North Jutland	1.27***	[1.23 ; 1.31]	1.30***	[1.27 ; 1.34]
Number of observations	264,733		*394,486*	
Share of car ownership	60%		68%	
Log Likelihood	-128,124		-177,474	

***, **, * indicates that estimates are significantly different from zero at the 0.01, 0.05, and 0.10 levels respectively

The overall model fit from the two samples is similar, but the income parameters are found significantly different at the 5% level. The parameter estimates are intuitive and correspond to the relations found in literature (Johansson-Stenman, 2002; Nolan, 2010). Income has a positive effect on car ownership and the probability increases with age until a local maximum of 58 and 75 years. The correction for family types is also intuitive. Being single reduces the probability of owning a car with the highest impact for single females. The difference between male and female is found significant at the 5% level in the individual-based survey and close to 5% in the household-based survey. Having children increases the probability of owning a car, which is higher when having more than one child as also found in Bjørner and Leth-Petersen (2005). The difference between having one child or several children is also significant at the 5% level.

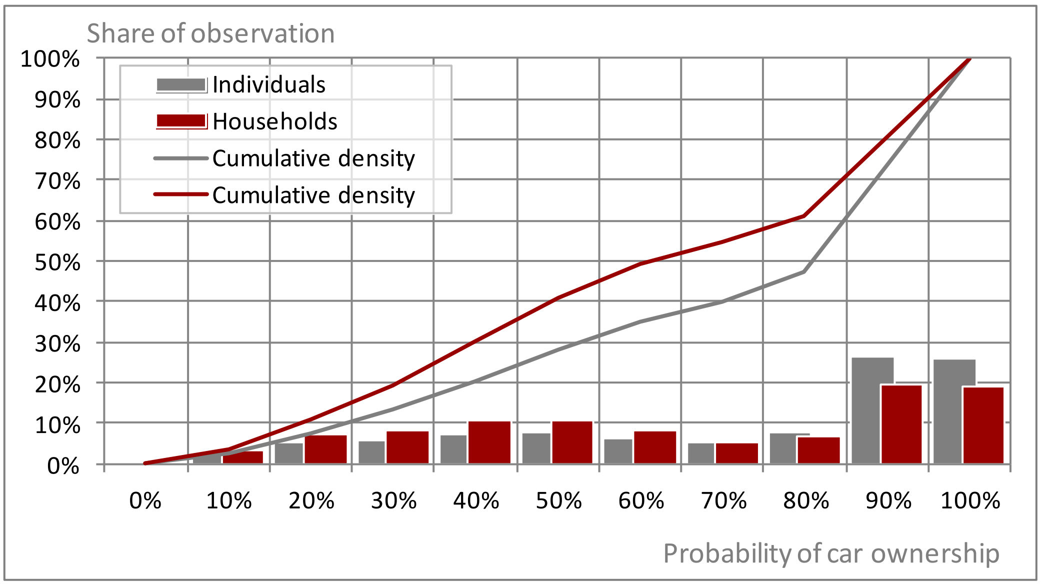

FIGURE 1: HISTOGRAM OF PREDICTED PROBABILITIES AND CUMULATIVE DISTRIBUTION OF THE PROBABILITY OF HAVING A CAR FOUND IN THE 10% SAMPLES OF THE DANISH HOUSEHOLDS AND DANISH POPULATION

The geographic correction implies increasing probability of car ownership outside the capital, with the lowest difference in Greater Copenhagen which also consists of higher density areas with good access to public transport. This also corresponds to what is generally found in literature (Bjørner, 1997; Johansson-Stenman, 2002; Nolan, 2010). The parameters with the highest relative impact are actually geography, whereas the status as single-family households has the highest negative impact. The intercept is of a relative high magnitude which suggests considerable variation not described sufficiently by the applied model specification.

The model estimates of the two samples generally overestimate car ownership and predict market shares of 64% and 74%, respectively, relative to the 60% and 68% shares found in the samples. The cumulative density functions of car ownership predicted from the two samples are illustrated in Figure 1 together with the histograms of the predicted probabilities in the two samples. The figure illustrates an asymmetric distribution with a significant share of respondents with very high probability of car ownership.

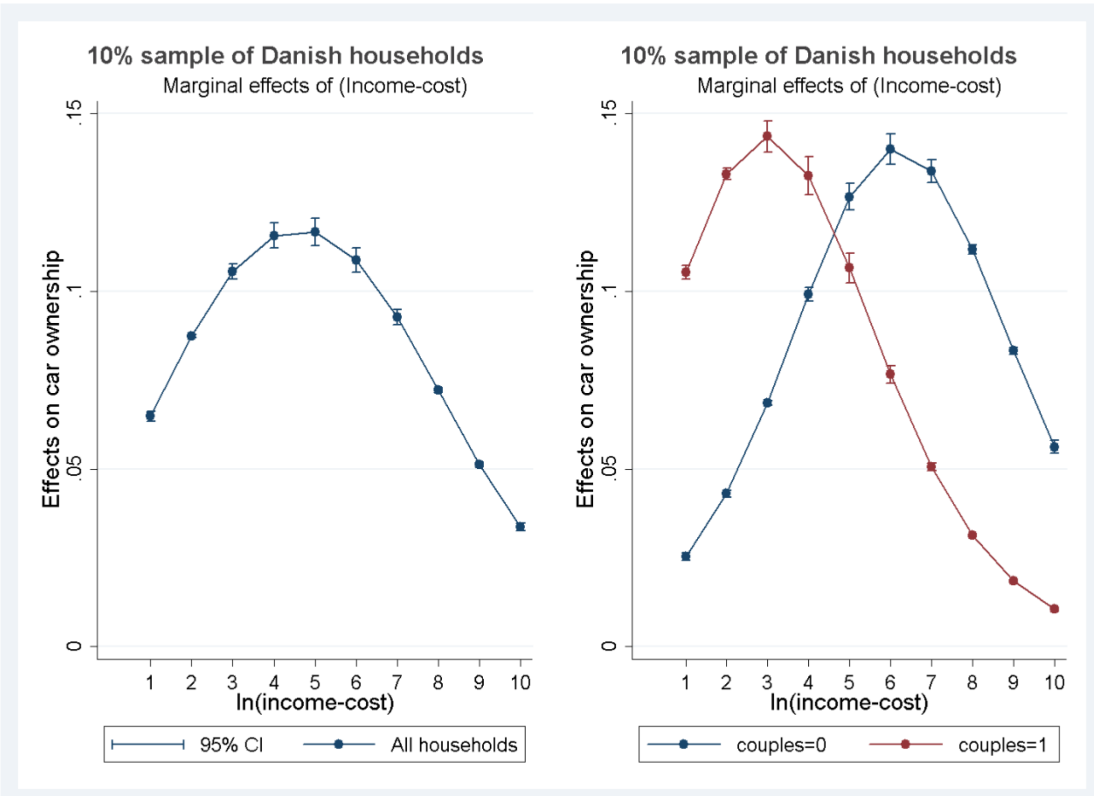

FIGURE 2: DISTRIBUTION OF MARGINAL EFFECTS FROM THE COMPLETE SAMPLE OF HOUSEHOLDS AND SEPARATED INTO SINGLE FAMILIES (COUPLES=0) AND COUPLES (COUPLES=1). THE EXPLANATORY VARIABLES $\ln(I_{House} - cost)$ BETWEEN 5 AND 6 CORRESPOND TO THE INTERVAL OF 148,000-403,000 DKK PER YEAR.

Figure 2 illustrates the distributions of the marginal effects estimated from the 10% sample of Danish households. The marginal effects are also shown for single-family households (couples=0) and couples (couples=1). The extreme values of the distributions rarely occur as the majority of single-family household incomes lie between 4 and 6 and the majority of the incomes of couples lies between 5 and 7 when considering the logarithm of household income adjusted for car costs: $\ln(I_{House,i} - cost)$. The difference in considering all households together or separately relative to family type is however apparent. The total sample of households has marginal effects that are relatively indifferent to income changes in the interval of incomes between 4 and 7. The sample of single-family households however shows substantial increasing effects from increasing incomes in the same income interval. The trend among couples is the opposite with a decreasing trend suggesting the highest impacts for low income families. This difference is also intuitive as the majority of high income couples already own a car and modelling the choice of a second car is of higher relevance. It is furthermore plausible that the probability of owning a car living in high income single-families is higher than for low income couples.

The difference between single families and couples is additionally compared with two separate model estimates based on a 10% sample of singles and couples. The parameter estimates are listed in appendix A and the differences in predicted probabilities are outlined in Figure 3. The figure shows some of the differences also outlined in Figure 1 and Figure 2.

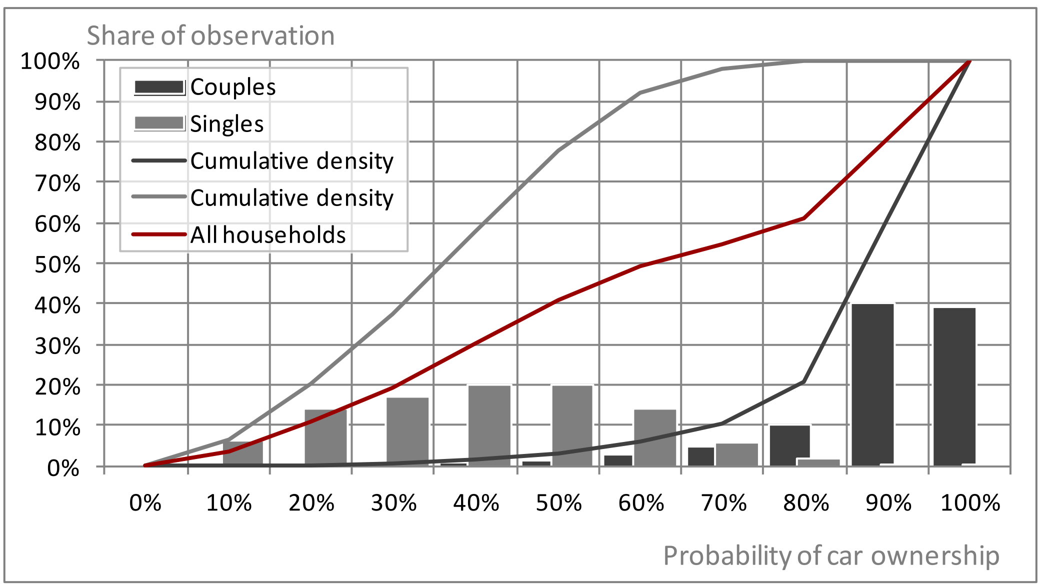

FIGURE 3: HISTOGRAM AND CUMULATIVE DISTRIBUTION OF THE PREDICTED PROBABILITIES OF CAR OWNERSHIP ESTIMATED FROM A SAMPLE OF COUPLES AND SINGLE-FAMILY HOUSEHOLDS

It is apparent how the two family types represent two very different segments of the population that relates differently to car ownership. The average share of car ownership for all households was 64% which falls somewhere in-between the two samples of family types. The figure supports the assumption of two different segments of the population that are highly correlated with family structure. This is a distinction also considered in (Bjørner &

Leth-Petersen, 2005). The distribution of single-family households approaches a normal distribution around 40-50% probability of car ownership. The distribution of couples is on the contrary highly asymmetric and most households have a probability of car ownership above 90%.

The income elasticity estimated from the whole population of Danish households is 0.23 compared with only 0.07 for couples and 0.43 for single-family households as listed in Table 5. The lower income elasticiy certainly stresses that owning a car is considered as a necessity among couples. Table 5 furthermore includes the elasticity based on the individual-based sample which has a higher share of couples and also higher car ownership. This difference is apparent from the significantly lower impacts on car ownership from changes in income.

TABLE 5: PREDICTED CAR OWNERSHIP AND INCOME ELASTICITY ESTIMATED FROM FOUR 10% SAMPLES OF THE DANISH POPULATION: DANISH HOUSEHOLDS, DANISH HOUSEHOLDS OF COUPLES, DANISH HOUSEHOLDS OF SINGLE FAMILIES, AND THE DANISH POPULATION.

	Car Ownership	Elasticity	$\ln(I_{House} - cost)$		
			Average	5%	95%
Household-based	64 %	0.23*** [0.22 ; 0.23]	5.6	4.5	6.8
Couples	87%	0.07*** [0.07 ; 0.07]	6.2	5.2	7.0
Single-families	33%	0.43*** [0.41 ; 0.44]	5.1	4.0	6.1
Individual-based	74 %	0.15*** [0.15 ; 0.16]	5.8	4.6	6.9

***, **, * indicates that estimates are significantly different from zero at the 0.01, 0.05, and 0.10 levels respectively

4.2 INCOME ELASTICITY OF CAR OWNERSHIP FROM TU SAMPLES

The model is also estimated based on the samples of TU respondents to outline the possible impacts of biased samples. In the previous section, the samples were randomly selected from the whole population and in this section it is the selection procedure and sample sizes from TU as well as the responses that determine the distribution of the population present in the samples. The original TU sample is considered as a representative sample of the population. This is confirmed by the similarities in income elasticities estimated from the TU sample and the 10% sample of the population as listed in Table 6. The biases outlined in the following are mainly related to the response biases from the TU samples.

Table 7 shows the model estimates based on TU responses. The estimates from the samples of non-response and from the complete TU survey are listed in Appendix B and Appendix C and the overall relations between household income and car ownership in the different TU samples are listed in Table 6 together with the estimates from the 10% samples as also presented in Table 5.

TABLE 6: ESTIMATED INCOME PARAMETERS, INCOME ELASTICITIES AND PREDICTED SHARE OF CAR OWNERSHIP FROM THE SAMPLES OF THE POPULATION AND THE DIFFERENT TU RESPONSES.

	β_{inc}	Car ownership	Elasticity
Household-based			
10% population	0.58*** [0.57 ; 0.60]	64%	0.23*** [0.22 ; 0.23]
10% couples	0.55*** [0.52 ; 0.58]	87%	0.07*** [0.07 ; 0.07]
10% singles	0.64*** [0.62 ; 0.66]	33%	0.43*** [0.41 ; 0.44]
TU sample	0.60*** [0.53 ; 0.68]	66%	0.20*** [0.18 ; 0.23]
TU non-response	0.58*** [0.48 ; 0.68]	51%	0.28*** [0.23 ; 0.33]
TU response	0.43*** [0.29 ; 0.56]	78%	0.09*** [0.06 ; 0.12]
Individual-based			
10% population	0.63*** [0.61 ; 0.64]	74%	0.15*** [0.15 ; 0.16]
TU sample	0.59*** [0.53 ; 0.65]	75%	0.15*** [0.13 ; 0.16]
TU non-response	0.61*** [0.52 ; 0.70]	61%	0.23*** [0.20 ; 0.27]
TU response	0.41*** [0.30 ; 0.53]	84%	0.07*** [0.05 ; 0.08]

***, **, * indicates that estimates are significantly different from zero at the 0.01, 0.05, and 0.10 levels respectively

Table 6 summarises the different outcomes from the various samples of the population. Individual-based surveys predict higher level of car ownership due to the higher share of couples. This results in lower average income elasticities. From the TU samples, the differences between individual-based samples and household-based samples are not found as evident as from the 10% samples of the population. This suggests that the share of couples and singles might not be the only bias present in the TU response sample. But it might additionally be affected by the smaller samples, hence lower significance of the estimates.

The bias related to response and non-response is however also evident. The higher share of single families in the sample of TU non-response results in higher income elasticities. The higher share of couples in the TU response sample become dominant and offsets the average income elasticity to a significantly lower level. This relation is present both for the individual-based and the household-based sample. The importance of couples in the household-based sample of TU responses is illustrated in Figure 4. Compared with Figure 3, the higher level of car ownership in the TU response sample is obvious. The distribution of single-families is less symmetric with most observations around a probability of car ownership of 60-70% instead of 40-50% as found in the population. The share of couples with probabilities of car ownership above 90% is furthermore found even higher than observed from the population.

TABLE 7: CAR OWNERSHIP PARAMETER ESTIMATES AND 95% CONFIDENCE INTERVAL OF MODEL ESTIMATION BASED ON THE TU RESPONSE SAMPLES OF HOUSEHOLDS AND INDIVIDUALS. THE INCOME APPLIED IS THE GROSS INCOME FROM REGISTER DATA (AGE SCALED BY FACTOR 10).

	Household-based survey		Individual-based survey	
	Estimate	95% Confidence	Estimate	95% Confidence
Constant	-5.69***	[-6.82 ; -4.56]	-5.30***	[-6.15 ; -4.45]
Income	0.43***	[0.29 ; 0.56]	0.41***	[0.30 ; 0.53]
Single male	-1.41**	[-2.57 ; -0.26]	-1.57***	[-2.48 ; -0.66]
Single female	-1.76***	[-2.92 ; -0.60]	-1.93***	[-2.85 ; -1.01]
One child	0.57***	[0.35 ; 0.80]	0.66***	[0.47 ; 0.84]
Two or more children	0.86***	[0.64 ; 1.09]	0.97***	[0.79 ; 1.14]
Age (person A)	1.45***	[1.16 ; 1.74]	1.37***	[1.09 ; 1.63]
Age (person B)	-0.08	[-0.57 ; 0.40]	-0.18	[-0.56 ; 0.20]
Age squared (person A)	-0.12***	[-0.15 ; -0.10]	-0.12***	[-0.14 ; -0.09]
Age squared (person B)	0.01	[-0.03 ; 0.06]	0.02	[-0.01 ; 0.06]
Greater Copenhagen	0.68***	[0.42 ; 0.93]	0.74***	[0.53 ; 0.95]
Outer Copenhagen	1.23***	[0.97 ; 1.49]	1.34***	[1.12 ; 1.56]
South Zealand	1.43***	[1.18 ; 1.68]	1.41***	[1.19 ; 1.62]
Funen and Bornholm	1.42***	[1.16 ; 1.68]	1.51***	[1.28 ; 1.73]
South Jutland	1.60***	[1.32 ; 1.88]	1.64***	[1.39 ; 1.88]
West Jutland	1.46***	[1.18 ; 1.73]	1.55***	[1.31 ; 1.79]
East Jutland (incl. Århus)	1.21***	[0.99 ; 1.42]	1.26***	[1.08 ; 1.44]
North Jutland	1.44***	[1.17 ; 1.71]	1.49***	[1.26 ; 1.72]
Number of observations	*7,343*		*11,578*	
Share of car ownership	72%		78%	
Log Likelihood	-3,156		-4,499	

***, **, * indicates that estimates are significantly different from zero at the 0.01, 0.05, and 0.10 levels respectively

The difference between Figure 1 and Figure 4 illustrates the considerable differences also found in income elasticities. The magnitude of the singles with lower probabilities of car ownership is significantly reduced and the construction of a household-based sample does not improve this bias considerably.

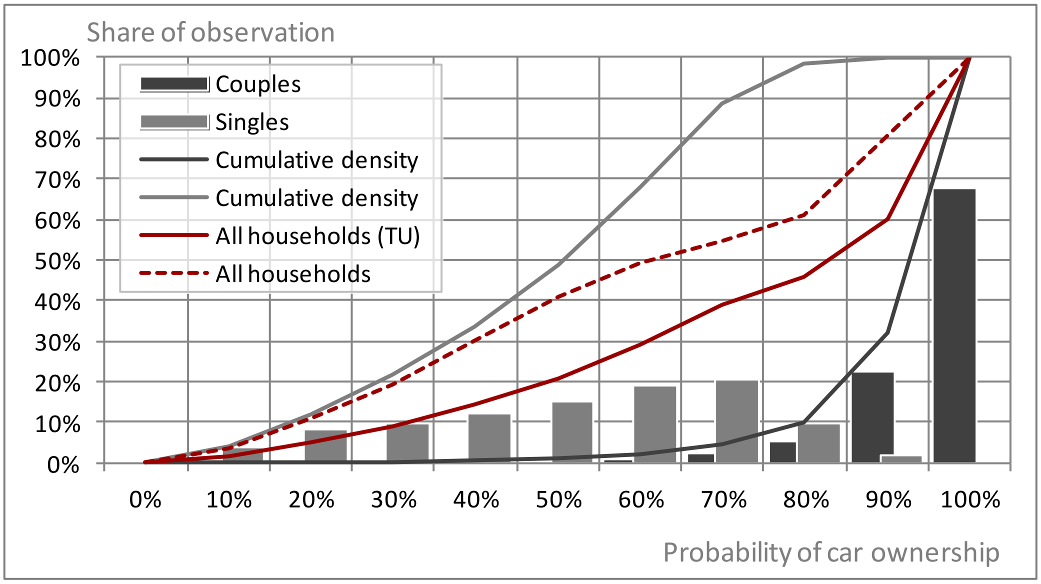

FIGURE 4: HISTOGRAM AND CUMULATIVE DENSITY FUNCTION OF THE PREDICTED PROBABILITY OF CAR OWNERSHIP FOUND IN THE TU RESPONSE SAMPLE OF HOUSEHOLDS. THE SUMMARY IS ADDITIONALLY MADE FOR COUPLES AND SINGLE-FAMILY HOUSEHOLDS.

4.2.1 SAMPLE SELECTION AND WEIGHTING PROCEDURES

Two different subsamples of households are constructed to account for the response bias and ensure an overall share of 49% couples as also found in the population. First of all 33% of the couples are selected instead of 50% applied when correcting for the individual-based sample. Secondly the 33% selected couples are further restricted relative to the car ownership found in the population. The second selection criterion is logically insufficient for modelling car ownership but it might shed a light on the bias present in the sample. Both samples are furthermore stratified relative to age groups, gender, geography, and income groups to ensure similarities with the original sample. Table 8 reports the relation between income and car ownership. The first selection only has minor impact on the estimates whereas the latter decreases the parameter estimate and increases the income elasticity to 0.15. This elasticity is however still somewhat lower than the income elasticities found in the population and in the original sample of TU respondents. It appears that other response biases are present in the sample.

This selection procedure however suggests that it might be possible to reduce the sample bias by a targeted selection procedure. This requires more detailed analyses of the sample bias besides just couples and single-families. The approach furthermore reduces the sample size considerably, which might become crucial for estimation. Another approach could be weighted model estimates (Ben-Aakiva & Lerman, 1985).

TABLE 8: ESTIMATED INCOME PARAMETERS, INCOME ELASTICITIES AND PREDICTED SHARE OF CAR OWNERSHIP FROM THE HOUSEHOLD-BASED TU RESPONSE SAMPLE APPLIED TWO DIFFERENT SELECTION CRITERIA AND TWO DIFFERENT WEIGHTING CRITERIA.

	β_{inc}	Car ownership	Elasticity
Household-based sample (reference estimates)			
TU Response	0.43*** [0.29 ; 0.56]	78%	0.09*** [0.06 ; 0.12]
Selection procedure			
#1 (family structure)	0.43*** [0.29 ; 0.56]	74%	0.11*** [0.08 ; 0.15]
#2 (#1 and car ownership)	0.40*** [0.26 ; 0.54]	64%	0.15*** [0.10 ; 0.20]
Weighting procedure			
#1 (family and income)	0.38*** [0.20 ; 0.56]	70%	0.11*** [0.06 ; 0.17]
#2 (#1 and age and geography)	0.48*** [0.32 ; 0.64]	69%	0.15*** [0.10 ; 0.20]

***, **, * indicates that estimates are significantly different from zero at the 0.01, 0.05, and 0.10 levels respectively

Two sets of person weights are estimated, the first is weighted relative to four income groups and family structure in terms of single-families and couples. The other is additionally weighted relative to age groups and geography. The weighting procedure finds similar improvements in income elasticities, but slightly different predicted shares of car ownership.

The tests generally illustrate that it appears possible to adapt data to reduce the impacts of response biases. However the tests also show that considering the share of couples and singles are not the only source of sample bias. Further research on the characteristics of the non-respondents could help improving the selection criteria or weighting criteria relative to other possible biases.

4.2.2 APPLYING BIASED PARAMETER ESTIMATES

Some degree of sample and response bias in surveys is difficult to avoid. In the following, the impacts of applying biased parameters are presented. The parameter estimates based on the samples of TU responses are applied the 10% sample of the Danish households to estimate the share of car ownership when applying biased parameters for predictions. The predicted level of car ownership and the simulated elasticities are listed in Table 9.

The original share of car ownership found from the 10% sample of Danish households was 60% and the predicted shares when estimating the model was 64%. When applying the biased parameters estimated from TU, the predicted shares are 65%. Even though the parameter estimates are proven considerably biased regarding especially family structure, this bias is considerably reduced when applying the estimates for predictions. The simulated income elasticity is still biased due to the biased income parameter and correspond very much to what was found from the TU response samples.

TABLE 9: SIMULATED SHARE OF CAR OWNERSHIP AND INCOME ELASTICITIES BASED ON THE ESTIMATED MODEL PARAMETERS FROM TU RESPONSE

	Elasticity (sample)	Car ownership (share)	Elasticity (simulated)
10% of Danish households	0.09 [0.06 ; 0.12]	65.4%	0.10
10% of Danes	0.07 [0.05 ; 0.08]	65.3%	0.10

***, **, * indicates that estimates are significantly different from zero at the 0.01, 0.05, and 0.10 levels respectively

4.3 UNCERTAINTIES IN STATED INCOME

The response bias present in TU affects the relation between household income and car ownership significantly. This relation is analysed by comparing stated gross income registered by the respondents in TU. The previous model estimation of the TU response samples is in this section repeated with stated gross income applied instead of the gross income available from register data.

TABLE 10: HOUSEHOLD INCOME ESTIMATED FROM GROSS INCOME FROM REGISTER DATA AND STATED GROSS INCOME REGISTERED IN TU

	All households		Single families		Couples	
	Average	Median	Average	Median	Average	Median
Gross income	528	503	260	238	623	594
Stated gross income	460	431	248	214	534	501
Difference	13%	14%	5%	10%	14%	16%

As expected there is considerable variance between stated gross income and gross income from register data. First of all most respondents register income in ten or hundred thousand and hence varies somewhat in accuracy, but it furthermore appears that the overall level of income is underestimated as outlined in Table 10. The difference suggests that the interpretation or knowledge about gross income varies considerably across the population and that the problems are highest regarding the income of the partner.

