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Environmental impact of long distance travel

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Abstract

This paper presents an analysis of the CO₂ emission resulting from long distance travel by Danes. The emissions are analysed as the Danes' footprint the whole way from Denmark to the final destination. International travel represents 31% of the Danes' CO₂ emission from passenger travel and the climate burden from long overseas distances is especially high even though only few travel overseas. The travel activity is furthermore increasing much more for long distances than for European destinations. Domestic travel activity with overnight stay is nearly stagnating. The study furthermore shows that the Danish development is not especially outstanding compared to other countries.

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Keywords: long distance travel; climate foot print; development long distance travel; air travel; Europeans' holiday activity

1. Introduction

Long distance travel is the fastest growing passenger mobility segment with an annual growth rate for Denmark over 3% above a 10-year period (Knudsen 2015). As long distance travel is close to 100% motorised this has a substantial and increasing environmental impact and is challenging the European policy for a reduced climate impact from the transport sector according to the White Paper (European Commission 2011). The mode choice furthermore challenges the policy to change modal-split for medium distance travel towards more transport by rail.

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According to a Danish long distance travel survey conducted in 2010–11 each Dane has on average 5.5 low-frequent journeys with overnight stay(s) per year. These represent 7,777 km corresponding to 2 return trips from Copenhagen to Milan. Roughly one third of the trips are international, one third goes to second homes and one third goes to other domestic destinations. However, 90% of the kilometres are bound for international destinations and 2/3 of the kilometres are related to long duration journeys (at least 5 overnight stays).

The purpose of this paper is to present the effect this travel activity has on the climate measured as the overall footprint of the Danes' travel activities. Data for the year 2010 is analysed. The results are shortly compared with the development in other European countries.

2. CO₂ emission and climate burden from long distance travel

Several references point to the fact that aviation only represents 2% of the global CO₂ emission, e.g. (Loo et al. 2014; Postorino and Mantecchini 2014). However, (Peeters and Dubois 2010) find that the overall tourism activity including both travel to the destination and the travel activity at the location represents 4.4% of the global CO₂ emission in 2005 with an annual growth rate of 3.3% forecasted up to 2035.

Various authors have shown the effect of long distance travelling from the aviation point of view by calculating the entire CO₂ emissions from e.g. European aviation (Alonso et al. 2014) or a certain airspace or airport, e.g. (Loo et al. 2014; Postorino and Mantecchini 2014). (Alonso et al. 2014) present three projections of a development in CO₂ emission from Europeans air travel from 2010 to 2030. In a central projection the CO₂ emission will increase from 216 to 293 megatonnes or 1.8% per year on average. The lower and upper projections are 207 megatonnes (0.2% decrease per year) and 334 tonnes (2.7% increase per year).

In this paper we intend to relate the emission and wider climate burden directly to the travel activity. Only by understanding the climate effect directly as a result of the travel activity in general is it possible to assess the long term development and eventually try to influence the effect in a more sustainable direction by policy and other means without affecting the fundamental demand for mobility.

Unfortunately, only few survey based studies exist about long distance travelling in Europe. For Norway, Sweden, Finland, Great Britain, Switzerland and France a long distance travel survey is part of the NTS. However, the British survey, even though it is well documented (Dargay and Clark 2012), only includes domestic travel. Finland and France have not published analyses of the development in journals but smaller unpublished analyses of travel behaviour exist. Results from the Swiss survey are not known to the author. For Sweden (Frändberg and Vilhelmson 2011) analyse the development in domestic and international Swedish long distance travel activity and report stagnating domestic travel, but a 50% increase in kilometres internationally from 1995 to 2006. More than half of the kilometres for domestic and international long distance travel all together were by air. For Norway (Vågane, Brechan, and Hjorthol 2011) report an increase in number of journeys per Norwegian by 33% from 1998 to 2009. International trips even increased by 53% from 2001 to 2009. 52% of the climate impact of all Norwegian passenger travel stems from air travel (Aamaas, Borken-Kleefeld, and Peters 2013).

