Climate change mitigation potentials of carbon labels in the aviation industry

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ABSTRACT

This chapter discusses the climate change mitigation potentials of carbon labels in the aviation industry. As this study shows, there are significant differences in the environmental performance of individual flights, even when operated on the same route or by the same airline. Selecting one flight over another can significantly reduce the carbon dioxide emissions of a single air passenger. Nevertheless, the currently available measures, such as carbon calculators, are not capable of presenting these differences, leaving air passengers with no means of comparing individual flights. Therefore, the use of carbon labels could be highly beneficial because it would give air passengers the opportunity to easily compare the carbon dioxide emissions of individual flights at the time of booking. By making better informed choices, air passengers could not only reduce their own individual carbon dioxide emissions but could also send a strong signal to the airlines. This could motivate airlines to improve their environmental performance, which could be made more visible through carbon labels.

INTRODUCTION

Air travelling is one of the most energy intensive forms of transportation, resulting in huge environmental impacts (Gössling et al., 2005). The major impacts are noise, local air pollution and greenhouse gas emissions (Green, 2003). The major greenhouse gas emissions produced by aircrafts are carbon dioxide (CO_2), nitrogen oxides (NO_X), water vapour (H_2O), emissions of soot particles, various sulphur oxides (SO_X), condensation trails and cirrus clouds (Daley, 2010). Of all greenhouse gas emissions, carbon dioxide has been clearly identified as the major contributor to climate change (Green, 2003). The atmospheric lifetime of carbon dioxide is anywhere between 50 and 100 years, far beyond that of any other greenhouse gas released by aircrafts (Rogers et al., 2002), and may affect the climate system for thousands of years to come (Archer, 2005). While there is substantial scientific understanding of the radiative forcing of CO_2 emissions, the understanding of non-CO_2 emissions remains limited to date (Preston, Lee & Hooper, 2012). Some emissions released from aircraft even have cooling effects (Lee et al., 2009). Aware of the uncertainty, previous research has mainly excluded remaining emissions and focused only on carbon dioxide emissions (Sgouridis, Bonnefoy & Hansman, 2011), the effect of which on climate change has been clearly identified.

Currently, the aviation industry accounts for about 2.5% of the worldwide CO_2 emissions (Lee et al., 2009). While this might not yet sound alarming, the industry has, however, seen steady growth rates of about 5% annually, doubling its size every 20 years (Cohen & Higham, 2011; Dubois & Ceron, 2006), and even higher growth rates are predicted for the future (Button, 2007; Gössling & Peeters, 2007). Past growth has already made its mark, as the carbon dioxide emissions released by aircrafts between 1991 and 2003 alone have grown by 87% (Rothengatter, 2010). Predictions for the future look similar, as Macintosh and Wallace (2009), for example, are expecting a 110% increase in CO_2 emissions between 2005 and 2025. If it remains the case in the future that the industry will face no restrictions on its emissions growth,

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it is estimated that aviation's share of worldwide CO_2 emissions could increase by a factor between 2.0 and 3.6 until 2050 (Owen, Lee & Lim, 2010). The relative contribution of the sector might also increase so strongly due to the expected improvements in emissions reductions achieved in other sectors (Sgouridis et al., 2011). Under these circumstances, there is a possible risk that regulation might restrict air transportation's future growth (Adler & Gellman, 2012), which would not only have a huge impact on the industry itself (Gössling et al., 2007) but also on economic development and social welfare (Janic, 2004). The aviation industry provides social and economic benefits in the form of leisure and business travel, job creation and by sharing knowledge and experiences (Cowper-Smith & de Grosbois, 2011). Our globalized economic system, as we know it today, would not exist without air transportation. Restricting air travel would certainly mean giving up huge benefits for the society and our global economy. Therefore, Adler and Gellman (2012) stress that, to avoid the possible risk of restrictions and to put aviation on a sustainable growth path, the industry needs to reduce its carbon dioxide emissions significantly.

With this in mind, I would like to discuss the use of carbon labels as one possible solution for reducing aviation's carbon dioxide emissions. I start by providing an overview of behavioral change, which is one of the five carbon dioxide reduction strategies that are currently discussed in the aviation industry. I then explain carbon labelling as an instrument of behavioral change in further detail. After that, I discuss how aviation carbon dioxide emissions should be calculated, before presenting the empirical study and my results. The conclusion, finally, provides recommendations for the use of carbon labels in the aviation industry.