TABLE 11: CAR OWNERSHIP PARAMETER ESTIMATES AND 95% CONFIDENCE INTERVAL OF MODEL ESTIMATION BASED ON THE TU RESPONSE SAMPLE, BUT APPLIED STATED GROSS INCOME RATHER THAN GROSS INCOME FROM REGISTER DATA (AGE SCALED BY FACTOR 10).

	Household-based survey		Individual-based survey	
	Estimate	95% Confidence	Estimate	95% Confidence
Constant	-3.56***	[-4.63 ; -2.49]	-4.12***	[-4.91 ; -3.34]
Income	0.14**	[0.03 ; 0.25]	0.14***	[0.05 ; 0.24]
Single male	-2.47***	[-3.62 ; -1.32]	-1.73***	[-2.63 ; -0.82]
Single female	-2.81***	[-3.97 ; -1.65]	-2.08***	[-2.99 ; -1.17]
One child	0.64***	[0.42 ; 0.87]	0.70***	[0.52 ; 0.88]
Two or more children	0.86***	[0.65 ; 1.08]	1.02***	[0.84 ; 1.20]
Age (person A)	1.68***	[1.39 ; 1.96]	1.55***	[1.29 ; 1.82]
Age (person B)	-0.43**	[-0.91 ; -0.05]	-0.12	[-0.50 ; 0.25]
Age squared (person A)	-0.15***	[-0.17 ; -0.12]	-0.13***	[-0.16 ; -0.11]
Age squared (person B)	0.04**	[-0.003 ; 0.09]	0.01	[-0.02 ; 0.05]
Greater Copenhagen	0.71***	[0.46 ; 0.96]	0.74***	[0.53 ; 0.96]
Outer Copenhagen	1.29***	[1.03 ; 1.54]	1.35***	[1.13 ; 1.56]
South Zealand	1.33***	[1.09 ; 1.58]	1.39***	[1.17 ; 1.60]
Funen and Bornholm	1.28***	[1.02 ; 1.54]	1.47***	[1.25 ; 1.69]
South Jutland	1.54***	[1.26 ; 1.82]	1.60***	[1.36 ; 1.84]
West Jutland	1.39***	[1.12 ; 1.66]	1.52***	[1.29 ; 1.76]
East Jutland (incl. Århus)	1.13***	[0.91 ; 1.34]	1.24***	[1.05 ; 1.42]
North Jutland	1.37***	[1.10 ; 1.63]	1.47***	[1.24 ; 1.69]
Number of observations	7,313		*11,578*	
Share of car ownership	72%		78%	
Log Likelihood	-3,215		-4,521	

***, **, * indicates that estimates are significantly different from zero at the 0.01, 0.05, and 0.10 levels respectively

Another issue is uncertainties relative to family structure. First of all, the respondents in TU register personal income and household income, hence in some cases the respondents also register the income of children. In the majority of cases, this additional income is assumed of minor relative magnitude. Another insufficient relation is a difference in social status found from the two data sources. Persons registered as couples in register data figure as singles in TU and the other way around. The differences might be due to e.g. single parents with grown up children or two or more singles living in shared flats. Another explanation might be changes in family structure during the year. Most of register data represent the status at the first of January and TU registers the status of the day of the interview. Additionally there might also be some uncertainties regarding general response errors. The estimates are also tested when excluding these respondents with different family structure and the impact is negligible.

The parameter estimates when applying stated gross income are listed in Table 11. Compared with the previous estimates, the difference in the income parameter as well as the correction for single-family households is obvious. The impact of income is reduced considerable when applying gross income from register data. The estimates of β_{inc} are found significantly different from the estimates in Table 7 at the 5% level. When considering stated income by the respondent instead of gross income from register data, the effect of household income is generally underestimated (see Table 12).

Table 12: Estimated income parameters, income elasticities and predicted share of car ownership from the TU response samples with gross income from register data and stated gross income.

	β_{inc}	Car ownership	Elasticity
Household-based			
Gross income	0.43*** [0.29 ; 0.56]	78%	0.09*** [0.06 ; 0.12]
Stated gross income	0.14** [0.03 ; 0.25]	80%	0.03** [0.01 ; 0.05]
Individual-based			
Gross income	0.41*** [0.30 ; 0.53]	84%	0.07*** [0.05 ; 0.08]
Stated gross income	0.14*** [0.05 ; 0.24]	86%	0.02*** [0.01 ; 0.04]

***, **, * indicates that estimates are significantly different from zero at the 0.01, 0.05, and 0.10 levels respectively

5 Conclusions

A simple car ownership model was estimated using different samples in order to analyse the impact of response biases and measurement errors present in transport surveys. The estimated income elasticities illustrate differences between the use of individual-based surveys and household-based surveys. The difference suggests an overestimation of car ownership and an underestimation of income elasticities when applying an individual-based survey. The difference between the two survey types is however not found significant from the TU samples and the constructed household-based TU samples even though the estimates also suggest higher income elasticities for household-based surveys.

The impact of the response bias present in TU is obvious from the model estimates. The response bias results in income elasticities of half the size of those found in the original sample. From the constructed household-based TU sample including all respondents selected to participate, the income elasticity of car ownership is 0.20, and from the sample of responses it is only 0.09. When the stated income from TU is included, the income elasticity is additionally reduced to 0.03.

The significant overrepresentation of couples found in the TU responses is only slightly accommodated by the construction of a household-based survey. When adapting the selection procedure to furthermore take the response bias into account, it is possible to reduce the differences in income elasticities. This has revealed the significant impact of the different family types that are proven biased from the responses. It is however recognised that family types are most likely not the only source of response bias and that detailed analyses are required to accommodate response biases when applying TU. It is also likely that this bias is in particular critical when applying data for estimations of car ownership that differs considerably between single-families and couples. The response bias of TU might be less important for behavioural analyses as travel behaviour might not differ significantly between family types.

Finally the paper has analysed the impacts of applying the estimated model parameters based on a biased sample for predictions. It is found that the predicted share of car ownership is improved considerably, but that the impact of the response bias still underestimates the estimated income elasticity.

Even though the design of the applied car ownership model is simple and would gain from improvements by e.g. including the choice of a second car, the high variation in the estimated income elasticities and predicted shares of car ownership is still significant. The significant differences stress the relevance of considering response biases in model estimations and furthermore to apply stated incomes with caution. The low level of income elasticities found in the present study is certainly the result of the non-representative sample of couples and single-family households that significantly overestimates car ownership in the population.

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7 APPENDIX

APPENDIX A: MODEL ESTIMATES OF 10% SAMPLES OF COUPLES AND SINGLES

	Couples		Single-family households	
	Estimate	95% Confidence	Estimate	95% Confidence
Constant	-6.62***	[-6.82 ; -6.41]	-7.71***	[-7.84 ; -7.57]
Income	0.55***	[0.52 ; 0.58]	0.64***	[0.62 ; 0.66]
Single male	0.64***	[0.59 ; 0.69]	0.43***	[0.39 ; 0.48]
Single female	0.83***	[0.78 ; 0.87]	0.68***	[0.62 ; 0.73]
One child	0.43***	[0.78 ; 0.87]	1.16***	[1.12 ; 1.20]
Two or more children	0.85***	[0.72 ; 0.98]	-	
Age (person A)	-0.03***	[-0.05 ; -0.02]	-0.10***	[-0.11 ; -0.10]
Age (person B)	-0.07***	[-0.08 ;- 0.06]	-	
Age squared (person A)	0.93***	[0.87 ; 0.99]	0.66***	[0.61 ; 0.71]
Age squared (person B)	1.26***	[1.19 ; 1.32]	1.01***	[0.96 ; 1.06]
Greater Copenhagen	1.44***	[1.38 ; 1.51]	1.15***	[1.10 ; 1.20]
Outer Copenhagen	1.52***	[1.45 ; 1.59]	1.07***	[1.02 ; 1.12]
South Zealand	1.69***	[1.61 ; 1.76]	1.30***	[1.25 ; 1.36]
Funen and Bornholm	1.56***	[1.49 ; 1.63]	1.19***	[1.14 ; 1.24]
South Jutland	1.43***	[1.37 ; 1.48]	1.08***	[1.03 ; 1.12]
West Jutland	1.49***	[1.42 ; 1.56]	1.12***	[1.06 ; 1.17]
East Jutland (incl. Århus)	*130,596*		*134,162*	
North Jutland	84%		36%	
Number of observations	-49,982		-78,587	

***, **, * indicates that estimates are significantly different from zero at the 0.01, 0.05, and 0.10 levels respectively

APPENDIX B: CAR OWNERSHIP ESTIMATES OF TU SAMPLE (AGE SCALED BY FACTOR 10)

	TU sample (household)		TU sample (individual)	
	Estimate	95% Confidence	Estimate	95% Confidence
Constant	-6.43***	[-7.08 ; -5.77]	-6.40***	[-6.89 ; -5.91]
Income	0.60***	[0.53 ; 0.68]	0.59***	[0.53 ; 0.65]
Single male	-0.96***	[-1.62 ; -0.29]	-0.88***	[-1.40 ; -0.36]
Single female	-1.27***	[-1.93 ; -0.60]	-1.17***	[-1.69 ; -0.65]
One child	0.56***	[0.43 ; 0.70]	0.53***	[0.41 ; 0.64]
Two or more children	0.90***	[0.77 ; 1.04]	0.83***	[0.72 ; 0.94]
Age (person A)	1.11***	[0.94 ; 1.27]	1.07***	[0.92 ; 1.22]
Age (person B)	0.04	[-0.23 ; 0.32]	0.08	[-0.13 ; 0.30]
Age squared (person A)	-0.10***	[-0.11 ; -0.08]	-0.09***	[-0.11 ; -0.08]
Age squared (person B)	0.004	[-0.02 ; 0.03]	0.0001	[-0.02 ; 0.02]
Greater Copenhagen	0.62***	[0.47 ; 0.78]	0.68***	[0.55 ; 0.81]
Outer Copenhagen	1.14***	[0.98 ; 1.29]	1.18***	[1.05 ; 1.31]
South Zealand	1.29***	[1.13 ; 1.44]	1.32***	[1.18 ; 1.45]
Funen and Bornholm	1.25***	[1.09 ; 1.41]	1.32***	[1.19 ; 1.45]
South Jutland	1.38***	[1.22 ; 1.55]	1.44***	[1.30 ; 1.59]
West Jutland	1.29***	[1.13 ; 1.46]	1.38***	[1.24 ; 1.52]
East Jutland (incl. Århus)	1.09***	[0.96 ; 1.22]	1.16***	[1.05 ; 1.27]
North Jutland	1.22***	[1.06 ; 1.38]	1.30***	[1.16 ; 1.43]
Number of observations	17,617		26,612	
Share of car ownership	62%		70%	
Log Likelihood	-8,369		-11,843	

***, **, * indicates that estimates are significantly different from zero at the 0.01, 0.05, and 0.10 levels respectively

APPENDIX C: CAR OWNERSHIP ESTIMATES OF TU NON-RESPONSE WITH 95% CONFIDENCE INTERVAL (AGE SCALED BY FACTOR 10)

	TU non-response (household)		TU non-response (individual)	
	Estimate	95% Confidence	Estimate	95% Confidence
Constant	-5.92***	[-6.82 ; -5.02]	-6.21***	[-6.89 ; -5.53]
Income	0.58***	[0.48 ; 0.68]	0.61***	[0.52 ; 0.70]
Single male	-0.63	[-1.53 ; 0.27]	-0.51	[-1.22 ; 0.20]
Single female	-0.96*	[-1.86 ; -0.06]	-0.82**	[-1.54 ; -0.11]
One child	0.47***	[0.28 ; 0.66]	0.44***	[0.28 ; 0.59]
Two or more children	0.94***	[0.74 ; 1.13]	0.85***	[0.70 ; 1.00]
Age (person A)	0.83***	[0.61 ; 1.05]	0.80***	[0.59 ; 1.01]
Age (person B)	0.13	[-0.25 ; 0.51]	0.21	[-0.09 ; 0.50]
Age squared (person A)	-0.07***	[-0.10 ; -0.05]	-0.07***	[-0.09 ; -0.05]
Age squared (person B)	0.001	[-0.04 ; 0.04]	-0.01	[-0.04 ; 0.02]
Greater Copenhagen	0.52***	[0.31 ; 0.72]	0.61***	[0.44 ; 0.78]
Outer Copenhagen	0.92***	[0.71 ; 1.13]	1.01***	[0.82 ; 1.19]
South Zealand	1.03***	[0.82 ; 1.25]	1.11***	[0.93 ; 1.30]
Funen and Bornholm	1.06***	[0.84 ; 1.28]	1.11***	[0.92 ; 1.45]
South Jutland	1.14***	[0.91 ; 1.38]	1.25***	[1.04 ; 1.40]
West Jutland	1.07***	[0.84 ; 1.28]	1.20***	[1.00 ; 1.07]
East Jutland (incl. Århus)	0.83***	[0.64 ; 1.02]	0.91***	[0.75 ; 1.29]
North Jutland	0.96***	[0.73 ; 1.18]	1.09***	[0.90 ; 1.29]
Number of observations	*7,920*		*11,235*	
Share of car ownership	50%		59%	
Log Likelihood	-4,094		-5,606	

***, **, * indicates that estimates are significantly different from zero at the 0.01, 0.05, and 0.10 levels respectively

PAPER #2

ANALYSING THE SPATIAL DISTRIBUTION OF LEISURE AND HOLIDAY TRAVEL

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ANALYSING THE SPATIAL DISTRIBUTION OF LEISURE AND HOLIDAY TRAVEL

- AN ASSESSMENT OF DANISH TRAVEL BEHAVIOUR

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ABSTRACT

Leisure travel activities contribute significantly to the total mileage of individuals, and international holiday travels in particular have experienced considerably growth during the latest decades. Long distance travel activities only represent a minor share of the total number of trips that persons carry out, but long distance travel nevertheless contributes significantly to the total mileage travelled and hence also to energy consumption and greenhouse emissions. There is however not much quantitative knowledge on the driving forces behind the development of the spatial distribution of long distance travelling. This paper thus investigates the drivers of the development in leisure and holiday travel based on three different Danish travel surveys. A Heckman selection model was estimated for leisure travel describing travel distances conditional on the probability of travelling or not. The model revealed that income had a large impact on the travel patterns, where elasticities were highest for the less frequent leisure activities, which are on average also the longest, and often includes one or more overnight stays. This means that income growth will result in a significant change in the spatial distribution of long distance travel, as well as a shift towards travel with overnight stays, rather than a uniform growth of leisure travel as such. Besides a significant impact from income, the results also revealed dependencies on other socio-economic variables, as well as where in Denmark the household was located.

Keywords: Leisure travel; holiday travels; long distance travel; income elasticity; travel survey methodologies.

1 INTRODUCTION

The general trend within the transport sector over the last decades has been an increase in travel mileage fostered by improved supply and increased demand. New and improved technology has resulted in increased travel speed and decreasing travel costs (Ausubel and Marchetti, 2001; Banister, 2011; Knowles, 2006). Higher income levels have furthermore increased travel demand. This has led to an increase in car ownership which again has led to increasing speed and thereby travel distances (Schlich et al., 2004). Despite this, it has recently been observed that the daily domestic travel seems to have peaked in many industrialised countries (Metz, 2010; Millard-Ball and Schipper, 2011).

This stagnation in domestic travel has, for some countries, been offset by an increase in international travels (Frändberg and Vilhelmson, 2011; Schroten et al., 2011). International travelling has become more frequent and embedded as an expected part of the yearly travel behaviour of individuals (Bauman, 2000; Böhler et al., 2006; Frändberg, 2006). This adds a substantial dimension to the overall activity space of relevance when considering travel behaviour. From developed countries in particular, it is possible to reach destinations further away with the same or only slightly higher travel times and travel expenses. This has added some complexities in predicting travel distances, as the overall choice set of destinations more or less covers the whole world.

Previously, a 100 kilometer distance threshold has often been applied to define long distance travel and to isolate infrequent travel activities (Brög et al., 2003; Frei and Axhausen, 2009; Kuhnimhof and Last, 2009; Youssefzadeh and Axhausen, 2003). But from Ohnmact et al. (2009), Schlich et al. (2004), and the analysis of Danish travel behaviour in Knudsen (2014a), leisure travel is found of high importance both as a significant part of peoples' everyday life, but in particular as a travel type segment that contributes considerably to the total level of travelled kilometres. Leisure travel is also discussed as an important driver of the negative externalities from transportation (Ballingall et al., 2003; Schroten et al., 2011). In the present paper, we thus analyse leisure travel in general instead of focusing on a specific distance threshold.

Based on the significant growth in travel distances observed during the years of economic growth in several industrialised countries (Millard-Ball and Schipper, 2011), travel distances are generally expected to be positively correlated with income. This relationship is however relative complex, since it also depends on the purpose of the trip and transport mode. Several studies of travel distances are based on a joint decision process of car ownership and car use (De Jong, 1990; Golob and Van Wissen, 1989; Johansson-Stenman, 2002). But most studies do not distinguish between travel purposes and mainly focus on weekday travel activities. Long distance travel and leisure travel are rarely considered isolatedly. An exception is the study of long distance travel by Dargay and Clark (2012) that outlined increasing income elasticity when travel distances increase and also analysed differences related to travel purposes and transport mode.

The purpose of this paper is to get a better understanding of the drivers behind the growth and spatial distribution of leisure travel activities, including the impact of income as well as other spatial and socio-economic variables. This will provide a better basis for forecasting the growth in transport, and how migration of the population will affect leisure travelling.

Section 2 of the paper describes the three travel surveys applied in this study, section 3 outlines the model specification and identification, and section 4 presents the results from the estimations. Finally, section 5 summarises and discusses the overall findings of the study.

2 DATA

The study is based on three Danish Travel Surveys: i) the Danish National Travel Survey (TU) which is a daily mobility survey that registers all travel activities during an average day, ii) the TU overnight survey which registers the main activity of the day during a maximum of 14 consecutive days, and iii) the Danish Holiday and Business Survey (HBS) that registers all travel activities with overnight stays during the latest three months. The two TU surveys are managed by DTU Transport and the HBS is managed by Statistics Denmark.

The survey sample from TU represents 2009, whereas the TU overnight survey and the HBS cover 2010. The sample sizes are 11,576, 7,781, and 5,727, respectively. Due to the longer survey period in the TU overnight survey and the HBS, these surveys include a larger sample of infrequent travel activities, i.e. TU includes 410 respondents with holiday activities or 4% of the respondents compared with 1,361 in the TU overnight survey and 1,816 in the HBS or 17% or 32% of the respondents, respectively.

The definition of leisure travel is the same in all surveys and includes the categories: visiting friends and relatives ("Visits" in the following), doing sport, going for a walk, run or drive, entertainment, holiday, excursions, vacation homes, and other leisure activities (Christiansen and Skougaard, 2013). Other private travel purposes such as shopping and bringing or picking up things or persons are categorised as errands and are not considered in this study as they are mainly short distance travels and do not include an overnight stay (Knudsen, 2014a).

The travel surveys vary somewhat in definition and purposes: TU only registers domestic travel activities with complete travel details[1], whereas the TU overnight survey and the HBS register both domestic and international travel activities. Only respondents between 18 and 84 are included in the analysis.

2.1 The TU surveys

The definition of travel purposes and transport modes are relatively comparable in the two TU surveys, but the surveys register travel activities at rather different aggregation levels and serve different purposes:

In TU, every single travel activity is registered chronologically during 24 hours. From TU it is possible to analyse leisure travel as a common travel purpose that represents a significant part in people's daily life and a broad sample of different leisure activities. But it is also possible to analyse subsamples of less frequently completed leisure purposes, such as e.g. holiday travelling or entertainment. These are however described from small samples.

The TU overnight survey also registers daily travel behaviour, but only the main activity of the day. The majority of leisure activities registered is consequently less frequently completed activities that might be less sufficiently described in the smaller samples in the ordinary TU. The respondents should ideally register the main activity of the day, the total travelled kilometres, and the location of the overnight stay during 14 consecutive days. The travel distances registered are the stated total travel distance during the day no matter the number of activities actually completed. The travel distances are consequently difficult to validate and also represent other travel purposes when several activities are completed

[1] International destinations are registered in TU, but travel distances and travel times are only registered until the Danish borders.

during the day. The location of the overnight stay is the home address in the majority of the interviews as the survey describes many average week-day activities. But due to the consecutive survey design, the survey also describes more activities of longer durations. The survey is affected by response fatigue and survey changes why the most comprehensive sample of respondents and travel activities is found when only including the first week of the travel survey.

2.2 The Holiday and Business Survey

The HBS differs more from the two TU surveys in the survey approach as well as in travel details. The survey contains some apparent uncertainties as it i) registers travel destinations at a highly aggregated level, and ii) only registers the destination of the three latest activities of visits and holiday travels, respectively. These travel activities were scaled to fit the stated totals by estimated journey weights (Knudsen, 2014a). These weights influence visits the most, whereas holiday activities are assumed to be described sufficiently in the survey. The survey is furthermore assumed to be affected by memory loss as is generally the case for retrospective travel surveys (Denstadli and Lian, 1998; Frändberg, 2006; Schlich et al., 2004).

Visits are defined as visiting friends and relatives and travel to own or borrowed vacation homes. Rented vacation homes are registered as holiday travels. The travel destinations are registered at a fairly aggregated level, and the travel distances are estimated as crow fly distances. International destinations are registered at country level and domestic destinations are registered inside one of the five Danish regions. The estimated travel distances are consequently measured with error. The survey is however included in this study as it holds larger samples of holiday travels than available in the two TU surveys.

2.3 Data processing

All three travel surveys were merged with annual register data from Statistics Denmark that provides detailed background information on the respondents. Income is only registered in TU. The incomes registered in TU is found biased from measurement errors as respondents have difficulties in recalling income in a comprehensive way and as a significant share of the respondents do not register their income (Knudsen, 2014b; Madsen and Mulalic, 2012). Register data furthermore ensures uniform specification of income in all three surveys, and furthermore ensures homogenously defined household characteristics applied in the model specification.

The travel activities are summarised for each respondent as a total budget of leisure activities during the respective survey periods, i.e. during a day in TU, one week in the TU overnight survey, and three months in the HBS. This is to ensure a representative sample of the population and not oversampling the high frequent travellers that are likely also to have higher incomes. This means that each single travel activity is not analysed separately, which is however accommodated by analysing subsamples of leisure activities as e.g. holiday travels or travels with overnight stay.

TABLE 1: AVERAGE TRAVEL LENGTH PER DAY, HOUSEHOLD INCOME, AND OBSERVATIONS IN THE THREE SURVEYS WHEN SAMPLING LEISURE TRAVEL.

	TU (2009)	TU overnight (2010)	HBS (2010)
All leisure activities			
Avg. leisure travel length per traveller (kilometres)	30.3	30.7	29.0
Avg. income (1000 DKK[2)] p.a. in 2000 prices)	516.8	649.5	592.8
Number of respondents	5,113	5,378	3,317
Holiday travels and travelling to vacation homes[1)]			
Avg. leisure travel length per traveller (kilometres)	40.7	72.7	39.0
Avg. household income (1000 DKK[2)] p.a. in 2000 prices)	557.9	568.3	632.9
Number of respondents	410	1,361	1,816
Visits			
Avg. leisure travel length per traveller (kilometres)	34.5	13.4	10.8
Avg. household income (1000 DKK[2)] p.a. in 2000 prices)	484.7	498.7	595.4
Number of respondents	2,234	2,565	2,360
All respondents			
Avg. leisure travel length per respondent (kilometres)	8.4	21.2	28.0
Avg. household income (1000 DKK[2)] p.a. in 2000 prices)	528.4	537.7	524.8
Number of respondents	11,576	7,781	5,727

1) In the HBS, vacation homes are mainly registered together with visits
2) €1=7.45 DKK in 2010

Table 1 illustrates how the three surveys describe leisure travel in different ways, however with some similarities between the surveys. The differences are counterbalanced in the estimated average travel length per traveller per day which is between 29 and 31 kilometres. On the contrary, the average travel length per respondent illustrates the considerable differences in the travel surveys due to the excluded international leisure activities in TU and the longer survey period of the HBS. The differences in survey periods also influence the share of travellers with leisure activities. 44% of the population has a leisure activity during a day, whereas the share is 69% during a week and 58% during three months due to longer survey horizons. The share of travellers in the HBS is lower than in the TU overnight survey as it only includes travel activities with overnight stay(s).

The table furthermore reports the average annual household gross income in 1000 DKK[2] as it is registered in register data. The differences in income are first of all related to the difference between 2009 and 2010, but are also influenced by non-response biases from non-uniformly distributed responses of the population (Knudsen 2014b; Christensen, 2004; Verhoeven et al., 2008; Groves et al., 2013). From all three surveys it appears that the respondents that register holiday travel have higher average incomes than found in the total sample of respondents, whereas the income of the respondents registering visits is lower.

3 Model Specification and estimation

This section describes the models that were estimated in order to explain the causal relationships between the explanatory variables and leisure travel distances. The total leisure travel distance per person per day, week, or quarter was estimated from a log-log specified regression. Linear and loglinear approaches were also tested, but the log-log relation improved the model fit and was considered plausible as the marginal effect of distances most likely diminishes as distances increases as also tested in Mulalic et al. (2013). Heckman's two-step sample selection model (Heckman, 1979) in (1)-(3) was applied to estimate leisure travel distances conditional on travelling or not. The leisure travel distance d_i^* (kilometres per person per day, week, or quarter) was estimated from (1), where the model specification corrects for self-selection by including the probability of travelling or not in the selection equation Q_i^* specified in (2) with the selection criteria in (3). The correction for self-selection is important since selection of travelling is inevitable (Guo and Fraser, 2010) i.e. that travel distances are dependent on the endogenous dummy variable of travelling or not. For comparison, leisure travel distance as described in (1) was also estimated separately with an Ordinary Least Squares Regression (OLS).