Most of the European-wide research literature is methodological as in the case of the two European Union projects MEST carried out from 1996–99 (Axhausen et al. 2003) and Kite from 2007–09 (“Kite – A Knowledge Base for Intermodal Passenger Travel in Europe” 2009). Two cross-country databases collected by Eurostat exist, Dateline (Gomes and Santos 2004; Madre et al. 2007) from 2001/02 covering Switzerland and 15 member states and the continuous Tourism Demand Survey. The latter has been collected mandatorily from the actual member states since 1996 and some indicators are reported to Eurostat (see <http://ec.europa.eu/eurostat/web/tourism/data/main-tables>). Data from the Tourism Demand Survey is unfortunately not analysed at a cross-country level based on micro-data. However, for Denmark a full micro-dataset collected since 1996 is available and has been used by the author for some of the results in this paper.

3. Method

3.1. Data

Calculation of CO₂ emission from air travel is based on data from two passenger databases, the international ticketing database Sabre for scheduled air travel and a Danish Airport database for all air travel from Danish

airports, the OAG database (www.OAG.com) for air traffic and an emission database for air crafts from the Environmental Agency (Winther et al. 2013).

The data are extracted for the year 2010 in the following way:

- Sabre data: The number of Danish passengers by scheduled air traffic in and out of Denmark is extracted. Danish passengers, understood as people living in Denmark, are identified by the IP number of the computer by which the tickets were bought. Data include information about the final destinations and the airports at which the passengers changed flight on their way. Some corrections have been needed due to imprecise information and some errors which have been impossible to correct for are still actual, see (Christensen and Dargay 2015).
- Danish Airport data: Number of passengers of all nationalities who fly in and out of Denmark by both scheduled and charter traffic with information about their first destination airport.
- OAG data: Number of flights in and out of Danish airports with information about their destination, number of seats and aircraft type.
- Emission database: Emission of CO₂ and other pollutants for each operation of a flight dependent on aircraft types and distance.
- Distances between the airports are mainly found from www.world-airport-codes.com (updated every time a new airport was added to the database during 2010–2015. Smaller changes might therefore have occurred).

3.2. Method to calculate CO₂ emission from air travel

The calculations are split into two parts. In the first part the emission is calculated for Danish passengers from the airport where the aircraft departs from Denmark and till the first international airport for either final destination or for a hub. The first part also comprises the emission for Danish passengers at their homebound trip from the last hub/destination before the Danish airport. The emissions for which Danish passengers are responsible are calculated as their share of the overall emissions from the aircraft. The emission from the domestic air travel is added to this as part of the calculations. The second part of the calculations concerns the emissions between the hub airport and the final destination and at all transfer flights underway.

The first part of the calculations is based on a combination of the following steps:

1. Calculation of CO₂ emission from the aircrafts at the first stage in and out of Denmark based on information about the distance between the airports, the aircraft types and numbers according to the OAG database and the CO₂ emission for each operation of the flight based on data from the emission database. An air flight consists of a- LTO part (taxiing in the airport, take off, climbing and landing) which is independent of the travel distance and a cruise part dependent on the travel distance. The emission database includes all emissions from each of these operations.
2. The calculated CO₂ emission is applied for all passengers at the actual connection according to the Airport database (including transfer and transit passengers). A share of these passengers are Danes; the number is derived from the Sabre database. The calculated share is used as the CO₂ emission for the Danish passengers at the first stage in and out of Denmark
3. Similar calculations are made for domestic travel, including the transfers between a province airport and Copenhagen. The calculation of the domestic travel only includes the outbound trip to avoid double counting.

The Sabre database as well as the OAG database only or mainly include scheduled air traffic. Emissions from charter traffic therefore need to be added based on some assumptions which is done in the second part too.

The transfer part of the international travel from one hub to another or to the final destination as well as the charter travel are made by aircrafts which are not known. Some assumptions about their emissions must therefore be made. The first assumption is that the CO₂ emission from these aircrafts on average has an emission coefficient similar to the mean coefficient for the first stage travel at the same distances. It is furthermore assumed that the mean seat occupancy is the same as for the first stage flights in and out of Denmark. Calculation of the second part follows these steps:

1. The CO₂ emission per seat kilometre is calculated for the first stage flights based on the calculated CO₂ emission per flight in point 1, the number of seats per plane according to the OAG database and the distance between the two airports.
2. The seat occupancy is calculated based on a combination of the number of seats from the OAG database and the overall number of travellers at each airport pair according to the Airport Database.
3. For different distances is chosen a CO₂ emission per seat kilometre and a seat occupancy which is used for all flights at the chosen distance interval (see below).
4. The CO₂ emission from all transfer and charter passengers and the rest is calculated for each pair of airports by multiplying the emission coefficient per seat kilometre, the distance and the number of Danish passengers according to the Sabre database and dividing by the seat occupancy.

For the charter travel the number of Danish travellers is unknown. Only the overall number of charter travellers in and out of Danish airports is known. It must therefore be assumed that all charter travellers are Danish which is obviously not fully correct. Residents in southern Sweden are known to use Copenhagen Airport because it is the airport closest to their home. On the other hand many residents living in the southern part of Jutland prefer to drive to Hamburg where the number of destinations is higher than from the Danish charter airport in Jutland (Billund) and parking is free.

3.3. Choice of emission coefficients

For the trips from Denmark to the destination and to the first hubs the results are calculated directly from the emissions of the used flights to the destinations as described above. For the trips to the final destinations of the transfer passengers, the parameters to be used for the calculations must be chosen.

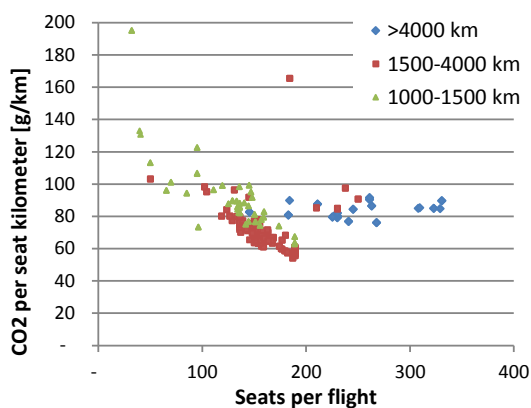


Fig. 1. CO₂ emission per seat kilometre dependent on number of seats per flight. Colours indicate the length of the route.

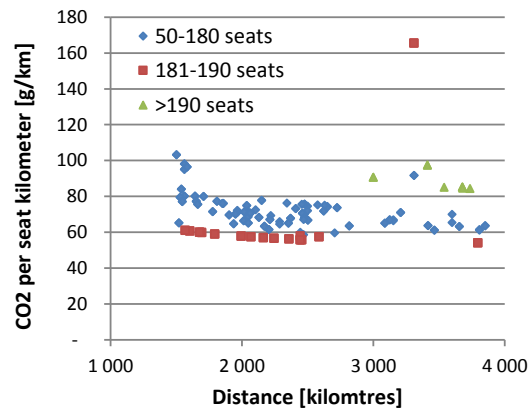


Fig. 2. CO₂ emission per seat kilometre shown dependent on distance. Colours indicate the length of the number of seats.

CO₂ emission coefficients calculated as the emission per seat kilometre are dependent on the size of the aircraft and on the distance between the airports due to the emission from the cruise part of the flight. The LTO part, which is independent of the distance, is rather big compared to the cruise part at short distances whereas it is negligible for long haul flights.

Figure 1 shows the emission per seat kilometre dependent on number of seats for 3 distance bands. These are chosen so that the emissions for each distance band differ rather clearly from each other. For the routes longer than 4,000 km the emission per seat km is only varying a little and is independent of the number of seats. As can be seen from the number of seats nearly all these routes are served by wide-body jets. A mean emission coefficient (85 g/seat km) can be used for all travellers having a stage longer than 4,000 km.

At the distances from 1,500–4,000 km the emission varies according to the size of the aircraft, i.e. the more seats the smaller the emission per seat kilometre. In general, the emission is lower per seat km than for the long haul wide-body jets. This is probably due to the single-aisle aircrafts used for these distances. The length of the body only seems to have little influence on the emission per km causing a lower emission coefficient per seat km the longer the aircraft is. For a few of the observations in the interval a wide-body jet seems to be used and an outlier is included too. Figure 2 shows that it is acceptable to use a common emission coefficient. This is calculated to 71 g CO₂ per seat kilometre for the distance interval.