The leisure travel distance d_i^* was modelled relative to household income ($I_{House,i}$) and a sum of household specific control variables $X_{i,k}$ having ε_1 as a normal distributed error term as specified in (1). The leisure distance is offset by 1 as the magnitude of short travel

[2] €1=7.45 DKK in 2010 (www.statistikbanken.dk, accessed the 10th of January 2014)

distances otherwise is attributed a high relative magnitude which may be inaccurate. The log-log specification describes a constant relation between changes in income and changes in travel distances, and the income elasticity corresponds to the estimated model parameter β_{inc}. The structural equation, Q_i^* specified in (2) is a binary Probit model that includes almost the same household characteristics $\gamma_k X_{i,k}$ as in (1) and additionally the instrumental variables that predicts selection, $\tau_j W_{i,j}$. The model instruments ensure that the latent endogenous variable Q_i^* and ε_1 is not correlated and avoids biased and inconsistent parameter estimates (Guo and Fraser, 2010). The two error-terms, ε_1 and ε_2, are assumed to be bivariate normal with mean zero and non-zero correlation (Guo and Fraser, 2010). The model specifications applied in the three travel surveys are similar.

$$\ln(d_i^* + 1) = \alpha_1 + \beta_{inc} \ln\left(I_{House,i}\right) + \sum_k \beta_k X_{i,k} + \varepsilon_1 \quad \textbf{(1)}$$

$$Q_i^* = \alpha_2 + \gamma_{inc} \ln\left(I_{House,i}\right) + \sum_k \gamma_k X_{i,k} + \sum_j \tau_j W_{i,j} + \varepsilon_2 \quad \textbf{(2)}$$

Where:

$$Q_i = \begin{cases} 0 & if\ d_i^* = 0 \\ Q_i^* & if\ d_i^* > 0 \end{cases} \quad \textbf{(3)}$$

The model specification included the household-related variables age and age squared for the respondent and the partner[3]. The model specification is further corrected relative to household structure with control variables for single males or single females relative to couples, and for having one child or more than one child relative to not having children.

The base model specification of travel distance was further corrected for geography by applying eight control variables for regions relative to the Capital (the municipalities of Copenhagen and Frederiksberg). Finally the model specification was corrected for yearly variations, which in this case are the 11 calendar months relative to January. In TU, the correction parameter is the actual travel month, whereas the interview month is applied for the TU overnight survey and the HBS as their survey periods might extend across several

[3] Age is scaled down by a factor 10 to increase the relative magnitude of the model parameters and squared to include the non-linearity in the relation between age and transportation

months. The interpretation of the estimated parameters consequently varies between the different surveys. The model specification of travel distance in the TU overnight survey and the HBS was furthermore corrected for travelling with overnight stay, which is expected to be positively correlated with travel distances.

The applied model instruments are all proxies of time available for travelling which is assumed to influence the choice of travelling rather than the travel distance. The choice of model instrument is justified by the fact that time availability in this case refers to time available after completing daily obligations and not minutes or hours available to increase the travel length as discussed in Metz (2008). This is considered a reasonable assumption regarding daily travel behaviour as busy people on average week-days have less time available to carry out leisure activities. When, however, considering the less frequent leisure activities the model instrument might be questionable as the majority of infrequent activities were completed on non-average days where travel behaviour was not as restricted from other obligations and the busy people are likely to have more disposal income for travelling and travel longer. It can consequently not be completely rejected that having time available due to holidays or weekends influences travel distances, but in this case it is presumed that time available increases the probability of having a leisure activity and the actual travel distance is derived from other determinants.

In the present model specifications, the model instruments applied the three travel surveys corrected for whether or not the respondent had a full time job. The model instruments applied the TU surveys furthermore corrected for whether or not the survey period includes a non-average day or week which are expected to increase the probability of having a less frequent leisure activity. Finally TU was also corrected for the number of other activities completed during the day, which is expected to reduce the probability of having a leisure activity or not. For the same reason the model instruments included in the model specification of holiday travel in the HBS was corrected for the number of visits completed during the same survey period.

4 RESULTS

The Ordinary Least Square regression (OLS) and the Heckman relation were estimated on the two samples of leisure travel activities registered in the two TU surveys. The income elasticities estimated from the two surveys are listed in Table 2 together with the income elasticities from the samples of visits and holiday activities. The complete list of the OLS parameter estimates is included in Appendix A and the parameter estimates from the Heckman procedure are listed in Table 6 and Table 7 in Appendix B. The parameters from the Heckman estimations are in the appendices separated into one table describing leisure travel distances based on the relation specified in (1) and another table describing the probability of having a leisure activity or not as specified in (2). The parameter estimates of the Heckman estimates of the subsamples of visits and holiday travels are listed in Appendix C and Appendix D, respectively.

Even though TU registers more leisure activities and more common weekday travelling, the estimated relation between income and leisure travel distances is similar between the two surveys when applying the Heckman procedure. The income elasticity of leisure travel distance was estimated at 0.23 and 0.25, which corresponds to an expected growth of 0.23% and 0.25% if income increases by 1%. The OLS estimates however differed more with an income elasticity of only 0.14 based on TU and 0.29 based on the TU overnight survey.

Table 2: Income elasticities estimated from TU and the TU overnight survey with Ordinary Least Square estimates and the Heckman procedure, with travel distances estimated from (1) and the choice of travelling or not estimated from (2)

		TU		TU overnight	
Model	Travel activities	Elasticity	95% CI	Elasticity	95% CI
OLS	All leisure activities	0.14***	[0.07 ; 0.21]	0.29***	[0.18 ; 0.40]
Heckman (1)	All leisure activities	0.23***	[0.11 ; 0.36]	0.25***	[0.15 ; 0.36]
	Visits	0.30***	[0.16 ; 0.45]	0.31***	[0.19 ; 0.43]
	Holiday travels	0.25	[-0.09 ; 0.58]	0.12	[-0.29 ; 0.53]
Heckman (2)	All leisure activities	0.07***	[0.02 ; 0.13]	0.08***	[0.05 ; 0.12]
	Visits	-0.03	[-0.13 ; 0.07]	0.04	[-0.04 ; 0.12]
	Holiday travels	0.49***	[0.20 ; 0.78]	0.43***	[0.30 ; 0.55]

***, **, * indicates that estimates are significantly different from zero at the 0.01, 0.05, and 0.10 levels, respectively

It is plausible that this difference between the OLS estimates is related to the difference in the survey horizons. The probability of having a leisure activity is 44% in TU compared with 69% in the TU overnight survey due to the one week survey period in the TU overnight survey. To be able to compare the two surveys it is proven important to adjust for the considerable difference in the probability of having a leisure activity during a day compared with the probability of having a leisure activity during a week. It is consequently necessary to account for sample selection as the sensitivity in the TU travel distances would otherwise be underestimated.

The income elasticity of the samples of visits in Table 2 also found similarities between the two travel surveys with income elasticities of 0.30 and 0.31. The elasticities are similar despite the considerable difference found in average travel distances per day and week as listed in Table 1. These elasticities were a little higher than the income elasticity of leisure travel in general, but as the confidence intervals show they were not significantly different.

The relation between holiday travel distance and income was not found significant in any of the two TU surveys. This might be related to the sample sizes; in TU the sample only included 409 respondents with holiday activities, whereas the TU overnight survey included 1,361. Both surveys register excursions and holiday travels as the same travel purpose, which might have complicated the estimates. It is however also plausible that most people have some kind of holiday activity no matter income and that it is the characteristics of the holiday activities that are strongly correlated with income, not the actual travel distance. In relation to this, the missing travel costs in the survey might furthermore have been of significant importance.

Table 2 also includes the estimated elasticities of travelling or not from the Heckman estimation. The estimations illustrate a relatively inelastic relation between income and having a leisure activity when considering leisure as a common travel purpose. The parameter estimates are listed in Table 7 in Appendix B. Isolated, holiday travels were found somewhat more elastic with an income elasticity of 0.49 in TU and 0.43 in the TU overnight survey (see also the parameter estimates in Table 11 in Appendix D).

It has not been possible to estimate the choice of visiting friends and relatives in the two TU samples (The parameter estimates are listed in Table 9 in Appendix C). Both surveys found small and insignificant income elasticities. This illustrates the complexities inherent to visits as a common travel purpose, as visits represent the span from visiting the neighbours to visiting relatives in another part of the country for several days. These activities were undertaken by most respondents no matter income. Nevertheless, the Heckman estimates revealed that visit travel distances were dependent on income.

From the estimates of leisure travel in general, see Appendix B, especially the TU overnight survey found significant relation between travel distances and place of residence. Both surveys found that leisure travel distances generally increased outside the capital, which is correlated with higher car ownership (Knudsen, 2014b; Scheiner, 2010) and consistent with other studies (Giuliano and Dargay, 2006; Dargay and Clark, 2012). The impacts were highest for respondents living in the southern part of Zealand, which also correspond to the general trend of longer travel distances when going to the Copenhagen region.

The TU overnight survey additionally found a significant relation between travel distance and survey month which reflects the higher share of less frequent holiday-related activities during the summer months. The impacts on travel distances of age and family structure were generally not estimated to be significant. The relations were a little different for visits, where the TU overnight survey found positive correlation between single families and travel distances and negative impacts when having children (see Table 8 in Appendix C).

The parameters influencing the probability of travelling or not in Table 7 in Appendix B found higher probabilities of having leisure activities for single families and smaller probabilities for families with children. The geographic impacts were not found significant which is reasonable as most respondents have leisure activities no matter the place of residence. Regarding leisure in general, special week days increase the probability of travelling or not and having full time work reduces the probability. According to TU, the number of other activities during the day furthermore reduces the probability of having a leisure activity.

Similar relations were found for visits in Table 9 in Appendix C. If on the contrary considering the subsamples of holiday travels in Table 11 in Appendix D, most parameters describing the probability of travelling or not was found significant. Geography has the opposite impact on travelling or not than on travel distances; living outside the capital generally reduced the probability of having a holiday activity.

4.1 Infrequent travel activities

Due to troubles in estimating the income elasticity of holiday travels, the sample of leisure activities registered in the TU overnight survey was furthermore analysed into more details by selecting subsamples that represent long distance travel in different ways. The estimations were repeated for samples of travelling above or below 100 kilometres, having domestic or international destinations, or daily versus multiday travelling. The estimated income elasticities of travel distances as well as travelling or not are listed in Table 3[4].

TABLE 3: INCOME ELASTICITIES ESTIMATED FROM THE TU OVERNIGHT SURVEY ON VARIOUS SUB-SAMPLES OF LEISURE ACTIVITIES. THE TABLE FURTHERMORE INCLUDES THE ESTIMATES OF INCOME ELASTICITIES OF HOLIDAY TRAVEL BASED ON THE HBS.

	Elasticity of travel distance		Elasticity of travelling or not		Probability
	E	CI	E	CI	Share
All leisure activities	0.25***	[0.15 ; 0.36]	0.08***	[0.05 ; 0.12]	70%
Visits	0.31***	[0.19 ; 0.43]	0.04	[-0.04 ; 0.12]	33%
Holiday and vacation homes	0.12	[-0.29 ; 0.53]	0.43***	[0.30 ; 0.55]	16%
Daily travel	0.29***	[0.19 ; 0.40]	0.07***	[0.03 ; 0.11]	68%
Multiday travel	0.44*	[-0.02 ; 0.89]	0.41***	[0.25 ; 0.56]	11%
Short distance (<100 km)	0.16***	[0.08 ; 0.24]	0.04*	[-0.004 ; 0.09]	61%
Long distance (≥100 km)	0.004	[-0.21 ; 0.22]	0.40***	[0.29 ; 0.52]	20%
Domestic travel	0.21***	[0.12 ; 0.31]	0.08***	[0.04 ; 0.12]	69%
International travel	-4.10	[-54.64 ; 46.45]	0.74***	[0.43 ; 1.04]	3%
Holiday travel (HBS)	0.58***	[0.21 ; 0.95]	0.42***	[0.32 ; 0.52]	30%

***, **, * indicates that estimates are significantly different from zero at the 0.01, 0.05, and 0.10 levels, respectively

The income elasticity for leisure travel below 100 kilometres was lower than the average of 0.25, whereas the income elasticity of travelling above 100 kilometres was not found significantly different from zero based on the limited sample of long distance travel activities. Domestic travel also had lower income elasticity than the average, but it was not possible to estimate the income elasticity of international leisure activities alone. If, on the other hand, dividing the leisure activities into daily and multiday travel, the income elasticity of leisure distances could be estimated from both samples. The income elasticity of leisure travel distances for travels with an overnight stay was 0.44. The elasticity of leisure travel with overnight stays was however only estimated at the 10% level of significance and was not significantly different from the other estimates.

The estimations listed in Table 3 revealed higher income elasticities of the travel distances of the more infrequent leisure activities as also found in Dargay and Clark (2012). This relation was however mainly found by detecting a decreasing elasticity for the more frequently completed travel purposes than the other way around. Even though they were not found significantly different, the estimates from the TU overnight survey found income

[4] Subsamples of short and long distance travel were also selected from TU, but the relation between income and travel distance was not found significantly different from zero.

elasticities of 0.16 for short distance leisure travel, 0.31 for visits, and 0.44 for leisure activities with overnight stays.

This relation of increasing income elasticity as leisure activities become less frequently completed activities was furthermore supported by estimating the relation between leisure distance and income from the HBS. It was difficult to determine an appropriate model instrument when including both visits and holiday travels, but the model specification of holiday travel distances isolatedly was found reasonable. The income elasticity of holiday travel distances was estimated to be 0.58. The full list of parameter estimates is included in Table 12 in Appendix E. It was unfortunately not possible to estimate sufficient relations from sub-travel purposes of e.g. international holiday travels, plane travels, or when segmenting the holidays relative to duration.

In the HBS, geography actually showed the opposite trend that distances decreased outside the capital. This might suggest that people living in city centres are more likely to complete more and longer leisure activities with an overnight stay. This might be related to easier access to the airport, or reflect some considerable lifestyle differences that involve different travel behaviour.

The difficulties in analysing holiday distances into greater details might reflect the various less measurable determinants of tourism travels that are considered relevant (Ohnmacht et al., 2009; Oppermann, 1995; Um and Crompton, 1990), but not included in the present model specification. This could be e.g. travel motivation, travel traditions, or lifestyles. But it might on the other hand also suggest that holiday distances are not as such dependent on income. Another important factor is travel costs and travel expenses. The complex price structure of holiday travels is not necessarily linear with travel distances hence higher income does not always corresponds to longer travel distances. A holiday nearby might be more expensive than a holiday at a popular charter destination further away due to e.g. the differences in living costs and discounts from travel packages. Nor does an increase in income necessarily correspond to longer travel distances, but the holidays might be upgraded with more expensive accommodations or higher travel frequencies.

Table 3 also shows the estimated elasticities of the probability of having a leisure activity or not for the different subsamples of leisure activities. These estimates support the relations also suggested from the travel distances: The less frequent travel activities were more sensitive to income changes than the more weekday-related activities. Having a leisure activity during a week was relatively indifferent to income changes, with an elasticity of 0.08. Having daily leisure activities, short distance leisure activities, and domestic leisure activities also had low elasticities between 0.04 and 0.08. Holiday travels, travel with overnight stays, and long distance travel above 100 kilometres however had elasticities of 0.40-0.43, whereas international travelling had an income elasticity of 0.70. The income elasticities of multiday travel and long distance travel were both 0.4 and were both significantly higher than the income elasticities of daily and short distance travel. This stresses some evident similarities between the two types of segmentation into infrequent travelling that support the most commonly applied distance threshold, but also the segmentation relative to travel duration.

4.2 HAVING LEISURE ACTIVITIES WITH OVERNIGHT STAY

Due to the difficulties in estimating holiday travel distances in a comprehensive way, the HBS was analysed separately considering only the selection equation in (2), but analysing several different samples of travel segments with overnight stay. This adds some additional information on the most infrequent travel activities and how different travel type segments are expected to develop relative to income changes as listed in Table 4. Leisure travel with overnight stays had an income elasticity of 0.35 and travelling outside Europe had an income elasticity of 0.79. Table 4 furthermore includes income elasticities estimated from different subsamples of the visits and holiday activities that show differences in income elasticities relative to the more frequent and infrequent travel types.

International travelling was more sensitive to income changes than domestic travel activities. Air travelling was more sensitive than car travelling and significantly higher than travelling with other transport modes. The same relation was present when only considering international travel activities inside Europe with an income elasticity of European air travel being 0.72 compared with 0.53 for cars. The income elasticity of car travels was on the other hand found relatively robust no matter whether the destinations were domestic or European.

It appears from the elasticities listed in Table 4 that several of the travel types with the highest income elasticities are also the travel types that have experienced the most apparent growth during the latest decades as outlined in (Knudsen, 2014a). This is the case for European travels in general, travelling outside Europe as well as European short duration travels. Income elasticities from 0.72 to 0.80 might give cause for concern regarding the future emissions from travelling. This is in particular the case for European air travelling of 1-3 nights' duration which has an income elasticity of 1.38.

TABLE 4: THE PARAMETER ESTIMATES OF HAVING LEISURE ACTIVITIES OR NOT ESTIMATED FROM THE HOLIDAY AND BUSINESS (HBS) SURVEY

	Parameter β_{inc}	CI	Elasticity E	CI	Probability share
All leisure activities	0.53***	[0.45 ; 0.61]	0.35***	[0.30 ; 0.41]	59%
Visits and vacation homes	0.49***	[0.40 ; 0.57]	0.46***	[0.38 ; 0.54]	41%
Holiday travels	0.36***	[0.27 ; 0.44]	0.42***	[0.32 ; 0.52]	30%
Travel (Europe)	0.42***	[0.33 ; 0.50]	0.54***	[0.43 ; 0.66]	24%
Travel (Denmark)	0.42***	[0.34 ; 0.50]	0.39***	[0.31 ;0.46]	42%
Travel (outside Europe)	0.35***	[0.20 ; 0.49]	0.79***	[0.46 ; 1.12]	3%
Air travel	0.43***	[0.33 ; 0.53]	0.67***	[0.52 ;0.82]	15%
Car travel	0.50***	[0.41 ; 0.58]	0.47***	[0.39 ; 0.55]	41%
Other transport modes	0.13***	[0.03 ; 0.23]	0.21***	[0.05 ; 0.37]	13%
Air travel (Europe)	0.42***	[0.32 ; 0.53]	0.72***	[0.55 ; 0.90]	11%
Car travel (Europe)	0.28***	[0.17 ; 0.40]	0.53***	[0.31 ; 0.74]	8%
Other modes (Europe)	0.12*	[-0.02 ; 0.26]	0.27*	[-0.03 ; 0.57]	4%
Air travel (Denmark)	0.08	[-0.17 ; 0.34]	0.25	[-0.51 ; 1.01]	0.4%
Car travel (Denmark)	0.47***	[0.38 ; 0.55]	0.50***	[0.41 ; 0.59]	35%
Other modes (Denmark)	0.12**	[0.01 ; 0.22]	0.21**	[0.02 ; 0.39]	9%
Travel (Europe 1-3 nights)	0.41***	[0.29 ; 0.53]	0.80***	[0.56 ; 1.04]	6%
Travel (Europe 4-5 nights)	0.24***	[0.12 ; 0.37]	0.49***	[0.25 ; 0.74]	6%
Travel (Europe >5 nights)	0.34***	[0.24 ; 0.44]	0.56***	[0.40 ; 0.73]	13%
Travel (Denmark 1-3 nights)	0.40***	[0.32 ; 0.49]	0.43***	[0.34 ; 0.52]	34%
Travel (Denmark 4-5 nights)	0.26***	[0.14 ; 0.38]	0.50***	[0.27 ; 0.73]	7%
Travel (Denmark >5 nights)	0.12**	[0.003 ; 0.23]	0.23**	[0.01 ; 0.45]	7%
Air travel (Europe 1-3 nights)	0.56***	[0.39 ; 0.73]	1.38***	[0.96 ; 1.81]	2%
Air travel (Europe 4-5 nights)	0.31***	[0.16 ; 0.46]	0.74***	[0.38 ; 1.10]	2%
Air travel (Europe >5 nights)	0.33***	[0.21 ; 0.44]	0.61***	[0.40 ; 0.83]	8%
Car travel (Europe 1-3 nights)	0.28***	[0.13 ; 0.43]	0.64***	[0.30 ; 0.98]	3%
Car travel (Europe 4-5 nights)	0.26***	[0.08 ; 0.43]	0.62***	[0.19 ; 1.05]	2%
Car travel (Europe >5 nights)	0.29***	[0.15 ; 0.43]	0.63***	[0.32 ; 0.94]	4%

***, **, * indicates that estimates are significantly different from zero at the 0.01, 0.05, and 0.10 levels, respectively

5 SUMMARY AND CONCLUSIONS

This paper has investigated the drivers of the development of leisure and holiday travel based on three different Danish travel surveys. A Heckman model was estimated for leisure travel distances, whereby it was possible to estimate elasticities for how leisure distances depended on socio-economic variables, location of the household, and when the journey was carried out when also correcting for the probability of having a leisure activity or not. The study of the two TU surveys found increasing elasticities as the travel types became less frequently completed activities. This was furthermore supported by the estimates based on the Danish holiday survey (HBS).

The study of leisure distances outlined a range of income elasticities from 0.16 to 0.58 for different leisure travel segments. The lowest elasticities were found for leisure travel in general or for samples of short distance leisure activities. This is strongly related to the significance of leisure travel in peoples' everyday life, which is not as strongly related to income. The income elasticity of leisure travel distances was estimated to be 0.44 for travels with overnight stays and 0.58 for holiday travels.

The significant relation between income and multiday travel was supported by the selection equation of having leisure activities or not. The income elasticities varied more for different travel segments where the most common leisure activities or short distance leisure activities were found relatively indifferent to income changes with income elasticities between 0.04 and 0.08. Leisure activities with overnight stays or long distance leisure activities on the contrary had income elasticities above 0.4. The probability of having holiday activities significantly increased with income, and international travels were somewhat more sensitive to income changes than domestic travelling.

The study of travel demand based on the travel activities described in the HBS furthermore revealed travel segments of considerable interest regarding future travelling if the economic growth continues: Travelling outside Europe, air travelling inside Europe, and European travelling of 1-3 nights' duration had income elasticities above 0.7. Together with the general income elasticity of 0.58 for holiday travel distances, these travel segments are highly relevant in the discussion of emissions from transportation. Compared however with income elasticities close to, and above, unity found for purchasing plane tickets and travel packages (Knudsen 2014c), the income elasticities found in this study are somewhat lower. This is assumed related to not including travel costs in the present study. Travel costs are expected to increase the income elasticity due to a negative correlation between travel costs and travel demand.

The overall conclusion is thus that long distance travel will increase more than daily travel patters if income increases. Growth in incomes will increase the probability of long distance travel as well as the travel distances. This involves a tendency towards more journeys with overnight stays. This will change the spatial distribution of long distance travel and increase the share of transport mileage, as well as energy use and CO_2 emissions. This is also likely to result in a growth in tourism travel, the hotel industry, and spatial interaction. However, during economic crises, long distance travel is also the most volatile part of the transport sector.

Besides these main conclusions, it was shown that the population in some provincial parts of Denmark travelled longer for leisure purposes than in the Copenhagen Region. The study however also found that holiday travel distances were shorter outside Copenhagen, which is likely to be explained by the much better accessibility to air transport in Copenhagen. In relation to this, it was also found that the probability of having leisure activities was higher for people living in the city. This may be explained by the larger number of possible activities available in Copenhagen. In Denmark there is a strong tendency of migration to Copenhagen from the rest of Denmark, which according to our analyses will lead to reduced daily leisure travel distances, but on the contrary longer holiday travel distances and higher probability of leisure and holiday travels.

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APPENDIX A: OLS ESTIMATES OF LEISURE TRAVEL

TABLE 5: LOG-LOG OLS ESTIMATES OF LEISURE TRAVEL DISTANCES BASED ON TU AND THE TU OVERNIGHT SURVEY.

	TU – leisure travel		TU overnight – leisure travel	
	Estimate	95% CI	Estimate	95% CI
Intercept	0.39	[-0.12 ; 0.91]	0.80**	[0.08 ; 1.53]
Household income	0.14***	[0.07 ; 0.21]	0.29***	[0.18 ; 0.40]
Single male	0.31	[-0.24 ; 0.86]	0.37*	[-0.05 ; 0.79]
Single female	0.43	[-0.12 ; 0.98]	0.59***	[0.17 ; 1.01]
One child	-0.22***	[-0.32 ; -0.13]	-0.26***	[-0.41 ; -0.10]
Two or more children	-0.27***	[-0.36 ; 0.18]	-0.33***	[-0.47 ; -0.18]
Age (person A)	-0.16*	[-0.34 ; 0.02]	-0.30**	[-0.53 ; -0.07]
Age (person B)	0.04	[-0.18 ; 0.27]	0.07	[-0.05 ; 0.19]
Age squared (person A)	0.01	[-0.01 ; 0.02]	0.03**	[0.04 ; 0.05]
Age squared (person B)	0.003	[-0.02 ; 0.02]	0.005	[-0.01 ; 0.02]
Greater Copenhagen	0.002	[-0.14 ; 0.14]	0.11	[-0.11 ; 0.33]
Outer Copenhagen	0.01	[-0.12 ; 0.14]	0.07	[-0.14 ; 0.29]
South Zealand	0.02	[-0.11 ; 0.15]	0.16	[-0.06 ; 0.37]
Funen and Bornholm	0.16**	[0.02 ; 0.29]	0.19*	[-0.03 ; 0.41]
South Jutland	0.13*	[-0.005 ; 0.27]	0.18	[-0.05 ; 0.40]
West Jutland	0.15**	[-0.01 ; 0.28]	0.21*	[-0.02 ; 0.43]
East Jutland (incl. Århus)	0.06	[-0.06; 0.17]	0.13	[-0.06 ; 0.33]
North Jutland	0.15**	[0.01 ; 0.28]	0.18	[-0.04 ; 0.40]
February	0.08	[-0.10 ; 0.26]	0.23**	[0.01 ; 0.45]
March	0.18*	[-0.001 ; 0.35]	0.34***	[0.12 ; 0.56]
April	0.35***	[0.17 ; 0.52]	0.39***	[0.17 ; 0.61]
May	0.24***	[0.06 ; 0.42]	0.43***	[0.21 ; 0.65]
June	0.34***	[0.19 ; 0.50]	0.10	[-0.12 ; 0.32]
July	0.43***	[0.27 ; 0.58]	0.61***	[0.39 ; 0.83]
August	0.44***	[0.28 ; 0.59]	0.10	[-0.12 ; 0.33]
September	0.31***	[0.15 ; 0.46]	0.46***	[0.23 ; 0.69]
October	0.19**	[0.04 ; 0.35]	0.05	[-0.16 ; 0.27]
November	0.16**	[0.01 ; 0.32]	0.08	[-0.13 ; 0.28]
December	0.15*	[-0.01 ; 0.30]	-0.64***	[-0.86 ; -0.43]
Nights	-	-	2.78***	[2.63 ; 2.92]
Observation	11,576	(44% traveller)	7,781	(69% traveller)
R^2	0.014		0.19	

***, **, * indicates that estimates are significantly different from zero at the 0.01, 0.05, and 0.10 levels, respectively

Appendix B: Heckman estimates of leisure travel

Table 6: Parameter estimates of leisure travel distances from the log-log Heckman relation in (1) based on TU and the TU overnight survey.