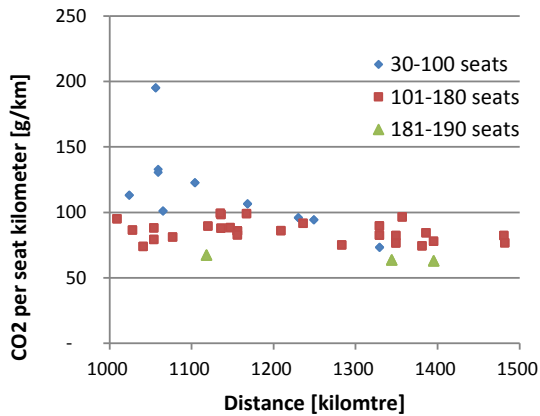


Fig. 3. CO₂ emission per seat kilometre dependent on number of seats per flight for the airport pairs. Colours indicate the number of seats per flight.

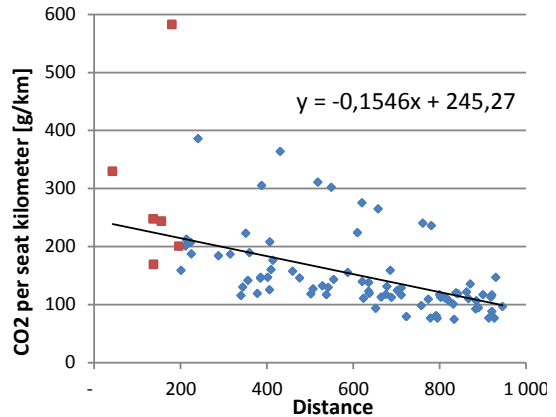


Fig. 4. CO₂ emission per seat kilometre shown dependent on distance for short distance flights. The equation for the trend line for distance band 200–1,000 km is shown in the figure.

For the shorter distances of 1,000–1,500 km the emission varies by number of seats in the aircraft in the same way as for the 1,500–4,000 km distances, but the level is a bit higher. This is due to the shorter cruise distance and higher influence of the LTO part of the trip. Figure 3 shows a small increase in the emission coefficient by shorter distances. The linear approximation: $-0,0697 \cdot \text{distance} + 175$ is used as CO₂ emission in g per seat kilometre.

Finally, the emission per seat km is much more unclear for short distances less than 1,000 kilometres (see Figure 4). One reason is the bigger influence from the LTO operation and consequently the exact distance. Another reason is the use of a broad range of different types of aircrafts at the short distances with both jets and turbo props and possibly also both very small and old aircrafts. The linear approximation $-0,1546x + 245$ is used for CO₂ emission in g per seat kilometre for the distance band of 200–1,000 km. Under 200 km no rules can be used and an average emission based on domestic flights is calculated.

It is decided to use the average seat occupancy at the same distance bands, i.e. 82% for long haul, 73% for 1,500–4,000 km, 71% for 1,000–1,500 km and 69% for short distance trips and 61% under 200 km (based on domestic trips). The choice can be justified by the values listed in (Doganis 2009) who mentions that the European average passenger seat factor is 68.9% for network carriers at domestic/intra-European connections and a seat factor of 70 for SAS. For European and Middle East destinations the factor is 1% higher on average. When low-cost airlines with a seat-factor 12% higher according to (Doganis 2009) are considered too, an average seat factor of 69/71/73% for short and medium haul seems acceptable. No passenger seat factors are found in the literature for long haul.

As mentioned, charter traffic is not included in the OAG database and the emissions therefore need to be calculated based on the average emission factors in the same way as for the transfer stages. It is known that charter travel has a higher seat occupancy than scheduled traffic (Pels 2008). It is chosen to use a seat occupancy of 90%. Compared with figures mentioned by (Doganis 2009), a level between 85 and 90 seems to be correct.

3.4. Calculation of CO₂ emission for other traffic

To be able to compare the emissions from air travel with other kinds of traffic, CO₂ emissions from passenger cars and public transport are calculated too. The daily kilometres by passenger car as a driver and by public transport are found from the Danish National Travel Survey (DTU Transport's Data and Model Center n.d.). It is extracted for trips under 100 km and for 100 km and above, a distance which many countries consider as long distance travel. For travels with overnight stay is used a dedicated long distance travel survey conducted in 2010–11. In the survey the respondents were asked about their domestic and international journeys with overnight stay(s) during the last three months before the interview.

The CO₂ emission for car traffic is calculated with an emission coefficient of 206 g/km which is found to be the mean emission coefficient for the Danish car park in 2010 based on the national energy statistics and the car kilometre statistics found by odometer reading. For long distance travel for which only passenger kilometres are known the car kilometres are calculated from a car occupancy of 2.02 found in the survey.

For trains a CO₂ emission coefficient of 57 g CO₂ per passenger kilometre is used based on the annual account and the green account from the Danish Rail Company from 2010 (DSB 2011a and b). According to these the company produced 2,270 million passenger kilometres by regional and intercity trains emitting 129,378 tonnes of CO₂. The emission coefficient of 57 gr/kilometre is used for all public transport modes as a very rough approximation. For short distances a relatively high share of public transport is made by bus which has an emission coefficient per traveller that is possibly higher than for passenger cars due to a low seat occupancy outside the big cities. On the other hand a high share of the daily trips under 100 km is made by electric trains for which the emission is zero according to the rail account. For international public transport emission coefficients should be calculated based on the mix of train types, energy production and seat occupancy which, however, is not easily available.

4. Results

The calculated CO₂ emissions from air travel are shown in Table 1. The overall CO₂ emission is 3,810 million tonnes per year, 1.1 tonnes per Dane. ¼ of the emission is produced by the scheduled air traffic between the transfer airports or to the final destination. The contribution from charter traffic is smaller than the passenger kilometres reflect because of the high seat occupancy. 7% of the trips are domestic. 80% of the travellers fly directly to their destination from Denmark and only 14% of the travellers have a flight where they need a transfer outside Denmark. However, 18% of the passenger stages (counted in the airplanes so that each traveller counts as a passenger several times) are made by planes without any destinations in Denmark.

Table 1. Calculated passengers, mileage, and CO₂ emission for different types of air travel.

	Travellers [Mio.]	Passengers [Mio.]	Pass. km [Mio. km]	CO ₂ [Mio. ton]	CO ₂ /pass km [g/km]
Domestic	0.83 (7%)	1.24 (7%)	249 (1%)	80 (2%)	323
Between DK and destination/ first transfer	6.87 (58%)	11.373 (64%)	17,554 (51%)	2,116 (56%)	121
Charter	2.51 (21%)	2.51 (14%)	7,032 (21%)	578 (15%)	82
Transfer and between transfer and final destination	2.69 (14%)	2.66 (15%)	9,449 (28%)	1,036 (27%)	110
Total	11.90 (100%)	14.93 (100%)	31,902 (100%)	3,810 (100%)	111

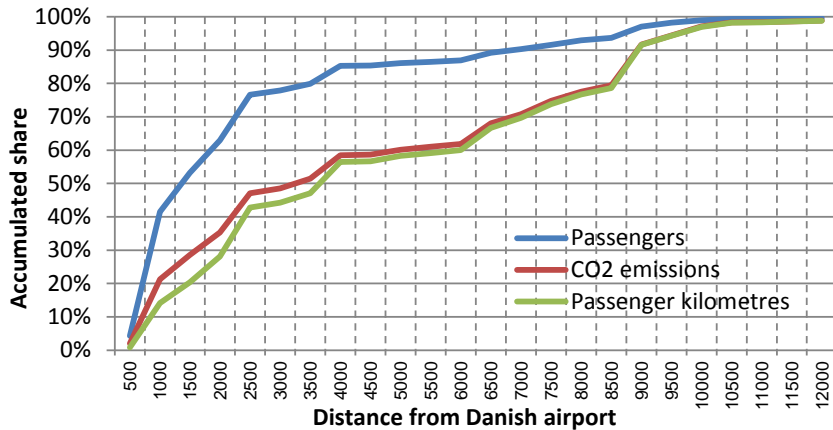


Fig. 5. Accumulated share of CO₂ emission, passenger stages and passenger kilometres by distance from Denmark to the location of the destination or flight change.