Leisure travel distance	TU		TU overnight	
	Estimate	95% CI	Estimate	95% CI
Intercept	2.22***	[1.24 ; 3.19]	2.39***	[1.58 ; 3.19]
Household income	0.23***	[0.11 ; 0.36]	0.25***	[0.15 ; 0.36]
Single male	0.79	[-0.19 ; 1.77]	-0.34	[-0.48 ; 0.33]
Single female	0.47	[-0.52 ; 1.44]	-0.48	[-0.78 ; 0.00]
One child	0.02	[-0.16 ; 0.21]	-0.05	[-0.20 ; 0.10]
Two or more children	0.04	[-0.13 ; 0.21]	-0.11	[-0.26 ; 0.04]
Age (person A)	0.09	[-0.24 ; 0.41]	0.08	[-0.15 ; 0.30]
Age (person B)	0.32	[-0.08 ; 0.72]	-0.07	[-0.19 ; 0.04]
Age squared (person A)	-0.003	[-0.04 ; 0.03]	-0.01	[-0.03 ; 0.01]
Age squared (person B)	-0.03*	[-0.07 ; 0.004]	0.01	[-0.003 ; 0.02]
Greater Copenhagen	0.32**	[0.07 ; 0.57]	0.16	[-0.04 ; 0.36]
Outer Copenhagen	0.23*	[-0.01 ; 0.46]	0.27***	[0.07 ; 0.46]
South Zealand	0.43***	[0.19 ; 0.67]	0.53***	[0.33 ; 0.73]
Funen and Bornholm	0.28**	[0.03 ; 0.52]	0.34***	[0.14 ; 0.54]
South Jutland	0.03	[-0.22 ; 0.28]	0.40***	[0.19 ; 0.60]
West Jutland	0.20	[-0.05 ; 0.45]	0.33***	[0.12 ; 0.53]
East Jutland (incl. Århus)	0.21*	[-0.002; 0.42]	0.33***	[0.15 ; 0.50]
North Jutland	0.30**	[0.05 ; 0.54]	0.43***	[0.23 ; 0.63]
February	-0.01	[-0.35 ; 0.33]	0.11	[-0.09 ; 0.31]
March	-0.16	[-0.49 ; 0.17]	0.22**	[0.02 ; 0.42]
April	0.10	[-0.23 ; 0.43]	0.32***	[0.12 ; 0.52]
May	0.10	[-0.27 ; 0.39]	0.41***	[0.20 ; 0.61]
June	-0.01	[-0.30 ; 0.29]	0.53***	[0.32 ; 0.73]
July	-0.10	[-0.60 ; 0.19]	0.80***	[0.60 ; 1.00]
August	-0.22	[-0.51 ; 0.08]	0.45***	[0.24 ; 0.66]
September	-0.24	[-0.54 ; 0.05]	0.36***	[0.19 ; 0.57]
October	-0.06	[-0.35 ; 0.23]	0.62***	[0.42 ; 0.83]
November	0.05	[-0.24 ; 0.34]	0.39***	[0.20 ; 0.59]
December	0.10	[1.24 ; 3.19]	0.59***	[0.28 ; 0.89]
Overnight stays	-	-	1.45***	[1.35 ; 1.55]

***, **, * indicates that estimates are significantly different from zero at the 0.01, 0.05, and 0.10 levels, respectively

Table 7: Parameter estimates of the structural equation of the Heckman selection model in (2) describing the probability of having a leisure activity or not based on TU and the TU overnight survey

Having leisure travel or not	TU		TU overnight	
	Estimate	95% CI	Estimate	95% CI
Intercept	-0.26	[-0.68 ; 0.16]	-0.04	[-0.52 ; 0.44]
Household income	0.08***	[0.02 ; 0.14]	0.17***	[0.10 ; 0.24]
Single male	-0.01	[-0.45 ; 0.42]	0.34**	[0.07 ; 0.61]
Single female	0.15	[-0.29 ; 0.58]	0.61***	[0.34 ; 0.89]
One child	-0.13***	[-0.21 ; -0.05]	-0.14***	[-0.24 ; -0.04]
Two or more children	-0.15***	[-0.22 ; -0.08]	-0.17***	[-0.26 ; -0.08]
Age (person A)	-0.06	[-0.21 ; 0.08]	-0.21***	[-0.37 ; -0.06]
Age (person B)	-0.06	[-0.23 ; 0.12]	0.06	[-0.01 ; 0.14]
Age squared (person A)	-0.003	[-0.02 ; 0.01]	0.02	[0.003 ; 0.03]
Age squared (person B)	0.01	[-0.01 ; 0.03]	0.001	[-0.01 ; 0.01]
Greater Copenhagen	-0.07	[-0.18 ; 0.04]	-0.05	[-0.20 ; 0.09]
Outer Copenhagen	-0.04	[-0.15 ; 0.06]	-0.11	[-0.24 ; 0.03]
South Zealand	-0.09*	[-0.20 ; 0.01]	-0.17**	[-0.30 ; -0.03]
Funen and Bornholm	0.005	[-0.10 ; 0.11]	-0.06	[-0.21 ; 0.08]
South Jutland	0.07	[-0.05 ; 0.18]	-0.09	[-0.24 ; 0.05]
West Jutland	0.03	[-0.08 ; 0.14]	-0.02	[-0.17 ; 0.13]
East Jutland (incl. Århus)	-0.01	[-0.10 ; 0.08]	-0.07	[-0.19 ; 0.06]
North Jutland	0.004	[-0.10 ; 0.11]	-0.12*	[-0.26 ; 0.02]
February	0.05	[-0.10 ; 0.19]	0.12*	[-0.02 ; 0.27]
March	0.15**	[0.01 ; 0.29]	0.06	[-0.09 ; 0.21]
April	0.15**	[0.01 ; 0.29]	0.04	[-0.11 ; 0.19]
May	0.09	[-0.05 ; 0.23]	-0.04	[-0.20 ; 0.12]
June	0.22***	[0.09 ; 0.34]	-0.14*	[-0.28 ; 0.001]
July	0.28***	[0.15 ; 0.40]	0.10	[-0.04 ; 0.25]
August	0.30***	[0.18 ; 0.43]	-0.09	[-0.23 ; 0.05]
September	0.27***	[0.14 ; 0.39]	0.14*	[-0.01 ; 0.29]
October	0.13**	[0.01 ; 0.25]	-0.18**	[-0.31 ; -0.04]
November	0.09	[-0.03 ; 0.22]	-0.12*	[-0.25 ; 0.02]
December	0.02	[-0.11 ; 0.14]	-0.67***	[-0.80 ; -0.53]
Special weekday or week	0.26***	[0.21 ; 0.31]	0.30***	[0.20 ; 0.41]
Fulltime work	-0.15***	[-0.21 ; -0.09]	-0.20***	[-0.27 ; -0.13]
Other trips	-0.06***	[-0.08 ; -0.05]	-	-
Mills ratio: λ	-2.38	[-2.77 ; -2.00]	-1.25***	[-0.52 ; 0.44]
Observation	11,576	(44% travel)	7,781	(69% travel)
Wald chi2	101		1,085	

***, **, * indicates that estimates are significantly different from zero at the 0.01, 0.05, and 0.10 levels, respectively

Appendix C: Heckman estimates of visits

Table 8: Parameter estimates of visit travel distances from the log-log Heckman relation in (1) based on TU and the TU overnight survey.

Visit travel distances	TU		TU	
	Estimate	95% CI	Estimate	95% CI
Intercept	2.61***	[1.46 ; 3.75]	1.25***	[0.36 ; 2.13]
Household income	0.30***	[0.16 ; 0.45]	0.31***	[0.19 ; 0.43]
Single male	0.24	[-0.92 ; 1.39]	0.53*	[0.06 ; 1.00]
Single female	0.24	[-0.91 ; 1.40]	0.42*	[-0.06 ; 0.89]
One child	-0.22**	[-0.45 ; -0.004]	-0.16*	[-0.33 ; 0.02]
Two or more children	-0.08	[-0.29 ; 0.13]	-0.25**	[-0.45 ; -0.04]
Age (person A)	-0.09	[-0.47 ; 0.29]	0.05	[-0.22 ; 0.32]
Age (person B)	0.23	[-0.25 ; 0.71]	0.08	[-0.06 ; 0.22]
Age squared (person A)	0.02	[-0.02 ; 0.06]	-0.02	[-0.04 ; 0.01]
Age squared (person B)	-0.02	[-0.07 ; 0.02]	-0.002	[-0.01 ; 0.02]
Greater Copenhagen	0.22	[-0.09 ; 0.53]	0.07	[-0.19 ; 0.33]
Outer Copenhagen	0.26*	[-0.04 ; 0.55]	0.20	[-0.05 ; 0.44]
South Zealand	0.29**	[0.01 ; 0.57]	0.36***	[0.11 ; 0.60]
Funen and Bornholm	0.12	[-0.17 ; 0.40]	0.02	[-0.23 ; 0.27]
South Jutland	0.01	[-0.29 ; 0.32]	0.31**	[0.06 ; 0.57]
West Jutland	0.17	[-0.13 ; 0.47]	0.31**	[0.05 ; 0.57]
East Jutland (incl. Århus)	0.16	[-0.10; 0.41]	0.32***	[0.09 ; 0.54]
North Jutland	0.22	[-0.08 ; 0.51]	0.18	[-0.08 ; 0.43]
February	0.33	[-0.09 ; 0.75]	0.13	[-0.12 ; 0.37]
March	0.27	[-0.15 ; 0.68]	0.25**	[-0.14 ; 0.48]
April	0.40*	[-0.01 ; 0.81]	0.35***	[0.07 ; 0.59]
May	0.34	[-0.07 ; 0.74]	0.34***	[0.10 ; 0.58]
June	0.02	[-0.35 ; 0.35]	0.22*	[0.10 ; 0.48]
July	-0.08	[-0.42 ; 0.27]	0.33**	[-0.04 ; 0.59]
August	0.11	[-0.24 ; 0.46]	0.12	[0.08 ; 0.38]
September	-0.01	[-0.37 ; 0.34]	0.21	[-0.15 ; 0.46]
October	0.27	[-0.08 ; 0.63]	0.25**	[-0.05 ; 0.50]
November	0.17	[-0.18 ; 0.51]	0.10	[0.01 ; 0.34]
December	0.24	[-0.11 ; 0.59]	-0.04	[-0.13 ; 0.20]
Overnight stay	-	-	1.14***	[0.87 ; 1.40]

***, **, * indicates that estimates are significantly different from zero at the 0.01, 0.05, and 0.10 levels, respectively

TABLE 9: PARAMETER ESTIMATES OF THE STRUCTURAL EQUATION OF THE HECKMAN SELECTION MODEL IN (2) DESCRIBING THE PROBABILITY OF HAVING A VISIT OR NOT BASED ON TU AND THE TU OVERNIGHT SURVEY.

Having visits or not	TU		TU overnight	
	Estimate	95% CI	Estimate	95% CI
Intercept	-0.22	[-0.70 ; 0.26]	-0.08	[-0.55 ; 0.39]
Household income	-0.02	[-0.09 ; 0.05]	0.04	[-0.03 ; 0.11]
Single male	-0.08	[-0.57 ; 0.41]	0.05	[-0.22 ; 0.31]
Single female	-0.06	[-0.55 ; 0.43]	0.25*	[-0.02 ; 0.52]
One child	-0.03	[-0.12 ; 0.06]	-0.08*	[-0.18 ; 0.01]
Two or more children	-0.14***	[-0.22 ; -0.06]	-0.28***	[-0.37 ; -0.19]
Age (person A)	-0.03	[-0.19 ; 0.13]	-0.17**	[-0.32 , -0.03]
Age (person B)	-0.13	[-0.33 ; 0.06]	0.02	[-0.06 ; 0.09]
Age squared (person A)	-0.01	[-0.02 ; 0.01]	0.01*	[-0.002 ; 0.03]
Age squared (person B)	0.02*	[-0.002 ; 0.04]	-0.001	[-0.01 ; 0.01]
Greater Copenhagen	-0.10	[-0.23 ; 0.02]	0.06	[-0.08 ; 0.20]
Outer Copenhagen	-0.08	[-0.20 ; 0.04]	0.08	[-0.06 ; 0.21]
South Zealand	-0.03	[-0.15 ; 0.09]	0.05	[-0.09 ; 0.18]
Funen and Bornholm	0.06	[-0.06 ; 0.18]	0.09	[-0.05 ; 0.22]
South Jutland	0.01	[-0.12 ; 0.13]	0.11	[-0.03 ; 0.25]
West Jutland	0.04	[-0.08 ; 0.17]	0.16**	[0.02 ; 0.31]
East Jutland (incl. Århus)	-0.04	[-0.14 ; 0.07]	0.06	[-0.06 ; 0.19]
North Jutland	-0.01	[-0.13 ; 0.12]	0.16**	[0.02 ; 0.30]
February	-0.06	[-0.24 ; 0.11]	-0.01	[-0.15 ; 0.13]
March	-0.10	[-0.27 ; 0.07]	-0.01	[-0.15 ; 0.13]
April	-0.05	[-0.22 ; 0.11]	0.10	[-0.04 ; 0.24]
May	-0.05	[-0.21 ; 0.12]	-0.18**	[-0.34 ; -0.03]
June	0.13*	[-0.01 ; 0.28]	-0.15**	[-0.30 ; -0.01]
July	0.17**	[0.03 ; 0.31]	-0.12*	[-0.26 ; 0.02]
August	0.05	[-0.09 ; 0.20]	-0.12*	[-0.26 ; 0.02]
September	0.10	[-0.05 ; 0.24]	-0.03	[-0.18 ; 0.11]
October	-0.05	[-0.20 ; 0.09]	-0.09	[-0.22 ; 0.05]
November	0.08	[-0.07 ; 0.22]	-0.07	[-0.20 ; 0.07]
December	0.01	[-0.13 ; 0.15]	-0.18***	[-0.32 ; -0.04]
Special weekday or week	0.38***	[0.33 ; 0.44]	0.26***	[0.16 ; 0.36]
Fulltime work	-0.11***	[-0.17 ; -0.04]	-0.22***	[-0.30 ; -0.15]
Other trips	-0.06***	[-0.07 ; -0.05]	-	-
Mills ratio: λ	-1.66***	[-2.00 ; -1.32]	-0.03	[-0.64 ; 0.58]
Observation	11,576	(19% traveller)	7,781	(33% traveller)
Wald chi2	91		200	

***, **, * indicates that estimates are significantly different from zero at the 0.01, 0.05, and 0.10 levels, respectively

Appendix D: Heckman estimates of holiday travel

Table 10: Parameter estimates of holiday travel distances from the log-log Heckman relation in (1) based on TU and the TU overnight survey.

Holiday travel distance	TU		TU overnight	
	Estimate	95% CI	Estimate	95% CI
Intercept	5.99***	[2.57 ; 9.40]	7.61***	[2.66 ; 12.57]
Household income	0.25	[-0.09 ; 0.58]	0.12	[-0.29 ; 0.53]
Single male	0.05	[-2.74 ; 2.84]	-1.16**	[-2.29 ; -0.02]
Single female	-0.41	[-3.19 ; 2.37]	-1.54**	[-2.76 ; -0.31]
One child	0.13	[-0.33 ; 0.58]	-0.02	[-0.32 ; 0.32]
Two or more children	0.24	[-0.19 ; 0.67]	0.17	[-0.17 ; 0.51]
Age (person A)	-0.46	[-1.38 ; 0.45]	-0.20	[-0.72 ; 0.32]
Age (person B)	0.08	[-1.01 ; 1.17]	-0.33**	[-0.59 ; -0.07]
Age squared (person A)	0.05	[-0.05 ; 0.14]	0.03	[-0.02 ; 0.08]
Age squared (person B)	-0.01	[-0.11 ; 0.09]	0.02	[-0.01 ; 0.04]
Greater Copenhagen	0.21	[-0.37 ; 0.79]	0.77**	[0.16 ; 1.37]
Outer Copenhagen	0.29	[-0.29 ; 0.88]	0.66**	[0.02 ; 1.29]
South Zealand	0.11	[-0.46 ; 0.68]	0.98***	[0.37 ; 1.58]
Funen and Bornholm	0.20	[-0.40 ; 0.80]	0.61**	[0.10 ; 1.12]
South Jutland	0.25	[-0.35 ; 0.86]	0.60**	[0.06 ; 1.13]
West Jutland	0.21	[-0.37 ; 0.78]	0.33	[-0.11 ; 0.78]
East Jutland (incl. Århus)	0.60**	[0.08; 1.11]	0.43**	[0.01 ; 0.85]
North Jutland	0.22	[-0.33 ; 0.78]	0.57**	[0.04 ; 1.10]
February	-0.76	[-2.15 ; 0.63]	0.31	[-0.30 ; 0.92]
March	-0.25	[-1.59 ; 1.09]	-0.43	[-1.21 ; 0.34]
April	-0.68	[-1.92 ; 0.55]	-0.45	[-1.16 ; 0.25]
May	-0.90	[-2.16 ; 0.35]	-0.66	[-1.67 ; 0.34]
June	-0.54	[-1.76 ; 0.67]	-0.59	[-1.52 ; 0.34]
July	-0.95	[-2.17 ; 0.27]	-0.48	[-1.76 ; 0.81]
August	-0.91	[-2.11 ; 0.29]	-0.73	[-1.67 ; 0.21]
September	-0.50	[-1.71 ; 0.70]	-0.19	[-0.96 ; 0.58]
October	-0.17	[-1.37 ; 1.03]	-0.39	[-1.22 ; 0.45]
November	-0.05	[-1.29 ; 1.18]	-0.36	[-0.99 ; 0.27]
December	-0.16	[-1.44 ; 1.11]	0.16	[-0.42 ; 0.75]
Overnight stay		-	0.29***	[0.13 ; 0.46]

***, **, * indicates that estimates are significantly different from zero at the 0.01, 0.05, and 0.10 levels, respectively

Table 11: Parameter estimates of the structural equation of the Heckman selection model in (2) describing the probability of having a holiday activity or not based on TU and the TU overnight survey.

Holiday travel or not	TU		TU overnight	
	Estimate	95% CI	Estimate	95% CI
Intercept	-4.23***	[-5.18 ; -3.28]	-2.7***	[-3.29 , -2.20]
Household income	0.21***	[0.08 ; 0.33]	0.28***	[0.20 ; 0.37]
Single male	0.30	[-0.66 ; 1.27]	0.62***	[0.31 ; 0.92]
Single female	0.41	[-0.56 ; 1.37]	0.71***	[0.40 ; 1.01]
One child	-0.19**	[-0.35 ; -0.03]	-0.09	[-0.20 ; 0.02]
Two or more children	-0.26***	[-0.40 ; -0.11]	-0.15***	[-0.25 ; -0.04]
Age (person A)	0.27*	[-0.04 ; 0.58]	-0.15*	[-0.32 ; 0.02]
Age (person B)	0.07	[-0.30 ; 0.45]	0.08*	[-0.004 , 0.17]
Age squared (person A)	-0.03*	[-0.06 ; 0.001]	0.01	[-0.01 ; 0.02]
Age squared (person B)	-0.003	[-0.04 ; 0.03]	0.002	[-0.01 ; 0.01]
Greater Copenhagen	-0.05	[-0.26 ; 0.16]	-0.35***	[-0.51 ; -0.19]
Outer Copenhagen	-0.16	[-0.37 ; 0.05]	-0.39***	[-0.54 ; -0.24]
South Zealand	-0.18*	[-0.39 ; -0.03]	-0.36***	[-0.51 ; -0.21]
Funen and Bornholm	0.16	[-0.37 ; 0.06]	-0.25***	[-0.41 ; -0.10]
South Jutland	-0.06	[-0.29 ; 0.16]	-0.27***	[-0.43 ; -0.12]
West Jutland	-0.003	[-0.22 ; 0.21]	-0.15*	[-0.31 ; 0.01]
East Jutland (incl. Århus)	-0.15	[-0.34 ; 0.04]	-0.19***	[-0.33 ; -0.06]
North Jutland	0.04	[-0.17 ; 0.24]	-0.28***	[-0.44 ; -0.13]
February	0.27	[-0.15 ; 0.69]	0.19**	[0.01 ; 0.37]
March	0.32	[-0.09 ; 0.73]	0.33***	[0.15 ; 0.51]
April	0.76***	[0.39 ; 1.13]	0.25***	[0.07 ; 0.44]
May	0.61***	[0.24 ; 0.99]	0.51***	[0.32 ; 0.69]
June	0.73***	[0.37 ; 1.09]	0.56***	[0.39 ; 0.73]
July	1.06***	[0.71 ; 1.40]	0.93***	[0.77 ; 1.09]
August	0.87***	[0.53 ; 1.23]	0.60***	[0.43 ; 0.77]
September	0.57***	[0.21 ; 0.93]	0.42***	[0.24 ; 0.60]
October	0.50***	[0.14 ; 0.86]	0.51***	[0.34 , 0.68]
November	0.25	[-0.12 ; 0.63]	0.27***	[0.10 ; 0.44]
December	0.08	[-0.31 ; 0.47]	-0.11	[-0.30 ; 0.08]
Special weekday or week	0.34	[0.24 ; 0.44]	0.23***	[0.12 ; 0.35]
Fulltime work	-0.07	[-0.18 ; 0.05]	-0.04	[-0.12 ; 0.04]
Other trips	-0.12	[-0.15 ; -0.10]	-	-
Mills ratio: λ	-1.30	[-1.79 ; -0.80]	-1.52*	[-3.17 ; 0.13]
Observation	11,576	(4% travellers)	7,781	(17% travellers)
Wald chi2	47		77	

***, **, * indicates that estimates are significantly different from zero at the 0.01, 0.05, and 0.10 levels, respectively

APPENDIX E: HECKMAN ESTIMATES OF HOLIDAY TRAVELS BASED ON THE HBS

TABLE 12: PARAMETER ESTIMATES OF HOLIDAY TRAVEL DISTANCES FROM THE LOG-LOG HECKMAN RELATION IN (1) BASED ON THE HBS.

	HBS: Holiday travel distance		HBS: Leisure travel distance	
	Estimate	95% CI	Estimate	95% CI
Intercept	1.18	[-2.67 ; 6.18]	1.95	[-1.50 ; 5.41]
Household income	0.58***	[0.21 ; 0.95]	0.59***	[0.18 ; 1.01]
Single male	1.69**	[0.35 ; 3.04]	0.86	[-0.17 ; 1.89]
Single female	1.70**	[0.33 ; 3.07]	0.94	[-0.24 ; 2.12]
One child	-0.28*	[-0.60 ; 0.05]	-0.39***	[-0.67 ; -0.11]
Two or more children	-0.49***	[-0.74 ; -0.24]	-0.45***	[-0.71 ; -0.19]
Age (person A)	0.22	[-0.25 ; 0.68]	0.28*	[-0.003 ; 0.57]
Age (person B)	0.61**	[0.07 ; 1.15]	0.30	[-0.11 ; 0.70]
Age squared (person A)	-0.03	[-0.08 ; 0.02]	-0.04***	[-0.07 ; -0.02]
Age squared (person B)	-0.06**	[-0.11 ; -0.01]	-0.03	[-0.06 ; 0.01]
Greater Copenhagen	0.03	[-0.25 ; 0.31]	-0.12	[-0.38 ; 0.14]
Outer Copenhagen	-0.15	[-0.43 ; 0.12]	-0.22*	[-0.48 ; 0.04]
South Zealand	-0.49**	[-0.90 ; -0.07]	-0.58***	[-0.96 ; -0.20]
Funen and Bornholm	-0.26	[-0.59 ; 0.07]	-0.29**	[-0.59 ; -0.0001]
South Jutland	-0.57***	[-0.92 ; -0.23]	-0.52***	[-0.87 ; -0.16]
West Jutland	-0.31**	[-0.63 ; -0.001]	-0.39**	[-0.71 ; -0.08]
East Jutland (incl. Århus)	-0.31**	[-0.62; -0.01]	-0.43***	[-0.70 ; -0.17]
North Jutland	-0.39*	[-0.79 ; 0.002]	-0.44**	[-0.82 ; -0.05]
February	0.11	[-0.27 ; 0.50]	0.03	[-0.23 ; 0.29]
March	-0.10	[-0.48 ; 0.27]	0.03	[-0.22 ; 0.29]
April	-0.21	[-0.61 ; 0.18]	0.12	[-0.14 ; 0.39]
May	-0.29	[-0.69 ; 0.31]	0.25*	[-0.05 ; 0.55]
June	-0.29	[-0.73 ; 0.15]	0.18	[-0.14 ; 0.51]
July	-0.08	[-0.59 ; 0.44]	0.29	[-0.08 ; 0.66]
August	0.17	[-0.63 ; 0.96]	0.66**	[0.10 ; 1.21]
September	0.05	[-0.77 ; 0.88]	0.66**	[0.14 ; 1.17]
October	0.31	[-0.51 ; 1.13]	0.80***	[0.25 ; 1.36]
November	-0.0005	[-0.51 ; 0.51]	0.40	[0.03 ; 0.76]
December	-0.13	[-0.52 ; 0.26]	-0.01	[-0.27 ; 0.25]

***, **, * indicates that estimates are significantly different from zero at the 0.01, 0.05, and 0.10 levels, respectively

TABLE 13: PARAMETER ESTIMATES OF THE STRUCTURAL EQUATION OF THE HECKMAN SELECTION MODEL IN (2) DESCRIBING THE PROBABILITY OF HAVING A HOLIDAY ACTIVITY OR NOT BASED ON THE HBS.