77% of the passenger stages end inside mainland Europe (2,500 km) and 85% inside Europe (including the Atlantic islands) and the Mediterranean countries (4,000 km). However, only 47% of the emissions are burned off inside European mainland destinations or hubs and 58% inside Europe/Mediterranean countries (see Figure 5). Great Britain and Ireland are taken as ‘mainland Europe’ for this reference. Figure 6 that the scheduled flights are dominating at the short European distances whereas charter travel is still the preferred mode to the Mediterranean holiday destinations. Direct flights are seldom outside Europe.

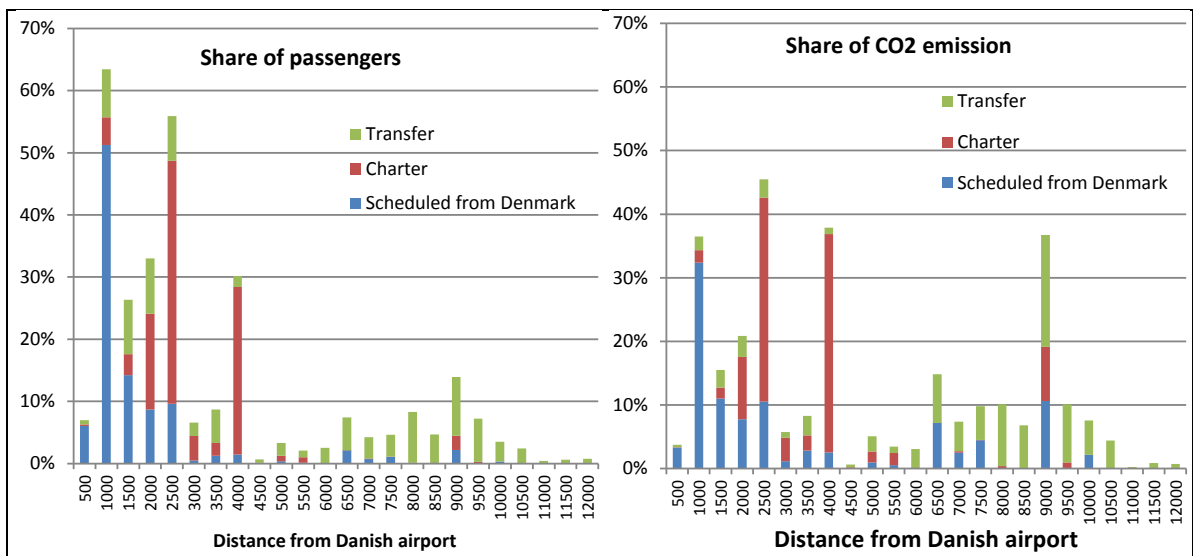


Fig. 6. Share of CO₂ emission (top) and passenger stages (bottom) from international travel shown at the distance their destination or flight change is away from Denmark.

Table 2 shows that the main contributor to the overall CO₂ emission from passenger traffic by Danes including daily travel is the passenger car which exhausts 68% of the CO₂ emissions whereas air travel represents 28%. In all, 31% of the emissions are due to international travel of which air travel is responsible for 88%.

Table 2. Calculated CO₂ emissions in thousand tonnes from daily travel and long distance travel by car, public transport and air. Source: Danish National Travel Survey and TU Overnight Survey (Christensen and Knudsen 2015).