	HBS: Holiday travel or not		HBS: Leisure travel or not	
	Estimate	95% CI	Estimate	95% CI
Intercept	-3.49***	[-4.13 ; -2.86]	-2.86***	[-3.47 ; -2.22]
Income	0.34***	[0.26 ; 0.43]	0.53***	[0.45 ; 0.61]
Single male	0.43	[-0.25 ; 1.10]	0.69**	[0.06 ; 1.31]
Single female	0.53	[-0.15 ; 1.20]	1.01***	[0.38 ; 1.64]
One child	-0.27***	[-0.38 ; -0.15]	-0.31***	[-0.43 ; -0.20]
Two or more children	-0.17***	[-0.27 ; -0.06]	-0.28***	[-0.39 ; -0.18]
Age (person A)	0.19*	[-0.01 ; 0.39]	-0.15	[-0.32 ; 0.03]
Age (person B)	0.19	[-0.07 ; 0.45]	0.26**	[0.02 ; 0.50]
Age squared (person A)	-0.03***	[-0.05 ; -0.01]	-0.002	[-0.02 ; 0.01]
Age squared (person B)	-0.01	[-0.04 ; 0.01]	-0.02*	[-0.04 ; 0.001]
Greater Copenhagen	-0.07	[-0.23 ; 0.08]	-0.21***	[-0.37 ; -0.06]
Outer Copenhagen	-0.05	[-0.20 ; 0.11]	-0.22***	[-0.38 ; -0.06]
South Zealand	-0.34***	[-0.50 ; -0.18]	-0.42***	[-0.57 ; -0.27]
Funen and Bornholm	-0.20**	[-0.36 ; -0.04]	-0.28***	[-0.44 ; -0.13]
South Jutland	-0.21**	[-0.38 ; -0.05]	-0.38***	[-0.53 ; -0.22]
West Jutland	-0.16**	[-0.32 ; -0.01]	-0.32***	[-0.48 ; -0.17]
East Jutland (incl. Århus)	-0.22***	[-0.35 ; -0.08]	-0.28***	[-0.42 ; -0.14]
North Jutland	-0.30***	[-0.46 ; -0.14]	-0.43***	[-0.58 ; -0.27]
February	-0.01	[-0.20 ; 0.18]	0.02	[-0.14 ; 0.19]
March	0.09	[-0.09 ; 0.28]	-0.01	[-0.17 ; 0.16]
April	0.18*	[-0.002 ; 0.36]	0.10	[-0.06 ; 0.26]
May	0.37***	[0.19 ; 0.55]	0.18**	[0.02 ; 0.35]
June	0.28***	[0.10 ; 0.46]	0.25***	[0.09 ; 0.42]
July	0.41***	[0.23 ; 0.59]	0.34***	[0.18 ; 0.51]
August	0.80***	[0.62 ; 0.98]	0.66***	[0.49 ; 0.83]
September	0.85***	[0.68 ; 1.03]	0.60***	[0.44 ; 0.77]
October	0.84***	[0.66 ; 1.01]	0.66***	[0.49 ; 0.83]
November	0.39***	[0.21 ; 0.57]	0.33***	[0.17 ; 0.50]
December	0.15	[-0.04 ; 0.33]	0.02	[-0.14 ; 0.19]
Fulltime work	0.08*	[-0.01 ; 0.16]	0.01	[-0.07 ; 0.10]
Visits	0.02***	[0.01 ; 0.04]	-	-
Mills ratio: λ	0.67	[-0.62 ; 1.96]	1.37*	[-0.05 ; 2.79]
Observation	5,727	(32% traveller)	5,727	(58% traveller)
Wald chi2	99		64	

***, **, * indicates that estimates are significantly different from zero at the 0.01, 0.05, and 0.10 levels, respectively

PAPER #3

TOURISM EXPENDITURES ON PLANE TICKETS AND TRAVEL PACKAGES

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TOURISM EXPENDITURES ON PLANE TICKETS AND TRAVEL PACKAGES

- A PRE-CRISIS ASSESSMENT

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ABSTRACT

The paper analyses household expenditure for Danish outbound tourism travel in two separate stages. Firstly, we analyse the overall expenditure on travel, leisure, and various non-durable commodities by estimating an Almost Ideal Demand System (AIDS). The model reveals income sensitivity at the general level for transport and leisure consumption, which among other things includes expenditures on tourism. Secondly, we analyse the specific expenditures on plane tickets and travel packages using a bivariate Tobit model. The Tobit analysis reveals household income and price elasticities, and contributes to the tourism research literature by underpinning that plane tickets and travel packages are differentiated products that appeals to different consumer segments with different expenditure profiles. More specifically, we find that the value-added content of travel packages is more sensitive to household income compared to the demand for pure plane tickets. The finding is not surprising although rarely evidenced in the tourism research literature. The current models are estimated on pre-crisis micro data from Danish households (1996-2007) in the form of a consumption survey consisting of approximately 10,000 observations.

Keywords: Tourism modelling, Expenditure, Income elasticity, Travel package, Plane tickets.

1 INTRODUCTION

The two main tourism segments are do-it-yourself (DIY) travellers and buyers of travel packages. With the revival of travel packages (Clancy, 2013; Thomas, 2013; Statistics

Denmark, 2011) it is increasingly relevant to consider plane tickets and travel packages as differentiated products. For UK citizens, 48% of all people who took a foreign holiday in 2012 booked it as a travel package. In 2010, this percentage was only 37% (ABTA, 2013). In this context, it is of interest whether the value-added components of travel packages are more sensitive to income effects compared to the expenditures on pure plane tickets. This may show in the form of "all-inclusive", "planned events", and/or safe and secured accommodation. In this sense, the value-added component of travel packages is considered as an element of luxury. This hypothesis is well in line with economic theory saying that luxury goods are those goods for which demand increases more than proportionally as income rises.

In the paper a Tobit model (Tobin, 1958) is specified for the choice of plane tickets and travel packages based on Danish micro consumer data between 1996 and 2007. The analysis reveals that travel package expenditures are significantly more sensitive to household income and that travel packages attract a different consumer base as also stressed in Plog (2004).

1.1 LITERATURE REVIEW

The literature on the relation between tourism and income is comprehensive. In an early meta-analysis, Crouch (1994) analysed more than 80 studies and found the general consumption of tourism to be a luxury good with elasticities significantly above unity. This early conclusion has recently been supported in a comprehensive meta-study of more than 195 studies (from 1961-2011) by Peng et al. (2014). Peng et al. (2014) find the overall income elasticity of international tourism demand is 2.5, however, this average represent a very heterogeneous set of studies with different demand measures. The average for expenditure studies, as considered in this paper, is significant lower at 1.691 and in combination with a lower elasticity for intracontinental travel these results from Peng et al. seems to comply well with the level of elasticities found in the present paper. For Europe there has been several studies on UK holiday travel such as in Graham (2000), in Blake and Cortes-Jiménez (2007) in a study on UK inbound tourism, and in Njegovan (2006) in a study of UK outbound leisure air travel. Graham (2000) finds air travel income elasticities varying between 1.72 and 2.15 in the period from 1984-1998, which is a little lower compared to the period from 1970-1998. Njegovan (2006) finds income elasticity of 1.5 for air travel and 1.9 for tourism abroad. At the international level, Smeral and Song (2013) analyse the asymmetry of income and price elasticities across the business cycle. For EU-15 countries income elasticity are found to be 1.39 in slow-growth periods and 2.14 in fast growth periods. This is significantly lower than for the US, Australia and Japan although higher than for Canada. The difference is explained with liquidity constraints and precautionary savings in recovery and slow-down periods.

When considering the methods applied for analysing tourism expenditure, a first and important distinction is whether the methodology applies an aggregated or disaggregated approach based on micro data (Song and Li, 2008).

Historically, due to the way data has been collected by public authorities, there has been a tradition of using aggregated data. Methodologies applied to aggregate data include time series, panel data and cross-sectional data analyses as discussed in Pablo-Romero and Molina (2013) and Li et al. (2005). A popular method is the single-equation form, which has been used in numerous studies (e.g., such as in Daniel and Ramos, 2002). However, even though the single-equation form is often represented as relative advanced dynamic error correction models, which include co-integration as a mean to determine lag-effects (Dritsakis, 2004), is has been criticised for not analysing the interdependence of budget allocations to different tourist products or tourist destinations. Several studies have included different substitution variables to meet these limitations; however, there seems to be general consensus about the advantages of applying demand systems such as the Almost Ideal Demand System as its underlying theory is much stronger (Song and Li, 2008; Divisekera, 2003; Papatheodorou, 2001). In recent years, AIDS models have gained ground for analysing aggregated expenditure shares. Again the foundation of these models has often been aggregated travel data (Durbarry and Sinclair, 2003; Han et al., 2006). Recent extensions to this framework include dynamic factors (Li et al., 2006) although the departure point is still aggregated data. A different approach is found in Eilat and Einav (2004) in their application of a discrete choice model on tourism demand. Still their model is based on aggregated data and may fail to account for heterogeneity among households.

The use of micro data and micro econometric methods for analysing tourism has become increasingly popular as more and more data are available at the level of the respondents. The choice of destination has been analysed using discrete choice models as in e.g. Eymann and Ronning (1997), Hubert and Potier (2003), and Eugenio-Martin and Campos-Soria (2010). The objective of these studies was, however, not to analyse expenditures but to model the heterogeneity in the choice of destination. Micro-econometric models applied for analysing tourism expenditure has recently been reviewed in Brida and Scuderi (2013). In their paper, linear approaches as well as non-linear approaches such as the Tobit approach (Tobin, 1958) and the double hurdle approach are reviewed. In total, fourteen examples applying the Tobit model are reviewed. This includes, e.g. studies of expenditures on vacation or leisure activities (Brida et al., 2012; Cai, 1998), or specific events such as sport events or festivals (Barquet et al., 2011; Kim et al., 2010). All of these papers apply the Tobit model in very specific expenditure contexts and the model applications are slightly different from the more general context of the choice between plane tickets and travel packages as in the current paper. Belenkiy and Riker (2013) analyse US demand for tourism with a double-log model. The survey is for air travellers only and elasticities are conditional on the specific sample selection. More recently Disegna et al. (2013) used a multivariate non-linear copula-based model to analysis tourism expenditure. As claimed by the authors the model is an alternative to the multivariate Tobit model, which is computationally cumbersome for more than two dimensions. However, the analysis suffers from lack of income and pricing data.

1.2 Findings and contributions of the paper

In this study, two econometric models are estimated for tourism expenditure. Firstly, an AIDS model (Deaton and Muellbauer, 1980a) is estimated to analyse expenditures on travel and leisure at the overall budget level, and secondly, a Tobit model for the specific expenditure on travel packages and plane tickets. While the main research contribution of the paper relates to the second model, the first model can be seen as a first stage estimation of the (overall) income elasticity. It is shown that the overall elasticity level of the two models is very similar as the weighted mean of income elasticities across the travel package and plane ticket nest in the Tobit model is similar to the average income elasticity in the AIDS model. This serves as robustness test, as two different models back the level of elasticity. The second model contributes to the tourism research literature by explicitly modelling the expenditure elasticity of income with respect to travel package and air tickets. The modelling effort is carried out using a bivariate non-linear Tobit model based on a household-based expenditure survey of approximately 10,000 households collected over a period of 11 years from 1996-2007. It is shown that the income elasticity with respect to travel packages is approximately 50% higher than for pure air tickets. This finding is in line with economic theory as the value-added component of travel packages can be considered as an element of luxury. Even so, to our knowledge, this finding has not been empirically evidenced in the literature. In the meta-study by Peng et al. (2014) based on 195 studies the distinguishing between travel package and air tickets is not mentioned or included as segment in the meta model. The general finding of the paper suggest that strong economic growth will cause substitution effects towards travel package, whereas an economic crisis may imply the opposite.

1.3 STRUCTURE OF THE PAPER

The paper is structured as follows: The formulation of the two models is outlined in Section 2 and data is described in Section 3 including an overall descriptive analysis of the expenditure shares of interest. The results are presented in Section 4 and the overall conclusions in Section 5.

2 METHODOLOGY

The study of expenditures on different commodity groups raises the challenge of dealing with interdependencies between the different commodities. To meet this challenge it is common to apply a system approach over a single equation approach as it includes the interdependence of budget allocations for different consumer goods and services. In order to analyse the expenditure shares of aggregated commodities, the AIDS model (Deaton and Muellbauer, 1980a; Deaton and Muellbauer, 1980b) is applied. The AIDS is one of the most widely used approaches for estimating consumer demand systems (Chern et al., 2003; Hausman, 1996; Chia-Lin, 2012). The model system is an extension of the Working-Leser model (Working, 1943; Leser, 1963) in which the budget share of the commodity i is linearly related to the logarithm of prices and total real expenditures.

The expenditure share w_i associated with the i-th commodity provides the general form of the AIDS model (1):

$$w_i = \alpha_i + \sum_j \gamma_{ij} \log p_j + \beta_i \log\{X/P\} \tag{1}$$

where $p_j = (p_1, \cdots, p_j)$ is the price vector of all goods included in the model and X is the total household expenditure. P is the non-linear price index as given in (2) whereas α, β and γ are the parameter vectors to be estimated.

$$\log P = \alpha_0 + \sum_i \alpha_i \log p_i + \frac{1}{2}\sum_i \sum_j \gamma_{ij} \log p_i \log p_j \qquad (2)$$

where $\gamma_{ij} = \gamma_{ji}$

Due to well-known properties of an expenditure function (see, e.g., chapter 3 in Mas-Colell, 1995) the parameters γ_{ij}, α_i and β_i must satisfy homogeneity and adding-up restrictions as listed in (3) and (4) below.

Homogeneity $$\sum_j \gamma_{ij} = 0 \qquad (3)$$

Adding up $$\sum_{i=1}^{n} \alpha_i = 1 \qquad \sum_{i=1}^{n} \gamma_{ij} = \sum_{i=1}^{n} \beta_i = 0 \qquad (4)$$

Changes in the relative price work through the γ_{ij} parameters and changes in expenditures work through the β_i parameters. The adding-up restrictions make sure that the sum of β_i add up to zero. The income elasticity is above 1 when β_i is estimated positive, whereas β_i being negative corresponds to an elasticity below unity. In this way, positive values of β_i correspond to luxury goods whereas negative values correspond to necessities (Deaton and Muellbauer, 1980a).

To address heterogeneity a variety of household specific constants H_k are added to the model (5).

$$w_i = \alpha_i + \sum_j \gamma_{ij} \log p_j + \beta_i \log\{X/P\} + \sum_k \delta_i H_k \qquad (5)$$

The vector H_k includes six household specific constants, where the household members are classified into five age groups: babies (0-2 years), small children before starting in school (3-6 years), children before the teens (7-11 years), teens (12-17 years) and household members above the age of 17 are all grouped as adults. The final variable is the number of retired persons in the household. An additional dummy variable representing family status (two adults or singles) and a time trend was included but not found significant.

The underlying theory of the AIDS model assumes no corner solution among individuals, which means that each household is assumed to have non-zero expenditures on all commodities. This implies that the model system is mainly appropriate for aggregated expenditure data. When looking at a detailed expenditure portfolio within a limited time frame, zero consumption may occur. In that case, additional conditions or other approaches need to be considered (Brännlund and Nordström, 2004; Chern et al., 2003). Even so, the AIDS approach has been widely applied on more disaggregated goods and even as specific as cereal brands (Hausman, 1996).

Endogeneity can be a problem in the AIDS model in the sense that correlation between explanatory variables and the error term may cause estimates to be biased. Hence, it may be related to the expenditure as well as the prices. However, usually, this is mostly an issue with respect to products that are "differentiated" (Gould, 2003) and less of a problem for aggregated groups. As a result, we present an generalised AIDS at the level of aggregated commodity groups and a Tobit model at the level of the differentiated products in order to validate the level of income elasticities across these models.

The most commonly applied models to account for zero expenditure shares among respondents is the two-stage Heckman's model (Heckman, 1979) and the standard Tobit model (Tobin, 1958; Amemiya, 1974). Each model is based on different assumptions regarding zero consumption.

If zero consumption is assumed to be due to sample selection, in the sense that no purchase of the particular item was made during the survey period (e.g., because of a short survey period), Heckman's two-step model is the appropriate model. The Tobit model on the other hand simply captures the corner solutions in a utility maximisation context, where zero actually represents no expenditures on the specific commodity (Brännlund and Nordström, 2004).

In the present expenditure survey to be described in Section 3, zero consumption might well exist as a combination of both sample selection and "true" zero consumption for certain household types. For a significant share of the included commodities, data are collected during a two-week period, and the probability of having the corner solution representing infrequency of purchase is high. However, some specific and rare commodities are also likely to actually have zero consumption in some households during a particular period of observation. Chern et al. (2003) handle this difference in explaining corner solution by applying both the Heckman and the Tobit approaches to outline a probable interval span of the elasticities. Due to the purchase of plane tickets and travel packages, it is reasonable to assume that the corner solutions actually correspond to zero expenditures and this is the reason why the Tobit model is applied.

2.1 Tobit model

The Tobit approach is an econometric model for censored endogenous variables proposed by James Tobin (Tobin, 1958). It was developed to describe the relationship between a non-negative dependent variable and a linear predictor. The current model is specified as in (6) and (7) below.

$$w_i = \begin{cases} w_i^* & if\ w_i^* > 0 \\ 0 & if\ w_i^* \leq 0 \end{cases} \tag{6}$$

With $$w_i^* = \alpha_i + \sum_j \gamma_{ij} \log p_j + \beta_i \log \mathrm{X} + \sum_k \delta_i H_k + \varepsilon_i, \quad \varepsilon_i \sim N(0, \sigma^2) \tag{7}$$

In this study the specification of w_i^* applies the model specification of the expenditure shares as also used in the AIDS model but without applying the general price index. Expenditure is a zero-censored variable and assuming it to be normally distributed is unrealistic as it is generally asymmetric. The Tobit model accounts for this bias by imposing restrictions as outlined in (3) and (4).

3 Data

The modelling effort is based on a Danish expenditure survey. The survey registers the total expenditure of Danish households divided into more than 1,300 commodities. Data cover a 12-year period from 1996 to 2007 and include expenditure information from approximately 900 households per year collected as a representative sample of the population. The selection of the period for is selected to maintain consistency in the data definition. Although being a few years old, it makes interesting as a pre-economic-crisis assessment of demand and expenditure. For all households, detailed background information is available, including household structure and income.

The survey only registers total expenditures on the different commodities and does not provide information about unit prices or product quantities. Instead, prices from the national Price Index were used (Statistics Denmark, 2013). These prices are divided into commodity groups that correspond to those in the expenditure survey.

Table 1 shows selected properties of the six aggregated commodity groups applied in the AIDS model. Plane and travel packages are included in the relatively broadly defined commodity group of transportation and leisure which accounts for 43 percent of the total expenditures. All expenditures are corrected for inflation and possible outliers are removed from the survey.

TABLE 1: DATA PROPERTIES WITHIN THE SIX OVERALL COMMODITY GROUPS (1996-2007)

	Observations >0	Share of Zero cells	Expenditure share
Food, drinks & tobacco	9,538	0 %	25 %
Clothes & footwear	7,870	17 %	7 %
Electricity & heating	9,507	0 %	15 %
Medicine & medical care	8,699	9 %	3 %
Communication & audio equipment	9,474	1 %	7 %
Transportation & leisure	9,538	0 %	43 %

The price index that corresponds to the different commodity groups is calculated as a weighted average from observed market shares of all sub-commodity groups in the expenditure survey. Durables are excluded from the survey, which implies no substitution between durables and non-durables.

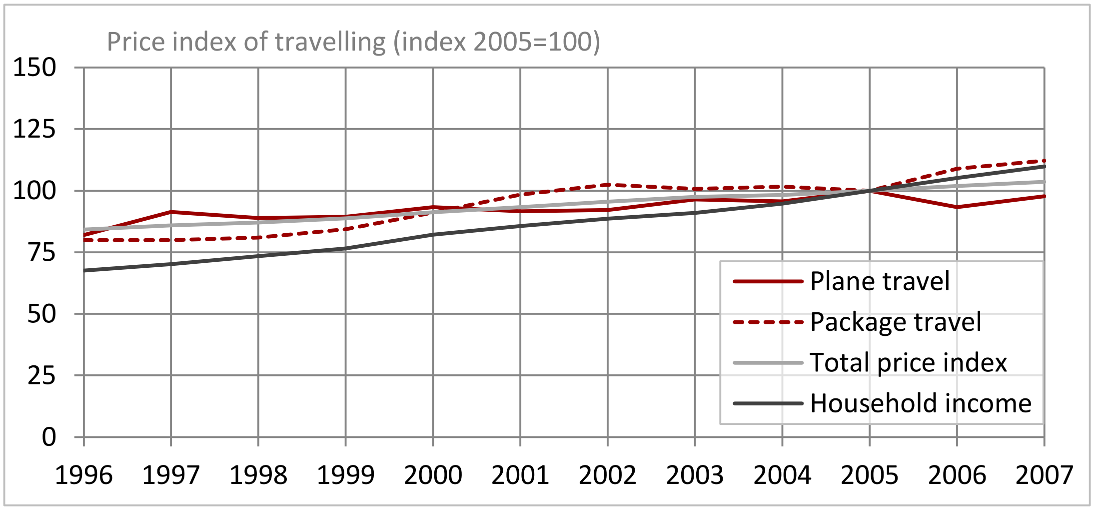

Figure 1: Development in the price indices of plane and travel packages having 2005 as base year

Figure 1 and Figure 2 illustrates the development in the price indices and the expenditure shares from 1996 to 2007. The prices of plane tickets and travel packages increased by 1.6% and 3.1% per year compared to a 1.9% growth in the general price index and a 4.3% increase in income. The changes in expenditure shares have been significantly higher than the corresponding price change. In total, travel expenditures increased by 5.4% per year, whereas expenditure on plane tickets increased by 8.7% and travel packages by 4.5%. Clearly, the growth in budget shares should be considered relative to the small average expenditure shares of 0.5% and 1.8%, respectively.

The total expenditures on most of the commodities are registered during a two-week period, but the consumption of more infrequent commodities is registered on an annual basis. The latter was the case for plane travel and travel packages. Still, there is a significant share of zero consumption (Statistics Denmark, 2010).

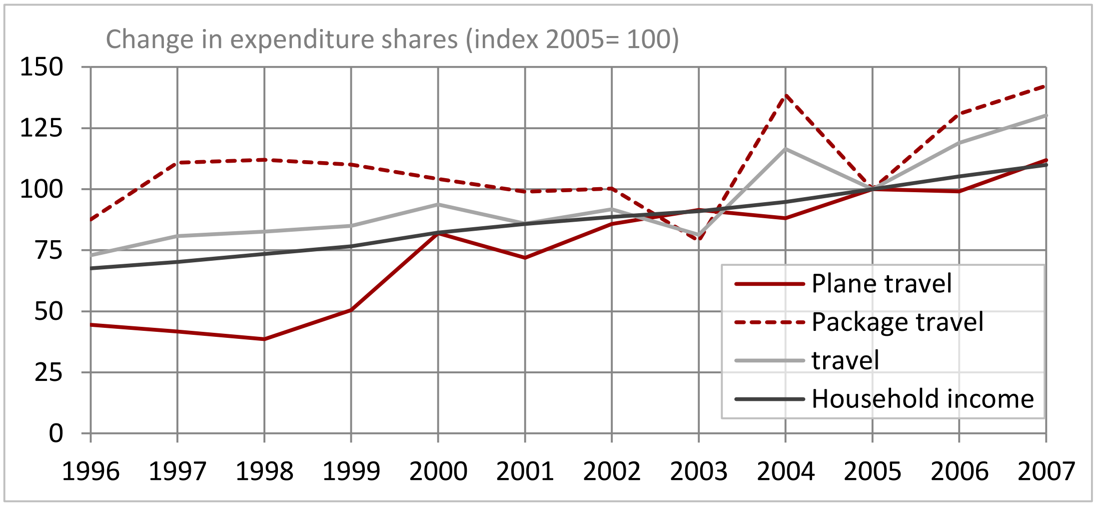

FIGURE 2: DEVELOPMENT IN EXPENDITURE SHARES OF PLANE TRAVEL AND TRAVEL PACKAGES HAVING 2005 AS BASE YEAR

4 RESULTS

The results are divided into two parts reflecting the results of the aggregated AIDS model in Section 4.1 and the results of the Tobit model on the specific expenditures on plane tickets and travel packages in Section 4.2. The expenditures are available at the individual level and are based on the travel budget of households for each commodity class. This has facilitated a general interpretation of the main factors of travel demand such as income and price elasticities.

4.1 AGGREGATED AIDS ESTIMATION

The AIDS model is clearly non-linear in parameters as it involves the non-linear price index. In the following it has been estimated as a non-linear seemingly unrelated equation system (SUR). More specifically, we have applied SAS software (Proc Model) and used the "iterated seemingly unrelated regression" method for estimating the parameters.

Table 2 shows the parameter estimates from the AIDS approach as described in Section 2. Due to the level of aggregation in the commodity groups, the problem of corner solutions can be ignored.

TABLE 2: DATA PROPERTIES WITHIN THE SIX OVERALL COMMODITY GROUPS (1996-2007)

	Food, drinks & tobacco	Clothes & footwear	Electricity & heating	Medicine etc.	Comm. & audio	Transp. & leisure
Food, drinks & tobacco	-0.018	0.057**	0.063*	0.055**	0.0092	-0.17**
Clothes & footwear	0.057**	-0.049	-0.12**	0.0049	0.029**	0.075*
Electricity & heating	0.063*	-0.12**	-0.028	-0.025	0.016	0.090
Medicine & medical care	0.055**	0.0049	-0.025	-0.019	-0.019*	0.0030
Communication & audio equip.	0.0092	0.029**	0.016	-0.019*	-0.032**	-0.0038
Transportation & leisure	-0.17**	0.075*	0.090	0.0030	-0.0038	0.00229
Income	-0.076**	0.041**	-0.054**	0.0048**	-0.015**	0.099**
Intercept	0.59**	-0.12**	0.412**	0.0097**	0.17**	-0.017
Babies (0-2 years)	0.0049	0.0054*	0.0024	-	-0.010**	0.0012
Small children (3-6 years)	0.0096**	0.00092	0.0033	-	-0.0078**	-0.0022
Children (7-11 years)	0.018**	-0.0021	0.0068**	-	-0.0032**	-0.014**
Teens (12-17 years)	0.024**	0.0045**	0.0071**	-	0.0043**	-0.037**
Grown-ups (above 17 years)	0.037**	-0.018**	0.0031*	-	-0.0033**	-0.017**
Retired persons	0.0049	-0.0063**	0.025**	-	-0.016**	-0.029**

** and * indicate that estimates are significantly different from zero at the 0.05 and the 0.10 level, respectively

The β parameters are well identified and provide a good basis for the estimation of income elasticities. Income elasticities can be measured as in (8) below.

$$e_i = \frac{\beta_i}{w_i} + 1 \quad (8)$$

Generally, the estimated elasticities from the aggregate estimation comply well with the literature. We have established a comparison based on a recent meta-study in Section 4.4. Moreover, as the AIDS model is estimated by commodity, it is relevant to comparison the elasticities for the different commodities. Table 3 compares elasticities with recent income elasticities from the USDA-Economic Research Service (Muhammad et al., 2011).

The aggregated AIDS model finds the three commodity groups: food, drinks and tobacco, electricity and heating, and communication and audio equipment to be necessities. Clothes and footwear, medicine and medical care, and transportation and leisure are estimated to be luxury goods. The estimates correspond well with the elasticities from USDA although the income elasticity of clothes and footwear has proven somewhat higher for the Danish expenditures.

TABLE 3: INCOME ELASTICITY ESTIMATED FROM THE RESULTS OF THE AIDS MODEL AND FOUND IN MUHAMMAD ET AL. (2011)

	Food, drinks and tobacco	Clothes and footwear	Electricity and heating	Medicine and medical care	Communication and audio equipment	Transporta-tion and leisure
Income elasticities	0.694	1.605	0.638	1.147	0.785	1.230
USDA elasticities	*0.507*	*0.964*	-	*1.238*	-	*1.1-1.3*

4.2 TOBIT ESTIMATION OF PLANE TICKETS AND TRAVEL PACKAGES

The Tobit model is estimated as a bivariate model system of the budget shares of plane tickets and travel packages relative to the total expenditures on travelling. The parameter estimates are given in Table 4. The parameters are maximum likelihood parameters, which are estimated using SAS software (Proc Qlim). Most β parameters are significant and, as for the aggregated AIDS, the parameters are estimated with low variance and give a good basis for the estimation of income elasticities.

The parameter that represents the price index of plane tickets was not significantly estimated. Arguably, this is due to lack of price variation in data; however it does not prevent the estimation of income elasticities. Income elasticities will be unbiased as long as the separability of the Tobit equation in terms of X and p holds.

The significant ρ-parameter indicates existence of correlation between the purchase of plane tickets and travel packages. This justifies the bivariate approach instead of using two separate univariate Tobit models. The household specific constants show that an increasing number of household members has negative impact on the expenditure shares of plane tickets and travel packages. The number of retired household members has the highest impact on the purchase of plane tickets, whereas the existence of babies in the household has the highest impact on travel packages.

TABLE 4: MULTIVARIATE TOBIT MODEL SYSTEM OF PLANE TICKETS AND TRAVEL PACKAGES WITHOUT ANY MODEL RESTRICTIONS

Parameter	Variables	Plane tickets	Travel packages
β	*Plane tickets*	0.819	-0.555**
	Travel packages	1.024**	-1.350**
	Income	1.125**	0.601**
	Intercept	-1.198**	-0.802**
	Babies (0-2 years)	0.0808	-0.169**
	Small children (3-6 years)	-0.0938*	-0.0818**
	Children (7-11 years)	-0.171**	-0.0893**
	Teens (12-17 years)	-0.132**	0.0180
	Grown-ups (above 17 years)	-0.0831**	-0.0834**
	Retired persons	-0.292**	-0.0360**
ε_i	*Error term*	1.125**	0.665**
ρ	*Correlation coefficient*		-0.696**

** and * indicate that estimates are significantly different from zero at the 0.05 and the 0.10 level, respectively

From the parameters in Table 4 it is not straightforward to work out the elasticities as the model represents the latent choice of purchasing a specific commodity and is non-linear in parameters. The conditional elasticities, however, can be worked out from the definition of elasticities (Green and Alston, 1990). The form of the conditional elasticity of expenditure e_i, the conditional price elasticity e_{ii} and the cross-price elasticity e_{ij} are all given below in (9)-(11).

$$e_i = \frac{\partial E[q_i|q_i^* > 0]}{\partial X}\frac{X}{E[q_i|q_i^* > 0]} = 1 + \frac{\hat{\alpha}_i\left[1 - \hat{z}_i\frac{\phi(\hat{z}_i)}{\Phi(\hat{z}_i)} - \left(\frac{\phi(\hat{z}_i)}{\Phi(\hat{z}_i)}\right)^2\right]}{\bar{x}_i\hat{\beta} + \hat{\sigma}_i\frac{\phi(\hat{z}_i)}{\Phi(\hat{z}_i)}} \quad (9)$$

$$e_{ii} = -1 + \frac{\hat{\beta}_{ii}\left[1 - \hat{z}_i\frac{\phi(\hat{z}_i)}{\Phi(\hat{z}_i)} - \left(\frac{\phi(\hat{z}_i)}{\Phi(\hat{z}_i)}\right)^2\right]}{\bar{x}_i\hat{\beta} + \hat{\sigma}_i\frac{\phi(\hat{z}_i)}{\Phi(\hat{z}_i)}} \quad (10)$$

$$e_{ij} = \frac{\hat{\beta}_{ij}\left[1 - \hat{z}_i \frac{\phi(\hat{z}_i)}{\Phi(\hat{z}_i)} - \left(\frac{\phi(\hat{z}_i)}{\Phi(\hat{z}_i)}\right)^2\right]}{\bar{x}_i\hat{\beta} + \hat{\sigma}_i \frac{\phi(\hat{z}_i)}{\Phi(\hat{z}_i)}} \tag{11}$$

With

$$\hat{z}_i = \frac{\bar{x}_i\hat{\beta}}{\sigma}$$

For comparison, the income and price elasticities are estimated with various degrees of restrictions on the parameters as presented in Table 5. The restrictions on γ correspond to the homogeneity restrictions in (3) whereas "all restrictions" also include the adding-up restrictions in (4).

TABLE 5: ESTIMATED ELASTICITIES FROM THE RESULTS OF THE TOBIT MODEL SYSTEM WITH AND WITHOUT RESTRICTIONS ON THE PARAMETERS

	Plane tickets	Travel packages
No restrictions		
Income elasticity	1.12	1.36
Price elasticity plane	-0.37	-0.33
Price elasticity travel packages	0.33	-1.80
Restrictions on γ		
Income elasticity	1.12	1.35
Price elasticity plane	-1.57	1.06
Price elasticity travel packages	0.57	-2.06
All restrictions		
Income elasticity	0.93	1.41
Price elasticity plane	-1.16	0.97
Price elasticity travel packages	0.16	-1.97

The restrictions impose structure to the model and make sure that the model complies with errors being normally distributed and with homoscedastic errors. In the estimation, the inclusion of constraints significantly improved the identification of parameters, but as the analysed model system only includes two nests of commodities, the applied restrictions however force the parameter estimates towards similar numerical values. For the homogeneity restrictions, it is important to stress that it does not affect the income elasticity but has impact on the price elasticity. The adding-up restriction influences both.

4.3 Interpretation of results

As seen in Table 5, the income elasticity of travel packages is higher than the one for plane tickets. This relation is observed for all the different applied model specifications and the income elasticities are relatively stable. This furthermore correspond to the difference in tourism abroad and leisure air travel abroad as presented in Njegovan (2006). The level of elasticities conforms well to the aggregated AIDS model in which income elasticities for the aggregated transport and leisure commodity were estimated at 1.23.

The conditional own price elasticities state that the purchased quantities of travel packages are more sensitive to price changes than plane travel. This has also turned out to be consistent across the different applied model specifications despite the price used for estimation being a weighted index. As for the cross-price elasticities, the results are more mixed. In the unrestricted multivariate model system, the demand for travel packages decreases when the prices of plane tickets increase, whereas the demand for plane tickets increases when the prices of travel packages increase. This indicates gross substitutes of goods (De Borger et al., 2013), which actually seems intuitive as travel packages most often also include plane travelling.

The elasticities are further estimated per year. Generally, the annual change is not great in magnitude, but during the 12-year period the income elasticity of plane tickets increased by 1.3% and the income elasticity of travel packages decreased by 2.0%. This indicates a change in the perception of the two travel types during the survey period. But while the income elasticity increased continuously during the years, the change for travel packages is observed from 1999 to 2002 and hereafter the income elasticity seems relatively constant.

A variety of different model specifications have been tested but have not been included in the final version of the paper. The tests included different specifications of dummies and also different specifications on how data are segmented into commodities. However, all of the estimates have been fairly robust for the different specifications and the main observations outlined in the previous sections hold for all of these. An issue, however, has been the lack of price variation in data. Price elasticities have not been strongly identified and are therefore deliberately not included as one of the key findings. Doing so would be an overstatement. An interesting agenda for further research would be to extend the analysis to include the period of the financial crisis in order to assess how the resulting drop in GDP in many countries affects travel packages and aviation.

4.4 Comparison to literature

It is relevant to compare the result of the two estimated models with elasticity values found in the literature. We base the comparison with the most recent and most comprehensive (to date) meta-study as described in Peng et al. (2014). The benefit of using Peng el al. is that they report elasticities as well as number of observations used to estimate the elasticities for a number of segments including origin of trip, type of statistical model, demand measure and distance. This enables us to derive an approximate average elasticity for segments that correspond to the data in this paper.

Table 6: The present model elasticities compared to meta-elasticities derived on the basis of Peng et al. (2014)

	Income elasticity	Price elasticity
Meta-elasticities		
Overall average	2.526	-1.281
Correction for distance	2.052	-1.383
Correction for demand quantity	1.374	-1.637
Correction for model type	1.124	-1.432
Correction for origin	1.522	-1.414
Model-elasticites		
AIDS (transport and leisure)	1.23	*
Tobit (plane tickets)	0.93	-1.16
Tobit (travel packages)	1.41	-1.97

Table 6 first present the meta-elasticities and we start out by presenting the uncorrected elasticities for income and prices given by 2.526 and -1.281. These values represent the overall mean of all meta-studies without taking into account which segment, model type or demand quantity is applied. As a result, we adjust these values for the various dimensions, first income, which correct the elasticity downward to 2.052, then a correction for the demand quantity applied in the model, then model type and finally place of origin. The final corrected meta-elasticities, 1.522 for income and -1.414 for prices can now be compared to the model-elasticities found in our study.

Overall, the results found in the present paper correspond well with the comparable income elasticities from Peng et al. (2014). The modelled income elasticities are slightly lower but considering the standard deviation as reported in the meta-study, they are actually not significantly different from the mean. Also, it is worth noting that the correction for the origin, which represents the biggest "uplift" of the meta-elasticities, is also the most uncertain (the segment with the highest relative standard deviation). Hence, there are considerable variations in the European market, which can explain the lower elasticities found in our study. Also, it is not clear from the meta-study whether the modelling entity refers to households (as in our paper) or individuals.

Generally, price elasticities are estimated with a higher variation as can also be seen in Peng et al. However, price elasticities correspond well with the finding of the meta-study. As for the income elasticities, it is interesting to see the relative difference between pure air tickets and travel packages, which is even more prominent for prices.

5 Concluding remarks

The paper has analysed both the general expenditures on travel and leisure as well as the specific expenditures on plane tickets and travel packages. Two separate modelling approaches were applied to the same Danish travel expenditure survey from 1996 to 2007 consisting of approximately 10,000 interviewed households.

In the first modelling approach an AIDS model framework was applied in order to analyse overall expenditures for travel and leisure. The model was estimated as a non-linear SUR model and revealed income elasticities with respect to expenditure on leisure and travel slightly above unity.

The second modelling approach applied was a bivariate Tobit model for the analysis of the expenditures on travel packages and plane tickets. The model was estimated using maximum likelihood methods. This revealed that the added value of travel packages was indeed perceived as an element of luxury for individual households since demand increases more than proportionally when income rises. It was hence found that travel packages had an income elasticity of 1.41 compared to an income elasticity of 0.93 for plane tickets in the fully constrained Tobit model. As discussed above, the income elasticities of travel packages and plane tickets in the Tobit model are similar to the overall income elasticity of transport and leisure in the AIDS model. This can be seen as an econometric robustness test of the results in the sense that different models are consistent in reproducing the mean.

When interpreting and comparing the results to the literature as in Section 4.4, the results are encouraging. When compared to the most recent and comprehensive meta-study by Peng et al. (2014) both income and price elasticities correspond well when compared with meta-elasticities. Given the relative high standard deviation as reported in the meta-study by Peng et al. this is encouraging. A comparison to commodity-based elasticities from the U.S. department of Agriculture, for the AIDS model, was given in Section 4.1. These values also comply well.

The impact of the findings in the present paper is of relevance to the tourism industry as it highlights the fact that travel packages are very different from plane tickets with respect to sensitivity to income and prices. Hence, a consequence of this is that travel packages can be expected to be more sensitive to business cycles than the expenditure on plane tickets. In more general terms it underline the importance of adjusting (optimal) pricing strategies in the tourism market with the business cycle and that these policies should be different for plane tickets and travel packages.

5.1 FUTURE RESEARCH DIRECTIONS

Future research directions, we believe, is mainly going in the direction of micro models estimated on the basis of pure micro data. These models have virtually no shortcomings as all of the methodology applied to aggregate modelling also applies to these. Moreover, they have the advantage of explicitly addressing heterogeneity and avoiding aggregation errors in estimation. Main challenges and directions for the future include.

- Development of methods for collecting data of good quality from the consumer end. The inclusion of reliable price information for the various products is essential.
- The use of panel data and panel-estimation methods to cope with lifecycle effects and correlation over time.
- The inclusion of additional wealth-effects not included in the income measure. This could include accumulated wealth-effects from housing or financial instruments such as stocks or bonds.
- Investigation of expenditure sensitivity through the years of the financial crisis. The variability in income and other wealth-effects (caused by the housing bobble) as

well a price-variation caused by oil-price variation and general fluctuations in the price of plane tickets should provide and interesting basis for empirical analysis.

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PAPER #4

EX POST SOCIO-ECONOMIC ASSESSMENT OF THE ORESUND BRIDGE

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Ex post socio-economic assessment of the Oresund Bridge

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ABSTRACT

The paper presents an ex post socio-economic assessment of the Oresund Bridge conducted ten years after the opening in July 2000. The study applies historical micro data to re construct the travel pattern with no bridge in place and compare this to the current situation. To complete the socio-economic assessment, the consumer benefits including all freight and passenger modes, are compared with the cost profile of the bridge. The monetary contributions are extrapolated to a complete 50 year period. It is revealed that the bridge from 2000–2010 generated a consumer surplus of €2 billion in 2000 prices discounted at 3.5% p.a., which should be compared with a total construction cost of approximately €4 billion. Seen over the 50 year period and by assuming a medium growth scenario the bridge is expected to generate an internal rate of return in the magnitude of 9% corresponding to a benefit-cost rate of 2.2.

A main advantage of analysing infrastructure ex post is the ability to learn and understand behavioural and methodological elements not foreseen at the ex ante stages. Following this we offer an extended discussion including two parts. Firstly we compare the ex ante predictions for the bridge to the current transport flows. The importance of having the right assumptions and the ability to model the phasing-in process are underlined. Secondly, we offer a wider discussion on why some projects are more beneficial than others. This is done by comparing the Oresund Bridge, the Channel Tunnel, and the Great Belt Link.

1. Introduction

In recent years large amounts of public funding have been channelled into infrastructure development. This has occurred at the European level as part of the development plans of the European Commission as well as at the national level in the different member states. Whereas there has been an increasing focus on ex ante assessment methods and models[1], little attention has been paid to ex post assessment as a means to analyse whether investments have met expectations and been socio-economically beneficial. An example is the French law on Internal Transport assessment[2], which requests an economic and social appraisal to be carried out before any major infrastructure project. However, as stated in Chapulut et al. (2005) it is rare that the actual performance is compared with the predicted one. Considering the size of many of these investments and the academic recommendation for more ex post studies as stressed in (Short and Kopp, 2005) this gives cause for concern. This is particular true as a large share of the ‘‘claimed’’ benefits of large infrastructure projects is related to dynamic effects and wider-economic benefits, which are often difficult to identify in ex ante studies. These effects emerge as economic multiplicative effects and are determined by the interaction between multiple markets (Lakshmanan, 2011; Koopmans and Oosterhaven, 2010). Dealing with these effects requires the development of spatial computable generalised equilibrium models (Adler and Prost 2010), which in many cases will be based on unrealistic assumptions. For instance, it may be difficult to reflect trade barriers and market imperfections properly and the aggregated nature of many of these models may not be suitable for coping with transport related impacts at a detailed geographical level. Further support for a more detailed ex post evaluation process is offered by Flyvbjerg et al. (2003), who provide evidence for ‘‘optimism bias’’ at the ex ante modelling stage.

In the paper we present an ex post socio-economic cost benefit assessment of the Oresund Bridge conducted ten years after the opening in 2000. The existing travel situation is compared with a counterfactual scenario, assuming no bridge, where transport costs as well as demand flows are projected from the base scenario without the bridge. Both scenarios are projected to 2050 using different growth assumptions. The consumer surplus

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[1] An example is the development of a common European transport demand model—the TRANSTOOLS model (Rich and Mabit, 2012)—which is currently being developed from its present version 2.6 to a version 3.0 to be finished by 2013. Other examples include the UK long distance model (Rohr et al., 2010) as well as national models in many countries.

[2] Loi d'Orientation des Transports Intérieurs—LOIT.

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Fig. 1. Zealand and South Sweden connected in the north by ferries between Elsinore and Helsingborg and in the south by the Oresund Bridge between Copenhagen and Malmö.

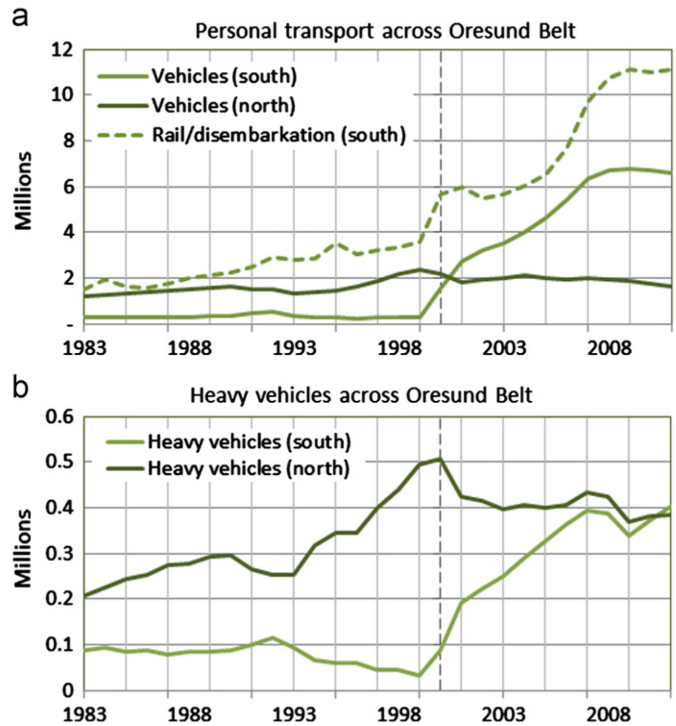

Fig. 2. (a and b) Passengers, vehicles and heavy vehicles crossing Oresund. Freight are included as heavy vehicles, however freight by rail is not represented in the figure.

effects are calculated from travel time and travel cost savings according to the "rule-of-the-half" approximation (Kidokoro, 2004). The calculation represents passenger benefits as well as freight benefits, which are further decomposed into various transport markets. The construction and maintenance cost profile of the bridge is calculated on the basis of annual reports and includes relevant land infrastructure in addition to the bridge.

1.1. Background

The Oresund Fixed link was opened in July 2000 and connects the Copenhagen area (the capital of Denmark) with Malmö, the second largest city in Sweden. The length of the fixed link—from shore to shore—is approximately 16 km and consists of 4 km immersed tunnel and 8 km cable-stayed bridge joined at an artificial island. The fixed link consists of a railway line and a two-lane motorway. Before the opening of the fixed link, three ferry routes connected Copenhagen with Sweden in the southern part of Oresund Belt; two in Malmö and one in Landskrona (a little north of Malmö) and a ferry route connected Elsinore and Helsingborg located on the coast of the narrow strait in the north. The three southern connections were replaced by the bridge whereas the Elsinore–Helsingborg connection has existed during the whole period but has gradually lost market shares to the bridge (Fig. 1).

Since the opening in 2000, the bridge has had a substantial impact on the transport pattern in the Oresund region, and the transport flow across Oresund Belt has increased significantly as seen in Fig. 2a and b below. The southern connection represented three ferry routes before 2000 and the bridge from July 2000.

Initially, right after the opening of the bridge forecasts seemed overoptimistic and the project economy looked challenging. However within the next five years, the traffic volumes changed and today exceed the prognoses from 1999 (Oresund, 1999).

Before the opening in 2000, the pay-back time of the bridge and the Danish landside constructions was estimated to 60 years using a 4% rate of interest (TRM, 2002). However, on the basis of the travel flow and revenues during the first year, this was raised to 70 and 100 years for a high and low growth scenario, respectively. After 2001, significant price reductions were introduced to improve the situation, in particular within the truck segment. In the following years passenger and freight demand started to rise and combined with favourable interest rates on loans the presently expected pay-back time is 50 years based on an average 3.5% rate of interest[3] (Oresund, 2010a). Clearly, this indicates the bridge as to be a sound investment also from a socio-economic perspective. However, no thorough retrospective analysis has been carried out in order to assess this in a detailed way. A reason for this is that the data requirement and preparation is substantial and requires a complete description of the before and after situations.

1.2. Literature

As pointed out in Short and Kopp (2005) and further emphasised in Sartori and Florio (2010), ex post studies should ideally play a central role in improving the process of infrastructure planning. However, planning and decision making in general tend to be politicised and ex post studies are rarely carried out in order to analyse whether projects and policies meet expectations. Olsson et al. (2010) divide ex post evaluations into four categories: (i) socio-economic evaluations, (ii) business value evaluations, (iii) holistic evaluations, and (iv) performance or indicator based evaluations. The socio-economic evaluation requires a variety of data to be available before and after the project implementation. These data should be decomposed into components which permit identification of the relative contribution of different factors as stated in Madsen and Jensen-Butler (1999). A further investigation of the effects in the labour and commodity market will either call for spatial generalised equilibrium (SGE) models or alternatively, data that can reveal the distribution of benefits. The literature is not rich on ex post studies and certainly not of the socio-economic type. However, an example is found in Anguera (2006) in an analysis of the Channel Tunnel. It was found

[3] The applied rate of interest was downgraded from 4% to 3.5% in 2006.

that, whereas consumer benefits increased due to lower prices as a result of competition from ferry operators, the gain for consumers was more than counteracted by capital costs and operation costs. As a consequence, the analysis revealed that the British economy would have been better off if the tunnel had never been constructed. This conforms well to the "optimism bias" hypothesis raised by Flyvbjerg et al. (2003) as the construction costs were significantly underestimated. Another study from 2004 on the Channel Tunnel is due to Hay et al.[4] . The study differs from the study of Anguera in the sense that it was based on indicators. However, the conclusion is largely identical. Hay et al. concluded that only little identifiable impact was found on any of the sectors that were expected to benefit directly or indirectly from the tunnel.

Meunier (2010) offers a detailed analysis of a large number of French projects and concludes that there is a large variation in cost as well as benefit estimates when comparing ex post observations with ex ante predictions. In his paper Meunier strongly argues for a need for ex post studies and in particular because these studies can be used to gain insight in the ex ante stage as regard parameters, elasticities and assumptions. Olsson et al. (2010) offer an ex post analysis of four different rail projects in Norway. In the study, only the level of transport flow is investigated (a socio-economic evaluation is not presented) in the before and after situations. It is indicated that the reference point for the ex post study is important for the outcome of the analysis. This is very much in line with the findings in the present paper as results obtained during the phasing-in process will be biased. Another Norwegian study is found in Kjerkreit et al. (2008), which consider post opening evaluation of eight road investment projects. The main finding is that seven out of eight projects perform better than expected due to the demand being higher than expected.

1.3. Organisation of the paper

The paper is organised into five sections. Section 2 describes the data and the zone system. Section 3 describes the social cost benefit assessment, discusses the method and describes how the consumer surplus is calculated in more details. Results are presented in Section 4 as a complete social cost benefit analysis, whereas a discussion and a conclusion are offered in Sections 5 and 6.