CO ₂ emission in thousand tonnes	Car	Public transport	Air	In all
Domestic trips <100 km	6,993	118		
Domestic trips > 100 km	1,673	222	80	
Domestic trips with overnight stay(s)	182	48		
International one day travel	2			
International travel with overnight stay(s)	395	101		
All International air travel			3,416	
Total domestic	8,848 (95%)	389 (4%)	80 (1%)	9,317 (67%)
Total international	397 (9%)	101 (2%)	3,730 (88%)	4,228 (31%)
Total	9,245 (68%)	489 (4%)	3,810 (28%)	13,545 (100%)

Car is dominating for international travel at distances less than 500 km with public transport as a secondary possibility (see Figure 7). From 500 km (Stockholm and Oslo for instance) there is a strong competition between all three modes up to 1,000 km (Paris, London, Basel, Budapest) from where public transport is getting less and less attractive whereas air travel and car is still competing up to 2,000 km (Rome). Over 2,000 km flights is more or less the only mode (2,200 km seems to be an outlier). The strength of the car for the middle distances compared to both public transport and air travel is properly the possibility to carry more passengers at the same price and the distance still being within one to two driving days.

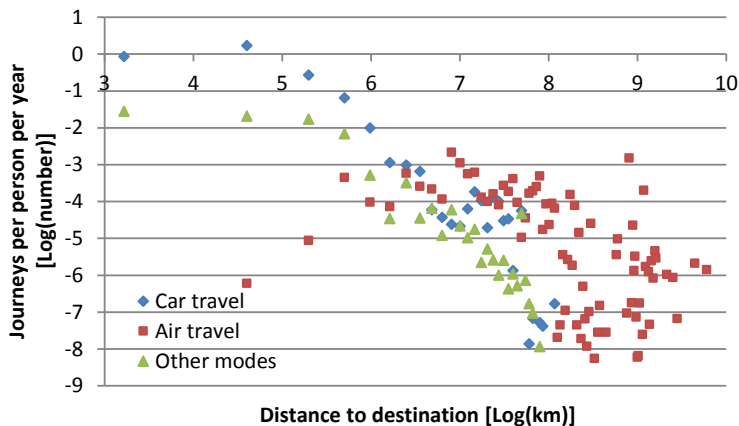


Fig. 7. Travel frequency by the three main modes at long distance travel dependent on travel distance. Both distance and frequency is shown as log values. Source: TU Overnight Survey (Christensen and Knudsen 2015).

5. Discussion and European comparison

When only domestic air travel is considered an important part of the climate burden from passenger travel is overlooked. In fact, the emission from domestic passenger travel is increased by 45% when international travel is added. On the other hand, air travel is better than a car driving from an environmental point of view when only one person is travelling at medium long distances due to lower emission coefficient per traveller.

Air travel conducted by Danes already has a substantial impact on the climate compared to the rest of the passenger mobility. Furthermore, Table 3 shows that long distance travel in general and especially air travel is increasing very fast with an annual increase in both number of journeys and travel distances of 5.5% over a 10-year period. It is especially the overseas travel that increases the most, 6.6% per year for air travel. The Holiday and business travel survey (the Danish version of the common European Tourism Demand Surveys) shows an increase in overseas kilometres of 7.5% per year over 7 years. In the evaluation of the effect of international air travel you should furthermore bear in mind that CO₂ emission at a height of 10 km is assessed to burden the climate twice as

much as the same CO₂ emissions at ground level (Jardine 2005). The increase is higher than the highest projection by (Alonso et al. 2014) who foresee a development increasing from 4.5% in 2013–2016 to 5.5% from 2026 for overseas air travel (2.8% increasing to 4.0% for European air travel).

Table 3. Average annual change in all long distance travel with overnight stays from 2002/03 to 2009/10 according to the Holiday and Business Travel Survey (HBS) and by air from 2002 to 2012 according to a combination of Sabre data and Airport data.