2. Data

In order to conduct a social cost benefit assessment, the total construction costs and the annual operation and maintenance costs are compared with the revenues and user benefits from operating the fixed link. These financial flows are found from (TRM, 2002) and from the annual reports of the three corporations running the bridge and landside constructions: The Oresund Consortium (Oresund, 2000, 2001, 2002, 2003, 2004, 2005, 2006, 2007, 2008, 2009, 2010a), A/S Øresund (A/S Øresund, 2004, 2005, 2006, 2007, 2008, 2009, 2010) and SVEDAB (SVEDAB, 2002, 2003, 2004, 2005, 2006, 2007, 2008, 2009, 2010).

To evaluate consumer behaviour, transport demand and transport costs describing the transport market before and after building the bridge, are required. More so, we need to project the actual travel situation to future years as well as constructing an artificial scenario describing the hypothetical development if no bridge were built in order to measure consumer surplus effects for the first 10 years and for the complete evaluation period of 50 years.

2.1. Zone system

It is important to introduce a common zone system in order to facilitate the disaggregated derivation of consumer surplus effects. The primary zone system is referred to as the IBU zone system (IBU, 2010). The IBU zone system is an extension of the European NUTS III[5] zone system. However, to limit the size of matrices for the present study, only five countries (Germany, Denmark, Sweden, Poland, and Norway) are considered which reduces the zone system from more than 1500 to 632 zones.

The advantage of applying the IBU system is that we can then apply existing IBU baseline matrices from 2005 and 2020, which are based on the TRANSTOOLS model (Rich et al., 2009). Another advantage is that these matrices are tour based and divided into proper transport modes and trip purposes.

The IBU system, however, is too detailed if paired with the applied micro data. In order not to "stretch" the micro data too much we have defined an aggregate zone system, here referred to as the AID system. The AID zone system is used to establish a set of aggregated travel matrices for the micro data, describing the actual travel flow to and from the crossing points of Oresund before and after the opening of the bridge. These are used to calibrate the total travel pattern from the IBU matrices.

The 632 IBU zones are aggregated to 12 AID zones; the 61 Danish IBU zones are aggregated to 5 Danish AID zones, 68 Swedish IBU zones aggregated to 6 Swedish AID zones, and finally 503 German, Norwegian and Polish IBU zones are aggregated to 1 common AID zone representing 'other countries'.

2.2. Travel demand

Most efforts are put into estimating the consumer benefits for personal transport. The two micro data sets, COMVIN1995/96 and WEEK9, describe in detail travel flows across Oresund before and after building the bridge. The travel proportions found in the two surveys are applied to construct travel matrices of the two scenarios analysed. The construction of these matrices also applies the Trans European matrices developed in the IBU project. Travel statistics from the different crossing points ensures exact crossing totals.

The COMVIN1995/96 travel survey includes approximately 30,000 observations and describes travel patterns across Oresund before the bridge had been built. The origin and destination of a trip is coded in a zone system corresponding to Danish and Swedish municipalities which are possible to join to the IBU (and AID) zone system. The data was collected as a part of the development of the Øresund Traffic Model by COMVIN J/V[6] (Oresund, 1999). The model was developed for the Oresund Consortium and designed for forecasting traffic on the Oresund Bridge.

The WEEK9 survey was conducted in week 9 in 2009 and describes travel patterns across Oresund after the bridge was built. The survey contains about 10,000 observations and can also be joined with the IBU zone system. Putting too much weight on this survey is troubled as it represents travelling at the end of February, which is not representative (the distribution of travel

[4] The paper exists only in a draft version, which is not to be quoted. The draft version can be found here: http://www-sre.wu-wien.ac.at/ersa/ersaconfs/ersa04/PDF/570.pdf.

[5] The IBU zone system is a refinement of the NUTS III zone system in southern Sweden and Northern Germany and was developed as a part of the HH corridor project (IBU, 2010).

[6] COWI Consulting Engineers and Planners, Denmerk & MVA Consultancy, UK & InRegia, Sweden.

Table 1
Overview of the crossings.

Crossing	Modes	Existence
Oresund Bridge; The new fixed link	Car and rail	Today
Ferry: Elsinore–Helsingborg	Ferry	Before the bridge and today
Hydrofoil boats: Malmö–Copenhagen	Ferry (only foot passengers)	Before the bridge
Ferry: Dragør–Limhamn	Ferry	Before the bridge
Hydrofoil boats: Landskrona–Copenhagen	Ferry (only foot passengers)	Before the bridge
Ferry: Copenhagen–Rønne[a]	Ferry	Before the bridge and today

[a] Rønne is the largest town of the Danish island Bornholm in Oresund. Bornholm also has direct ferry routes from Sweden and most Danish visitors to Bornholm take either the direct ferry route from Copenhagen or crosses Sweden to take the ferry from Ystad in Southern Sweden.

Table 2
Seven constructed trip matrices from the two parallel scenarios.

	2000	2005	2010	2020
Bridge		Bridge2005	Bridge2010	Bridge2020
No bridge	Base2000	NoBridge2005	NoBridge2010	NoBridge2020

purposes is skewed as many holiday and leisure trips are underestimated). Fortunately, the "after situation" is less critical as more data sources are available including the IBU matrices and crossing statistics.

Both data sets include detailed information about transport mode, trip purpose and the actual crossing point of Oresund. The transport market is separated into the four transport modes; car, rail, bus and ferry and the four travel purposes; business, leisure/shopping, holiday and commuting. The applied crossings are listed in Table 1 below and linked to the common zone system.

The division into different transport modes and trip purposes is mainly due to differences in value-of-time. Furthermore, for different travel purpose segments there are differences in the number of passengers per car. Although there is no difference between the commuting, leisure and holiday segments in terms of value-of-time their travel pattern is generally different.

In total, seven trip matrices and crossing totals are constructed describing the two parallel scenarios including the bridge and the hypothetical if no bridge had been built, as listed in Table 2 below.

The matrices are constructed such that the transport flow crossing Oresund reproduces the totals of the different crossings found from crossing statistics. In practise this is done by decomposing the matrices into three; an access and an egress travel flow matrix describing the travel flow from origin to the crossing and from the other side of the crossing to the destination, and a crossing matrix representing crossings differentiated into travel purposes and travel directions. These calculations are not that straightforward, since the crossing totals are not—by nature—differentiated into travel purposes. As a result forecasting has been based on growth assumptions as well as the travel flows of the scenarios. The construction of matrices is described in more details in Section 3.1.2.

The consumer benefits for heavy vehicles and freight are handled with a superficial approach based on crossing statistics and time-series. Travel flows, crossing statistics and financial flows are all projected to 2050 applying the expectations described in Oresund (2010a) and as described in Section 3.1.2.

2.3. Generalised cost and choice of route

To describe route and travel preferences we adopt a generalised cost formulation, which is essentially a measure of time and out-of-pocket costs weighted together in a monetary generalised cost term. To specify the generalised cost is challenging as we need information about the choice of route, which is often not recorded and especially not in a historical perspective. To facilitate this we apply two IBU cost matrices from the TRANSTOOLS model, which include information about average travel length and travel time components (free flow time, congestion time, wait time, etc.) between zone pairs in 2005 and in 2020. However, as a person living in Helsingborg and going to Elsinore is not likely to use the Oresund Bridge, we apply a weighted generalised costs that take account of specific crossing preferences conditional on the origin and final destination. This is accomplished by applying the proportions of route choices (or choice of crossings) revealed from the micro data.

To be able to calculate generalised cost matrices, travel costs are decomposed into three components; Access cost from the origin zone to the crossing point (on the same side), crossing costs of the specific crossing divided into mode and purpose, and finally the egress cost, which is the generalised cost from the crossing point (on the other side of the Belt) to the final destination. The access and egress matrices are based on the IBU cost matrices and the crossing costs are constructed from crossing characteristics. The total costs are then represented as the sum of these three components.

3. Social cost-benefit assessment

The construction of the bridge included several additional land side constructions in Denmark and in Sweden. The Oresund Consortium is managing the Oresund Bridge and the revenue of the bridge is split 50–50 between the two countries. Revenues are used to pay off the landside construction managed by A/S Øresund and SVEDAB AB. Consequently all relevant Danish and Swedish cash flows related to the whole infrastructure project, including the landside construction, are included in the assessment.

The approach generally follows the recommendations of the Danish Ministry of Transport. However, a discount factor of 3.5% as recommended by the European Commission is applied instead of the Danish recommended discount factor of 5%. Since 2006 the Oresund Consortium has also applied 3.5% internally. The higher Danish discount factor generally implies that large long-term investments are difficult to justify in socio economic terms.

All travellers including transit travellers are included in the assessment. The inclusion of transit travel is debatable as the user benefits are not related to Denmark or Sweden, however justified by the inclusion of EU subsidies within construction costs as the whole project is a part of the overall European infrastructure planning.

External impacts such as noise, accidents, emissions etc. are not included in the evaluation. As transport demand has increased, the external effects are likely to increase as well. However, as these effects to some extent may be substituted from central parts in Copenhagen and Malmö the sign may not always be negative. Also, emissions previously caused by ferries should be offset. In fact, as shown in Salling (2003), the net emission effect is positive although it account for less than 5% of the total B/C ratio.

Air traffic is not considered even though the whole infrastructure project included a significant upgrading of the accessibility to Copenhagen Airport. When the bridge opened, the catchment area of Copenhagen Airport was extended to include the southern part of Sweden. As Copenhagen Airport has a wide range of routes, it is reasonable to assume that the direct train connection from Sweden to Copenhagen Airport has resulted in substitution in Swedish access modes from transfer flights to train. The train passengers are included in the statistics; however their exact surplus might be imprecise. Additionally, the bridge connection may also have moved freight from seaways to rail, however, the magnitude is small.

3.1. User benefits

The method for calculating the consumer benefits follows standard principles and adopts the "rule-of-the-half" approximation as described in details in Kidokoro (2004) and further assumes a generalised cost form in which time and travel cost are weighted according to the different value-of-time components. A careful presentation of these principles can be found in Button (2010).

The current ex post study includes most direct and indirect benefits related to passenger transports. The fact that we are considering the surplus after ten years actually ensures that most of the phasing-in process has taken place and that many of the semi long-term effects are included and revealed. One example is the benefits related to changes in destination choice to the extent these affect the transport pattern, but also changes in choice of location (work and residence of individuals and the location of firms).

Not all indirect effects are included, however. One example is what may be referred to as "intra-margin effects" that may show up on both sides of the belt due to improved economic activity. These effects, which are of second or third order, could have been included if transport benefits were also measured for non-crossing traffic. However, this contribution, which could be negative or positive, has been left out as it would be fairly uncertain to represent e.g. congestion effects in an aggregated zone system. Note that consumer price reductions resulting from the increased competitiveness are beneficial for both consumers and firms. However, only consumer benefits are included in this approach.

It is assumed that foot passengers from ferries and rail passengers operate in the same transport market. As all ferry connections between Malmö and Copenhagen have been shut down, it is assumed that all foot passengers are converted to rail passengers. This is to some extent a technical definition making sure that we can calculate a consumer surplus effect for this segment. In any case, it will not change the way the surplus is calculated as we split trips by purpose and take account of differences in the origin, destination and crossing. Apart from significantly reduced travel times and waiting times, one may argue that the shift from ferry to train might result in additional comfort and reliability effects. These are not included separately, but are implicitly included within the time benefits. Furthermore, as most foot passengers between Copenhagen and Malmö used the connection from the centre of Copenhagen it is reasonable to assume that the route was less accessible than the rail connection of today. In total this implies that the actual consumer surplus of foot and rail passengers is in general underestimated.

3.1.1. Transport flow

As listed in Table 2, seven travel matrices have been constructed. The base2000 matrix is constructed from the COMVIN data and crossing statistics of the ferries. The micro data is up weighted to the base year and forecasted by using 1999 statistics from the ferries. The travel patterns are assumed identical to the observed in COMVIN, and the IBU matrices have been applied to include more details from the more disaggregated zone system.

The Bridge2005 and Bridge2010 matrices are constructed based on IBU2005 matrices, the WEEK9 survey and crossing statistics from 2005 and 2010. The forecasting of travel matrices involves constructing future marginal totals for the crossings. The IBU2020 scenario is applied to calibrate traffic flow from 2020 to 2050.

The transport flows of passengers are represented in tour matrices. These matrices have been calculated by decomposing IBU matrices at the crossings by applying the observed travel proportions from the two micro surveys. The IBU zones are aggregated to AID zones. As a result, the IBU trip matrix $T^{IBU}_{i,j,m,p}$ is separated into an access matrix $T^{Acc}_{i,o,m,p}$, a crossing matrix $M_{o,m,p,r}$, and an egress matrix $T^{eg}_{o,j,m,p}$ [7]. The access matrix describes the travel pattern from the origin i to the crossing point. The egress matrix is defined in a similar way and represents the trip from the other side of the crossing to the final destination j. The crossing matrix defines the transport flow on crossing o by mode m, purpose p and in direction r. The directional information in $M_{o,m,p,r}$ is automatically preserved in the final matrix as it is a "tour-matrix" in which an entry consists of two trips—the outbound trip and the homebound trip in combination. It is important to stress that all matrix components have to be tour-based including access and egress matrices as well as the probability matrix describing the travel pattern before and after the bridge.

The direction r defines whether the flow is going from Sweden to Denmark or in the opposite direction. Hence, the definition of index r relates to the origin and destination in that $r=1 \Leftrightarrow \{i,j | i \in DK, j \in SE\}$ and $r=2 \Leftrightarrow \{i,j | j \in DK, i \in SE\}$.

The trip pattern is then the "union" of the access and egress trip pattern and the crossing pattern

$$T_{i,j,o,m,p} = T^{Acc}_{i,o,m,p} \cup M_{o,m,p,r} \cup T^{Eg}_{o,j,m,p} \tag{1}$$

The two sub-matrices, $T^{Acc}_{i,o,m,p}$ and $T^{eg}_{o,j,m,p}$, are constructed as a product between the IBU matrices to the connection zones that relate to the crossings and a conditional probability matrix $\Pr\left(o | i \in i', j \in j', m, p\right)$ which in the before and after situation[8] expresses transport pattern as reflected in the micro surveys but aggregated to the AID zone system $\left(i', j'\right)$

$$T^{Acc}_{i,o,m,p} = \sum_j T^{IBU}_{i,j,m,p} \Pr\left(o | i \in i', j \in j', m, p\right) \tag{2}$$

$$T^{Eg}_{o,j,m,p} = \sum_i T^{IBU}_{i,j,m,p} \Pr\left(o | i \in i', j \in j', m, p\right) \tag{3}$$

The total trip matrix $\tilde{T}_{i,j,o,m,p}$ is constructed by letting $T_{i,j,o,m,p}$ be the sum of the access and egress matrices in Eqs. (2) and (3), and then calibrated to the count matrix $M_{o,m,p,r}$ matrix representing crossing statistics. This is described in (4). The final matrix, $\tilde{T}_{i,j,o,m,p}$, then conforms to the structure in the access and egress matrix but also to the counts on the various crossings represented by $M_{o,m,p,r}$. Hence, the final matrix is given by

$$\tilde{T}_{i,j,o,m,p} = \frac{T_{i,j,o,m,p}}{\sum_{o,m,p} T_{i,j,o,m,p}} M_{o,m,p,r}. \tag{4}$$

[7] A notation table is found in Appendix A.

[8] There are two probability matrices, one based on the COMVIN data measuring the before situation and one based on the WEEK9 and the IBU matrices measuring the after situation.

3.1.2. Forecasting of transport on the different crossings

Table 3 below shows estimated growth factors of the actual crossings of Oresund. The number of crossing cars and heavy vehicles increased by 4% p.a. from 1983 to 1999 and followed the general trend in GDP. But from 1993–1999 the growth was actually the double indicating high growth just before opening the bridge. After opening the bridge, cars increased by 6% and heavy vehicles by 3% p.a. from 2001–2011 which includes the effects of the global finance crisis and possible stagnation.

The Oresund Consortium operates with three forecasting scenarios (Oresund, 2010a): i) a growth scenario assuming growth in traffic as before the global recession starting with 5% growth p.a. and then declining towards a long term growth rate of 2.5% p.a., ii) a medium scenario starting with a 4% growth p.a. and declining to 1.8%, iii) and a scenario of stagnation starting up with negative growth followed by a moderate growth of 2% p.a. and declining to a long-term growth rate of 1% p.a.

The crossing totals of the hypothetical scenario of no bridge are applied a 4% growth proceeding the trend from 1983–1999. And the medium trend from Oresund (2010a) is applied to both scenarios from 2010 to 2050.

A challenge however, is to forecast the distribution of the transport market within the different crossing totals. Although we have information about trip purposes and modes in two reference years, these shares are far from stable over time. For instance, commuting has increased at a much higher rate than leisure and shopping trips.

The construction of a consistent $M_{o,m,p,r}$ matrix for all years is considered as a matrix estimation problem. Firstly, we create a set of constraints that represent: (i) flows on crossings by trip purpose and direction, and (ii) flows on crossings by transport modes. These targets have been forecasted on the basis of internal forecasts from the Oresund Consortium (Oresund, 2010a) and information that can be revealed from existing time series. The projection of "before" targets has assumed a linear development between 1983 and 1999.

The two constraints (i) and (ii) are then combined with a starting solution based on micro data and IBU matrices and subsequently fitted into an iterative proportional fitting algorithm (Deming and Stephan, 1940). The resulting matrix $M_{o,m,p,r}$ then reflects the information in the constraints (derived from aggregated forecast) and the transport pattern inherited in the micro data and the IBU matrices.

The travelling represented in the marginal totals of heavy vehicles and freight is not disaggregated further and is therefore estimated assuming linear extrapolation of the crossings.

3.1.3. Transport costs

Constructing the cost matrices follows a similar methodology as for the travel matrices. Hence, costs matrices are decomposed into three parts, describing access and egress costs as well as the crossing costs. The base of the estimations is the IBU cost matrices from the TRANSTOOLS model. The final cost matrix $C_{i,j,o,m,p}$ is given by

$$C_{i,j,o,m,p} = C^{IBU}_{i,o,m,p} + C_{o,m,p} + C^{IBU}_{o,j,m,p} \quad (5)$$

where $C^{IBU}_{i,o,m,p}$ represents average IBU cost matrix from the origin i to the crossing point o for mode m and trips purpose p.$C_{o,m,p}$ represents the crossing cost and is measure as total generalised costs related to the different crossing. It is calculated as

$$C_{o,m,p} = L_{o,m}KC_m + TT_{o,m}VoT^{TT}_{m,p} + WT_{o,m}VoT^{WT}_{m,p} + ST_{o,m}VoT^{ST}_{m,p} + CC_{o,p,m} \quad (6)$$

$L_{o,m}$ defines the length in kilometres and KC_m a driving cost per kilometre. It should be noted that $L_{o,m=train} = 0$. $TT_{o,m}$ is the travel time, $WT_{o,m}$ the waiting time and $ST_{o,m}$ the shift-time all weighted by a value-of-time component. $ST_{o,m=cars} = 0$ and refers to changing mode, e.g. disembarkation time before the bridge was build, but it also implicitly includes travel frequency considerations.

$CC_{o,m,p}$ is the crossing costs derived from current official prices. Price structure is assumed constant during the whole evaluation period even though prices continually have been adjusted to improve market shares. To calculate prices by transport purpose, we have assumed a discount structure in that commuters are supposed to have a commuter discount card. Moreover, from the micro data the average number of individuals per car has been used to deduct a price per person. Generally, as leisure trips usually involve more passengers, these tend to be relatively cheaper per person.

The price structure of heavy vehicles varies considerably according to the size of vehicle and number of crossings per year. As a result, a weighted average based on travel statistics has been applied.

The total generalised transport cost is then calculated as a weighted mean over all crossings as

$$GTC_{i,j,m,p} = \sum_o C_{i,j,o,m,p} \Pr\left(o \mid i \in i', j \in j', m, p\right) \quad (7)$$

where $\Pr\left(o \mid i \in i', j \in j', m, p\right)$ as before defines the probability of choosing a given crossing o conditional on $\{i,j,m,p\}$ and based on the AID zone system as described in Section 2.1.

A premise in the cost calculation in the after situation has been that the ferry routes before the bridge have maintained their price level. This is supported by the fact that all the ferries closed due to competition from the bridge. In other words, they were not competitive at the lower price level caused by the bridge. A detailed table representing monetary crossing costs represented by $L_{o,m} * KC_{car} + CC_{o,p,m}$ can be found in Appendix C.

Only the trips crossing Oresund are considered, hence we assume that the travel time for internal Swedish and Danish trips is unchanged and that the transport growth internally in Sweden and Denmark is not caused by the bridge. This simplification means that a congestion effect which may result from more Swedish cars (or Danish cars) in Copenhagen is not included. The effect may be negative or positive depending on the origin and destination of the trip and from where these trips have been substituted.

During the analysis it turned out that the detailed IBU cost matrices contributed with a lot of benefits in European zones relatively far from the Oresund Bridge. It was therefore decided, as a conservative precaution, to let $C_{i,j,o,m,p} = C_{o,m,p}$ and leave out time benefits anchored to $C^{IBU}_{o,j,m,p}$ and $C^{IBU}_{i,o,m,p}$. The magnitude of this approximation is difficult to determine. However, it is hard to imagine that significant detours are undertaken to use another crossing and we believe this effect will only have a minor impact on the overall picture.

3.1.4. Definition of the social value-of-time

The time benefits are driven by time savings, which are evaluated according to an external socio-economic value of time. In the study, we have applied standard value-of-time estimates derived from Fosgerau (2006) and available in TERESA[9]. The value of time components in 2010 DKK prices is listed in Tables 4 and 5. The driving costs and the heavy vehicle components are expressed in markets prices.

In this study 'Shift time' for rail represents the time spent on transfer between modes, e.g. access egress time of the ferries or the Oresund train.

[9] TERESA: A spreadsheet model for social economic analysis owned by the Danish Ministry of Transport available at www.transport.dtu.dk.

Table 3
Observed growth factors pro annum of the total crossings of Oresund.

	1983–2011 (%)	1983–1999 (%)	1993–1999 (%)	2001–2008 (%)	2001–2011 (%)
Cars	6	4	8	9	6
Heavy vehicles	4	4	7	4	3

The values have been converted from 2005 to 2020 by applying the principles defined by the Ministry of Transport. This implies that VOT are proportional to the gross national product in order to capture changes in productivity.

Wages are generally higher in Denmark as compared to Sweden and as a result the value-of-time is higher in Denmark. A problem, however, is that the standard classification of trip purposes in the official reference VOT are not completely identical for Denmark and Sweden. To create a consistent VOT table, we have applied the Danish classification and then scaled the value-of-time depending on mix of the residential location and work place. In Table 6 below, 'DK' refers to the official Danish VOT, whereas the "DK*0.8" represents the down scaling to Swedish values. The principle is that VOT follows the level of wages.

A Swedish business traveller travelling in Denmark will therefore have a lower value-of-time compared to a Danish business traveller travelling in Sweden or Denmark. Similarly, for commuters living in Sweden and working in Denmark we apply the Danish VOT.

The weighting of 0.8 in Table 6 is based on the ratio between a standard business VOT in Sweden and Denmark. In Sweden this value is approximately 240 DKK in 2010 prices (SIKA, 2009) corresponding to a Danish value of 325 DKK as listed in Table 4, also in 2010 prices. The difference in wages is supported by Eurostat. According to the earnings survey from 2006 the Danish fulltime annual wage was €29,824 compared to €20,598 for Sweden. In recent years the difference has decreased. The VOT component of 'other countries' is also weighted by 0.8 which is an approximation of German wages representing the main share of other countries.

3.2. Calculating consumer surplus

On the basis of the established matrices for trips and costs in the before and after situation, it is straightforward to calculate the consumer surplus as described in Kidokoro (2004).

All effects are calculated according to the 'rule-of-the-half' approximation, which in turn assumes a linear approximation of the demand curve. The rule-of-the-half is applied year by year in order not to use the approximation over a long time horizon.

As our main objective is to consider the average consumer surplus over a decade and not to mimic the shape of the demand curve, this approach facilitates our needs. We are however aware of the work by Nellthorp and Hyman (2001) stating that the changes in the generalised costs in a case like this could overestimate benefits by as much as 10% when applying the 'rule-of-the-half'. It should be said, however, that in this case the total revenue of the project are of such magnitude that a slightly overestimation of consumer surplus only has minor impacts on the Benefit Cost Ratio and the Internal Rate of Return. In other words, the overall picture is by no means affected by this potential overestimation. In addition it should be said that in general other assumptions have been conservative.

The consumer surplus $CS(i,j,p,m)$ is given by

$$CS(i,j,p,m) = \frac{(\Delta GTC_{i,j,p,m})\left(T^0_{i,j,p,m}+T^1_{i,j,p,m}\right)}{2} \tag{8}$$

where $\Delta GTC_{i,j,p,m} = GTC^0_{i,j,p,m} - GTC^1_{i,j,p,m}$ and where $GTC^0_{i,j,p,m}$ and $GTC^1_{i,j,p,m}$ define generalised monetary costs (weighted average between monetary costs and time costs) for the scenarios without and with the bridge. $T^0_{i,j,p,m}$ is the artificial demand matrix without the bridge, whereas $T^1_{i,j,p,m}$ is the demand matrix with the bridge. The total consumer surplus is given by (9) below:

$$CS = \sum_{i,j,p,m} CS(i,j,p,m) \tag{9}$$

However, for passengers we may also consider aggregations on mode or purpose in order to reveal the distribution of benefits within these markets.

4. Results

The contributions to the social cost benefit appraisal are grouped into two; the cost profile and the consumer surplus estimated from travel time and travel cost savings. All prices are in 2000 prices and discounted at 3.5% p.a. to the opening year of 2000. The approach follows the recommendations from the Danish Ministry of Transport, found in TERESA (2010).