	HBS 2002/03-2009/10		Air travel databases, 2002–2012	
	Journeys	Kilometres	Journeys	Kilometres
Domestic	2.3%	8.3%	-2.3%	-2.3%
European	3.1%	3.9%	5.2%	4.3%
Outside Europe	8.5%	7.5%	6.7%	6.6%
Air travel	4.9%	6.6%	5.5%	5.5%
Car travel	4.4%	5.8%		
Other modes	-5.3%	-1.8%		
Holiday	3.6%	8.3%		
Business	-0.03%	1.2%		
All travel activities	2.9%	4.2%		

Data available from Eurostat for holiday travel with at least 4 overnight stays can be used to compare development across Europe (see <http://ec.europa.eu/eurostat/web/tourism/data/main-tables>, table tour_dem). As seen from Table 3 holiday travel is the travel segment with the highest increase. As several analyses show that the most important driver for long distance travel is income, e.g. (Dargay and Clark 2012), the travel frequency in Figure 8 is therefore shown dependent on GDP per capita. Figure 8 shows an annual increase in overall holiday travel activity for nearly all countries. However, with the international economic crisis from 2008 travel activity decreased. When the income started to increase again after 2010, the number of journeys also increased again, for several countries at the same pace as earlier. The increase with income is even clearer for air travel than for the overall travel. From Figure 8 it can furthermore be seen that the Danish travel activity is not higher than that of other countries at the same income level. Nor is the increase in travel frequency increasing faster than in other comparable countries.

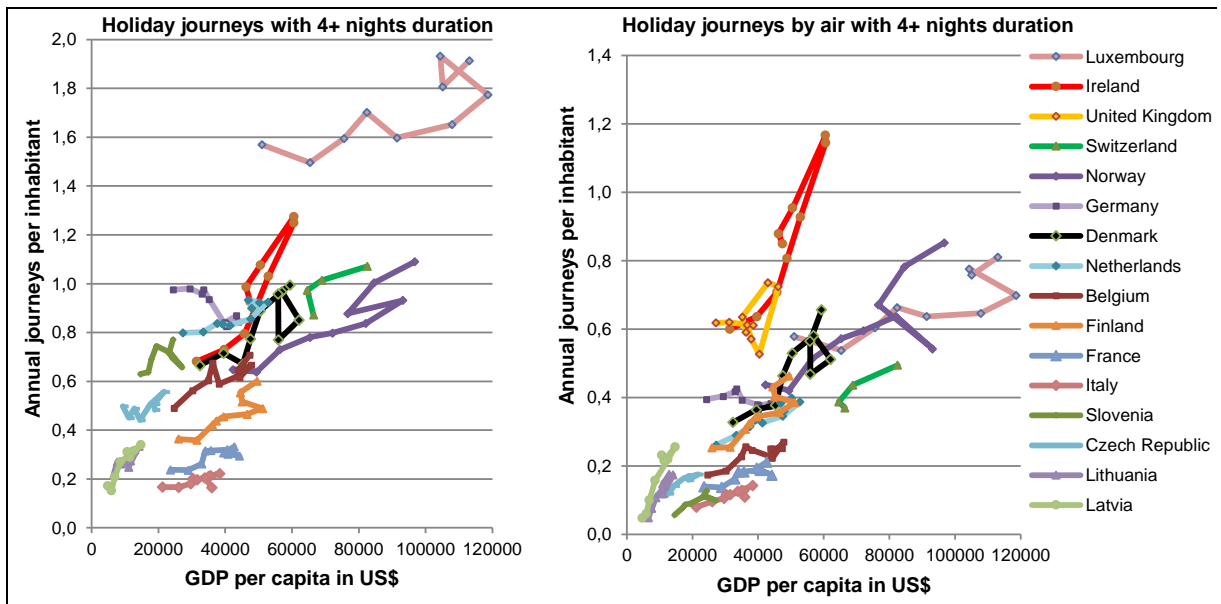


Fig. 8. Number of international holiday journeys per inhabitant per year by all modes (left) and by air (right). Travel frequency is shown for each year in the period 2003–2012 when available. Source: European Tourism Demand Survey.

6. Conclusion

The paper shows a very high and increasing long distance travel activity for Denmark. A similar high holiday activity is observed for most of the other middle and northern European countries. The international travel activity contributes severely to the climate burden. The increase in travel activity is especially problematic because it is first of all the overseas journeys which contribute most to the climate burden emissions that increase the most. Compared to the daily passenger traffic CO₂ emission from international air travel only represents a smaller share – 28% – but the increase rate is much higher.

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