4.1. Cost profile

The economic premises underling the statutory decision in 1992 was a total construction cost of 16.9 billion DKK 1990 prices. The final construction costs exceeded the budgeted cost by 42% and amounted in total to 29.5 billion DKK in 2000 prices (corresponding to €3.8) including landside constructions in Denmark and Sweden.

The construction costs are applied as a unit cost in 2000 and as a positive residual value in 2050 contributing with a total net present value of 17.5 billion DKK in 2000 prices corresponding to €2.3 billion. Further contributions to the total cost profile are the operation and maintenance costs, the revenue from running the three corporations (negative), and net financials such as interest income and expenses.

The operation costs are relatively constant during the 10 years. However a small increasing trend of 0.3% p.a. is detected and applied to the following 40 years. Revenues increase due to traffic growth. The major contribution to the revenue is the toll revenue. Interestingly, in the period from 2000 to 2010 traffic increases almost the double as the revenues due to a gradual lowering of crossing prices. For the future it is assumed that the current price structure is maintained and as a result it can be assumed that the forecasting of the revenues follows the traffic volumes.

From (Oresund, 2010a) it appears that the debt of the corporation will increase until approximately 2035 and afterwards decrease rapidly and attain zero around 2050. This trend is applied in the calculation of the future net financials as shown in Table 7. Depreciation allowance is not included as it is implicitly included in the construction costs. The figures show that relatively limited user benefits are actually needed for the project to be beneficial. The main driver of the cost profile is the revenues, and the forecasting of these has significant impact on the balance between the costs and benefits.

Due to the significant magnitude of the revenues, two additional forecasting scenarios are added; the stagnation scenario from Oresund (2010a) as described in Section 3.1.2 and an even more conservative scenario assuming no traffic growth from 2010 to 2050 (The effects origin from a general growth in the value-of-time). The three estimated net present values are listed in Table 8.

Table 4
Unit prices for passengers in DKK 2010 prices.

Mode	Component	Variable	Commuting	Business	Other
Rail	In-vehicle travel time	$VoT^{TT}_{m=rail}$	77	325	77
Rail	Waiting time	$VoT^{WT}_{m=rail}$	154	650	154
Rail	Shift time	$VoT^{ST}_{m=rail}$	116	488	116
Car	In-vehicle travel time	$VoT^{TT}_{m=car}$	77	325	77
Car	Congestion time/Waiting time	$VoT^{WT}_{m=car}$	116	488	116
Car	Driving cost per KM	$KC_{m=car}$	2.4	1.7	2.4

The vehicle operating cost is smaller for business travellers as we apply the market price approach.

Table 5
Unit prices for freight in DKK 2010 prices.

Mode	Component	Variable	*VoT*
Heavy vehicles	In-vehicle travel time	$VoT^{TT}_{m=rail}$	411
Heavy vehicles	Delay time	$VoT^{DT}_{m=rail}$	573
Heavy vehicles	Driving cost per KM	$VoT^{DT}_{m=rail}$	3.7
Rail (freight)	In-vehicle travel time	$VoT^{TT}_{m=rail}$	15.5

Table 6
Value-of-time applied for different residential-work combinations.

Residence	Place of work	VOT business	VOT commuting	VOT other
Denmark	Denmark	DK	DK	DK
	Sweden	DK*0.8	DK*0.8	DK*0.8
	Other country	DK*0.8	DK*0.8	DK*0.8
Sweden	Denmark	DK	DK	DK
	Sweden	DK*0.8	DK*0.8	DK*0.8
	Other country	DK*0.8	DK*0.8	DK*0.8
Other country	Denmark	DK	DK	DK
	Sweden	DK*0.8	DK*0.8	DK*0.8
	Other country	DK*0.8	DK*0.8	DK*0.8

4.2. User benefits

The traffic forecasts of passenger travel flows have been established as a combination of time-series trends and a matrix calibration in the given year. The travel flows of heavy vehicles and freight are found from time-series only. And the simplified approach for heavy vehicles and freight is outline in the following.

Busses and trucks are joined into a common heavy vehicle mode applying the unit price of trucks. This unit price implicitly includes average considerations of the goods transported. Busses are challenging as information about the number of passengers is unavailable. The number of busses represents less than 1% of the vehicles crossing Oresund and approximately 9% of the total number of heavy vehicles. The approximation of a common aggregated mode is therefore of less importance. The user benefits for heavy vehicles are estimated from crossing statistics, but supplemented by travel statistics from Statistics Denmark to differentiate the vehicles into nationality.

Very little information is available on rail based freight. To estimate the benefit of rail based freight, the goods weight is needed. From Statistics Denmark it is possible to isolate information of transit goods and goods going from Denmark to the rest of Scandinavia and vice versa. These statistics, which are available as time series form the base of estimating the user benefits of freight. The estimations assume that almost all freight travel through Denmark by rail crosses the Oresund Bridge.

Table 7
Cost profile discounted at 3.5% from 2000–2050 (million, 2000 prices).

Construction costs	−28,500 DKK	€−3824
Residual value	11,014 DKK	€1478
Operation cost etc.	−11,677 DKK	€−1567
Revenues	76,297 DKK	€10,236
Net financials	−37,127 DKK	€−4981
NPV	10,300 DKK	€1343

Table 8
Net present value discounted at 3.5% from 2000–2050 (million, 2000 prices).

Medium growth	10,007 DKK	€1343
Low growth	−6903 DKK	€−926
No growth	−14,634 DKK	€−1963

Table 9
Generalised costs in 2005, 2010 and 2020 for passengers, heavy vehicles and freight (in DKK 2010 prices).

		2005	2010	2020
Passengers	$GTC_{passenger}$ (No bridge)	397	421	470
	$GTC_{passenger}$ (Bridge)	319	331	364
	$\Delta GTC_{passenger}$	77 (€10)	89 (€12)	105 (€14)
Heavy vehicles	$GTC_{heavy\ vehicle}$ (No bridge)	1586	1590	1627
	$GTC_{heavy\ vehicle}$ (Bridge)	1160	1131	1164
	$\Delta GTC_{heavy\ vehicles}$	426 (€57)	459 (€62)	464 (€62)
Freight	$\Delta GTC_{freight}$ (Per Tonne)	12 (€2)	15 (€2)	16 (€2)

The estimation of generalised costs for passengers and heavy vehicles is based on the linear relation described in (6). The generalised cost of the hypothetical scenario assuming no bridge is a weighted average of the generalised costs of the available ferry routes, whereas the contribution from the scenario including the bridge is weighted between the market shares of the bridge and the northern ferry route. The generalised cost components from three selected years are listed in Table 9. The variation in generalised costs is due to changes in the value-of-time and the distribution of mode and market shares of the crossings. The reduced Swedish unit prices following the structure described in Table 6 are included.

Five estimated consumer surplus contributions are listed in Table 10. When we discount the contribution from the entire period from 2000–2050 at 3.5% p.a. to 2000, the total net present value is 72.3 billion DKK for passengers, 17.1 billion DKK for heavy vehicles and 2.5 billion DKK for rail freight. In total this corresponds to 91.9 billion DKK or €12.3 billion. The benefits from passengers alone represent 78% of the total consumer surplus.

As mentioned in Section 4.1, the robustness of the economic evaluation is tested by applying two less optimistic scenarios which have significant impacts on the magnitude of the total user benefits and revenues. The consumer surplus estimates are listed in Table 11 below.

4.2.1. Detailing the passenger consumer surplus

The data driven approach allows the passenger benefits to be decomposed into various transport markets. The contributions from the different travel purposes are interesting as they indicate whether gains are primarily accumulated in the labour market or due to leisure or shopping. The passenger consumer surplus estimated for 2010 amounts to 1965 billion DKK corresponding to an average of 56 DKK per crossing corresponding to €7.6. This number may at first glance seem as a high number if we think in

Table 10
Consumer surplus contributions (DKK, 2000 prices).

	2000	2005	2010	2020	2050
Passengers	1012	1370	1965	3517	7253
Heavy vehicles	72	330	448	799	1787
Freight (tons)	29	41	70	117	273
Total	1113 (€149)	1741 (€234)	2483 (€333)	4433 (€595)	9313 (€1249)

Table 11
Total consumer surplus discounted at 3.5% p.a. to 2000 in million DKK 2000 prices.

	Passengers	Heavy vehicles	Freight	Total
Medium growth	72,257	17,135	2537	91,929 (€12,333)
Low growth	55,515	13,329	2043	70,887 (€9510)
No growth	49,464	11,411	1803	62,678 (€8409)

Table 12
Consumer surplus for year 2010 divided by trip purpose.

Trip purpose	Consumer surplus (Million 2010 DKK)	Passenger per year, if no bridge (Million)	Passenger per year, bridge (Million)
Business	890 (56%)	3025	6082
Leisure and shopping	143 (9%)	6510	9203
Holiday	273 (17%)	8414	9513
Commuting	271 (17%)	5267	10,028
Total	177 (100%)	23,216	34,827

Table 13
Consumer surplus results for 2005, 2010, and 2020 by transport mode.

Year	Mode	Consumer surplus (Million 2010 DKK)	Passengers per year, if no bridge (Million)	Passengers per year, bridge (Million)
2005	Car	791 (64%)	6365	16,126
	Rail	444 (36%)	14,647	11,506
	Total	1235	21,012	27,633
2010	Car	976 (62%)	7800	19,316
	Rail	601 (38%)	15,416	15,511
	Total	1577	23,216	34,827
2020	Car	1357 (57%)	11,752	27,757
	Rail	1017 (43%)	18,646	23,409
	Total	2374	30,397	51,166

terms of short-term willingness-to-pay. However, as can be seen in Table 12, benefits are primarily generated in the business and commuter segment. The contribution from business trips is due to a much higher value-of-times.

Over time, the balance in the consumer surplus shifts towards a higher commuter share due to a more rapid increase in the commuter segment. In 2020, the commuter share is expected to be above 40% in terms of trips and just below 30% in terms of monetary surplus.

The consumer surplus of passengers is also disaggregated into the contributions from transport by car and rail in Table 13. It is seen that the cars have gained the most over the period (about 60%). However, as the growth expectations for rail passengers are higher than for cars, the balance is slowly shifting towards a more even balance. In 2020 it is expected that 43% of all benefits are related to rail compared to 36% in 2005. Again the balance is sensitive to the trend observed in the period from 2000–2010 where the slope of the rail passenger curve has been steeper. However, it reflects a best estimate given the data available.

When disaggregating the contribution to residential zones, Zealand (except greater Copenhagen) holds 22% of the passenger consumer surplus in 2005. Malmö holds 14% and Copenhagen 9%. In 2020 the share ascribed to Zealand will be reduced to 15%, whereas the consumer surplus ascribed to Malmö and Copenhagen will increase to 15% and 11%, respectively.

4.3. Cost-benefit assessment

The cost profile from Section 4.1 is compared with the consumer surplus contributions described in the previous sections to form a social cost benefit assessment shown in Table 14. The cost profile is extended by a contribution from tax distortion and net taxation factor of almost 10 billion DKK[10]. The total net present value is estimated to 91 billion DKK corresponding to approximately €12 billion. The internal rate of return is 9% and the B/C ratio is 2.2.

As discussed in Section 4.1, the financial flows themselves almost resulted in a beneficial project when applying the medium growth suggested in Oresund (2010a). Table 15 shows the estimated contributions when applying the two other less optimistic scenarios. In all three scenarios the social cost benefit assessments have B/C ratios significantly above 1. Even when assuming constant travel flows, hence also stagnation in revenues, the fixed link across Oresund would be a sound investment in a socio-economic perspective. When assuming status quo from 2010 to 2050, the only development applied is the yearly growth in prices of approximately 1% and still the B/C ratio is estimated to 1.4.

5. Discussion

As discussed in the introduction a major issue when investigating infrastructure projects ex post is to be able to learn and improve models and methods applied at the ex ante stage. Due to this we will start out discussing the modelling and forecasting efforts made prior to the bridge.

The base contributions presented to the Swedish and Danish governments ahead of the decision process are available in the document "The Government Proposition (1990/91)". The expected traffic volumes in the opening year were between 8000 and 10,000 cars per day and between 18,000 and 20,000 trips by train. The daily average travel flow during the first year was about 8700 cars and 14,600 train passengers.

The forecast from the Oresund Consortium forecasting model (Oresund, 1999) listed some of the expectations just before the

[10] Tax distortion and net taxation are estimated as 20% of all public cash flows and half the benefits of all business travel (TERESA, 2010).

opening of the bridge in greater detail. In Table 16 the expected flow of cars and trucks is compared with the actual crossing statistics. As the forecasting model expected the passenger ferries from Copenhagen to Malmø to continue operating after 2000, the passenger flows from public transport and disembarkation are difficult to compare with the actual statistics. Furthermore the forecasting model assumed instant inclusion of induced traffic resulting in very high expectations in 2000. However the 2010 forecast should be comparable with the newest crossing statistics as the forecasting model assumed a phasing-in period of up to 10 year.

The figures from 2010 show that the number of cars using the bridge has exceeded the expectations from 1999 by approximately 1300 cars per day. However the number of cars using the northern connection is almost 2000 less than expected.

Table 14
Cost benefit analysis, 2000–2050. Discounted 3.5% p.a. to 2000.

	(Million DKK, 2000 prices)	(Million EURO, 2000 prices)
Construction costs	−28,500	−3824
Residual value	11,014	1478
Operation costs	−11,677	−1567
Net financials	−37,127	−4981
Tax distortion and net taxation factor	−10,486	−1407
Total costs	−76,775	−10,300
Revenues	76,297	10,236
User benefit		
Consumer surplus passengers	72,257	9694
Consumer surplus heavy vehicles	17,135	2299
Consumer surplus freight	2537	340
Total benefits	168,225	12,269
Net Present value	91,450	12,269
Internal rate of return	9%	
B/*C* ratio	2.2	

Table 15
Cost benefit analysis, 2000–2050. Discounted at 3.5% p.a. to 2000.

	Medium growth	Low growth	No growth
Total costs DKK	−76,775	−77,836	−79,382
Revenues DKK	76,297	59,387	51,656
Consumer surplus DKK	91,929	70,887	62,678
NPV	91,450	52,438	34,952
B/*C* ratio	2.2	1.7	1.4
Internal rate of return	9%	7%	6%

Another imbalance in the market is the expected market shares for the different travel purposes. The forecasting model expected a relatively constant market shares with 80% leisure, shopping and holiday trips, however, it turned out to be around 40%. The figures in Table 17 show that in 2009, 41% of the trips were commuting trips compared with the expected 11%.

One of the main drivers of the growth in commuting trips across Oresund is the beneficial house prices in Skåne compared with the prices in the Greater Copenhagen. A significant share of the commuting trips actually consists of Danes moving to Sweden and continuing working in Denmark.

Table 18 below stresses the growth in integration in the Oresund Region; in 1999 the number of Danes moving to Skåne was 642, which corresponded to the number of Swedes moving to Denmark. However the year after the opening in 2001, the number of Danes moving to Skåne had increased by 150% compared with a 9% increase of Swedes relocating to Zealand.

The main lesson learned when looking at the ex ante forecasts is that the duration of the phasing-in process was difficult to forecast in detail. Also, the downward price pressure from the

Table 17
Expected and actual market shares of different trip purposes.

	Forecasting from 1999[a]			Actual market shares[b]	
	2000 (%)	2005 (%)	2010 (%)	2001 (%)	2009 (%)
Commuting trips	12	12	11	5	41
Business trips	9	9	8	29	19
Other trips	79	79	81	66	40

[a] The Oresund Consortium forecasting model (Oresund, 1999)
[b] Report about regional development (Oresund, 2010b)

Table 18
Agglomeration indicators.

	2001	2009
Daily business trips by car	2193 (29% of all trips)	3416 (18% of all trips)
Daily commuting trips by car	378 (5% of all trips)	7694 (41% of all trips)
Total commuters	3839	20,400
Swedes living in Copenhagen	2881	4000
Danes living in Malmö	3241	12,000
Relocations from Zealand to Skåne	1582 (74% are Danes)	3244 (75% are Danes)
Relocations from Skåne to Zealand	704 (52% are Danes)	2931 (70% are Danes)

Table 16
Number of cars and trucks per day 1995–2010.

			1995	2000	2005	2010
Car	Oresund Bridge	1999 forecasting[a]	0	13,606	15,224	17,085
		Actual travel statistics[b]		8658	12,710	18,367
	Elsinore–Helsingborg	1999 forecasting	3236	5070	5856	6803
		Actual travel statistics	4047	6061	5544	4813
Trucks	Oresund Bridge	1999 forecasting	0	979	1140	1320
		Actual travel statistics		347	737	899
	Elsinore–Helsingborg	1999 forecasting	798	425	494	573
		Actual travel statistics	810	1256	1020	983

[a] The Oresund Consortium forecasting model (Oresund, 1999)
[b] Travel statistics from the Oresund Consortium

Table 19
Comparison of passenger flows (thousand passengers) across the Oresund Bridge and the Channel Tunnel.

	Oresund[a]		Channel Tunnel[b]	
	2003	2008	2003	2008
Rail	5690	10,726	6300	9113
Car	9460	14,967	8600	7000
Total	15,150	25,694	14,900	16,113

[a] Travel statistics from the Oresund Bridge Consortium.
[b] Anguera (2006) and http://www.eurotunnelgroup.com/uk/eurotunnel-group/operations/traffic-figures.

ferries (TRM, 2002) was not foreseen. This caused a revision of the crossing prices, which turned out to be successful. A similar phenomenon was seen for the Channel Tunnel where the increased competition lowered crossing prices more than expected (Anguera, 2006; Chapulut et al., 2005). More specifically, the budgeted average crossing prices for the Oresund Bridge in 2002 turned out to be 38% lower for cars and 52% lower for trucks than included in the decision plans from 1991 (TRM, 2002). In this context it was largely an endogenous effect in the sense that it was caused by the competition between operators. However, it might also have been affected by exogenous factors as well, e.g. the development in wages, fuel prices and the housing market. In any case, it would have been difficult to solve the price-equilibrium problem prior to the bridge as it would have required a deep understanding of the business model for the ferry operators and such information was not public accessible.

5.1. Project evaluation—why the difference?

The present ex post study suggests that the Oresund Bridge was a sound investment from a social point of view. It is relevant to ask why this is the case, as other projects seems to be less beneficial. The Channel Tunnel project and the Oresund Bridge are in many aspects similar and an interesting match. Both projects connect two countries that were previously connected by ferries and only five years separate the two projects. Moreover, there is an almost identical passenger flow across the two connections in 2003 as seen in Table 19 below.

The figures show that the growth on the Oresund Bridge has outpaced the traffic growth in the Channel Tunnel and is approximately 50% larger in 2008. It is outside the scope of this paper to discuss the differences in the outcome in detail. However, it is obvious that the two projects are different in the sense that the Oresund projects seem to generate substantial induced traffic of which a significant part could be ascribed to "local agglomeration effects" between Copenhagen and Malmö. The Channel Tunnel project on the other hand is driven by long distance trips and may have been faced with more significant border effects. Furthermore, the tunnel faces strong competition from air transport, which in the past decade has experienced a steep price decline especially on major legs, such as London–Paris, where low-price carriers compete[11].

It is also interesting to compare the two projects with the Danish Great Belt Link from 1998. As the Oresund Bridge, the link across the Great Belt turned out to be a massive success for cars and not least for rail. In the period between 1996 and 2007 the number of passengers has grown from 11 Million to 28 Million (Storebælt, 2010). Compared to the Oresund Bridge, the Great Belt Link is different in the sense that it mainly services longer distance leisure trips and is not to the same extent driven by local labour market effects. However, it is similar in the sense that the transport across the Great Belt does not have serious competition from the airline industry as distances are too short. Moreover, compared to the Channel Tunnel project the Great Belt is an intra-country project and is therefore not affected by border effects.

In conclusion, three issues seem to have been relevant for the explanation of the success of the Oresund Bridge:

1. Low exposure to competition from aviation
2. Low degree of border effects once the project was completed
3. Large local labour market effects

The Oresund Bridge is strongly confirmative to the first and last statement. Due to the cultural and linguistic similarities between Sweden and Denmark the border effects seem less crucial. However the Channel Tunnel seems to have fallen short on all three statements. For the Great Belt project there is (to some extent) a lack of local labour market agglomeration effects, however, there is no exposure to competition from aviation and border effects do not exist.

6. Conclusion

The paper presents an ex post cost benefit analysis of the Oresund Bridge. The analysis was carried out ten years after the opening of the bridge in July 2000 and reveals that the bridge has generated significant consumer benefits, which over a ten year period discounted at 3.5% p.a. to 2000 amounts to €2 billion in 2000 prices, which amounts to 53% of the construction cost.

By applying the medium growth scenario from the Oresund Consortium assuming a long-term trend of 1.8%, the B/C ratio for a 50 year period is 2.2 with an internal rate of return of 9%. Further sensitivity tests show that not even stagnation during the next 40 years would make the B/C rate lower than 1.4.

The benefits of the bridge are widely driven by labour market effects, which is revealed from the business travel segment and commuting. In 2010 as much as 73% of the benefits were related to the labour market, a share that has been steadily rising since the opening. An important cause for this is the high integration in the Oresund Region.

The paper also provides an opportunity to compare ex-ante and ex-post studies for the Oresund Bridge as done in the discussion section. The main conclusion is that the developed traffic models generally performed reasonably well. The main problem was to actually project the dynamics of the phasing-in process and to incorporate the downward price pressure resulting from increased competition.

In the paper we also ask the more general question why some projects are beneficial and others are not? By comparing the Oresund Bridge, The Channel Tunnel, and the Great Belt Bridge we point to three issues that may have been decisive for the success of the Oresund Bridge: i) Low exposure to competition from aviation, ii) Low degree of border effects and, iii) Large local labour market agglomeration effects.

Appendix A. Notation

Notation	Description
$\{i,j\}$	Index of from and to zone within the IBU zones. Index of from and to zone within the AID zones.

[11] Ryanair and easyJet both passed the 10 million passenger mark in 2001.

$\{i',j'\}$	
o	Index of crossings.
m	Index of transport mode.
r	Index of travel direction between Sweden and Denmark.
p	Index of travel purpose.
$T^{IBU}_{i,j,m,p}$	IBU Trip matrix.
$T^{A}_{(i,o,m,p)}cc$	Access trip matrix, describing the travel pattern from the origin zone to the crossing point.
$T^{Eg}_{o,j,m,p}$	Egress trip matrix, describing the travel pattern from the crossing point to the destination.
$M_{o,m,p,r}$	Crossing matrix, describing the travel statistics on the different crossings.
Pr	Conditional probability matrix constructed from the micro data.
$T_{i,j,o,m,p}$	Total trip matrix including information of the crossings.
$\tilde{T}_{i,j,o,m,p}$	The final total estimated trip matrix.
$C_{i,j,o,m,p}$	Cost matrix.
$C^{IBU}_{i,o,m,p}$	Average IBU cost matrices from origin to the crossing.
$C^{I}_{(o,j,m,p)}BU$	Average IBU cost matrices from the crossing to the destination.
$C_{o,m,p}$	Total crossing costs.
$L_{o,m}$	Travel length.
KC_m	Driving costs (are 0 for rail).
$TT_{o,m}$	Travel time.
$VoT^{TT}_{m,p}$	Unit price for travel time.
$WT_{o,m}$	Waiting time.
$VoT^{WT}_{m,p}$	Unit price for waiting time.
$ST_{o,m}$	Shift time.
$VoT^{ST}_{m,p}$	Unit price for shifting.
$CC_{o,p,m}$	Crossing costs (ticket or toll prices).
$GTC_{i,j,m,p}$	Generalised travel costs.
$CS(i,j,p,m)$	Disaggregated consumer surplus on origin, destination, purpose and mode.
CS	Total consumer surplus.
$T^{0}_{i,j,m,p}$	The artificial demand matrix if no bridge had been built.
$T^{1}_{i,j,m,p}$	The demand matrix with the bridge.

Appendix B:. Acronyms

Acronym	Description
EC	European Commission.
TRANSTOOLS	A European large scale transport model, applied for the IBU project.
IBU	An Oresund Region project evaluating a fixed link between Elsinore and Helsingborg. The study is based on the TRANSTOOLS model. The base matrices (IBU2005 and IBU 2002) and the applied zone system origin from this study.
AID	The notation of an aggregated zone system.
COMVIN	A micro data survey from 1995/96 describing travel activities across Oresund.
WEEK9	A micro data survey describing travel activities across Oresund during week 9 in 2009.
HH	The travel corridor between Elsinore (Helsingør in Danish) and Helsingborg.
VOT	Represent ‘Value of Time’.
TRM	Danish Ministry of Transport.
CS	Consumer Surplus.

Appendix C:. Crossing costs 2010

Crossing point	Purpose	Mode	Price/ person*
Oresund Bridge	Commute	Car	181
	Leisure/ shopping	Car	194
	Holiday	Car	194
	Business	Car	309
	Commute	Rail/ Disembark	80
	Leisure/ shopping	Rail/ Disembark	128
	Holiday	Rail/ Disembark	128
	Business	Rail/ Disembark	160
HH	Commute	Car	183
	Leisure/ shopping	Car	175
	Holiday	Car	175
	Business	Car	399
	Commute	Rail/ Disembark	48
	Leisure/ shopping	Rail/ Disembark	48
	Holiday	Rail/ Disembark	48
	Business	Rail/ Disembark	48
Hydrofoil boats (Malmö)	Commute	Rail/ Disembark	72
	Leisure/ shopping	Rail/ Disembark	72
	Holiday	Rail/ Disembark	72
	Business	Rail/ Disembark	72
Dragør–Limhamn	Commute	Car	241
	Leisure/ shopping	Car	212
	Holiday	Car	212
	Business	Car	337
	Commute	Rail/ Disembark	150
	Leisure/ shopping	Rail/ Disembark	150
	Holiday	Rail/ Disembark	150
	Business	Rail/ Disembark	150
Hydrofoil boats (Landskrona)	Commute	Rail/ Disembark	120
			120

Leisure/ shopping	Rail/ Disembark	
Holiday	Rail/ Disembark	120
Business	Rail/ Disembark	120

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