BEHAVIORAL CHANGE

According to Daley (2010), the carbon dioxide emissions of air travel can be reduced through technological changes, market-based changes, operational changes, regulatory changes as well as behavioral changes. Several authors have identified behavioral change as the measure with the greatest mitigation potential. Davison, Littleford and Ryley (2014) argue that emissions reductions certainly rely on behavioral change, while the remaining measures, such as technological changes, play only a minor role. Gössling et al. (2007) came to similar conclusions, stating that technological and behavioral changes are the two measures able to bring aviation back to a sustainable growth path. However, they clearly stated that behavioral change is playing the key role in this. Behavioral change refers to any transformation or modification of human behavior. When looking more closely at behavioral change from the perspective of human impact on the environment, it can be defined as: "Behavior that consciously seeks to minimize the negative impact of one's actions on the natural and built world" (Kollmuss & Agyeman, 2002). Behavioral change in this context has to be understood as a form of mitigating environmental impacts caused by human activities. Such environmental impacts are according to Stern (2000) a by-product of human's desire for status, power, security, enjoyment, maintenance of family and tradition as well as mobility. In recent years these environmental impacts have become more visible and a connection between human activities and the impacts has been established. It has been understood that a change in behavior is needed and that human activities must be altered in a way that lessens the impact on the environment (Stern, 2000). Hillman (2004) emphasized that humans have to change their behavior if they want to be able to tackle the problem of climate change. Brewer and Stern (2005) see significant potential for major improvements in reducing environmental impacts from individuals and households changing their consumption behavior in areas such as housing, energy, water, food, waste and transportation. In the United States, for example, households alone account for almost half of the carbon emissions (Cutter et al., 2002). One way to motivate consumers to change their behavior is seen in carbon labelling (Anderson, Mastrangelo, Chase, Kestenbaum & Kolodinsky, 2013), which informs consumers about the climate impacts caused by the production, consumption and disposal of a product or service (Gallastegui, 2002).

CARBON LABELS

As the impacts of climate change start to become more evident, policy-makers, companies and consumers are considering more ways of reducing greenhouse gas emissions. One possible mitigation instrument is carbon labelling. Carbon labels, as one form of eco-labelling (Gössling & Buckley, 2016), provide consumers with information on the carbon emissions of particular products or services and their impacts on climate change (Brenton, Edwards-Jones & Jensen, 2009). Carbon labels take into account the entire life cycle of a product or service (Upham, Dendler & Bleda, 2011). Based on the information provided, consumers can make better-informed choices that reflect their concern about climate change. In this way, carbon labels provide the necessary information to consumers to make decisions that can have an influence (Gallastegui, 2002). Carbon labels can be understood as an additional product characteristic that consumers can take into account when comparing different product choices (Buckley, 2002). They can help to distinguish products or services that are less harmful from the remaining ones (Grankvist, Dahlstrand & Biel, 2004). Consumers often do not have the knowledge or time to investigate the climate impacts of products (Houe & Grabot, 2009), or they simply lack access to such information (Buckley, 2002). Carbon labels can therefore assist consumers as they convert credence attributes into search attributes and reduce consumer's search costs (Buckley, 2002; Thøgersen, Haugaard & Olesen, 2010). By providing information on the carbon dioxide emissions of products or services, carbon labels give the consumer the opportunity to choose products that meet their expectations, fulfill their needs or help them reach their (climate) goals (Thøgersen et al., 2010). Carbon labels can also act as a reminder to take climate change into account when purchasing goods or services (Bratt, Hallstedt, Robert, Broman & Oldmark, 2011; Thøgersen et al., 2010). Additionally, carbon labels provide the consumer with the opportunity to take climate actions without limiting their freedom of choice (Grunert & Wills, 2007). The labels create more awareness among consumers and encourage them to change their purchase behavior (Morris, 1997) by more actively choosing the less harmful product choices, further preventing climate change. Moreover, carbon labels can help close the gap of information asymmetry between consumers and producers over the question of what the climate impact of products are (De Boer, 2003; Rex & Baumann, 2007). They can hereby be understood as a market mechanism (Bratt et al., 2011), where the responsibility for improvements is put into the consumer's hands. By utilizing information provided on the carbon label, consumers can actively demand products that harm the climate less (Buckley, 2002). According to Morris (1997), the advantage is that the labels provide consumers with reliable information they would otherwise not be able to obtain, due to limited time or understanding, on the climate impacts of products. Wider exposure for the carbon emissions of products or services can also create incentives for companies to reduce their greenhouse gas emissions along their production lines, distribution channels as well as their entire supply chain in order to better serve consumer's needs (Brenton et al., 2009). Carbon labels can encourage companies to account for the climate impacts caused by their products or services, which can also help them to improve their image as well as their sales. For producers, carbon labels can also be understood as a benchmark for environmental improvements and competitiveness (Bratt et al., 2011).

CALCULATING CARBON DIOXIDE EMISSIONS

An essential element in the use of carbon labels is the method used to calculate carbon dioxide emissions. The more accurately the emissions are calculated, the better the quality of information is the carbon label provides and the more relevant are the decisions that are based on the carbon label. Currently existing aviation carbon labels such as the Flybe ecolabel (Flybe, 2018) or the Atmosfair Airline Index (Atmosfair, 2018a) fail to provide air passengers with real opportunities to compare different flights. They focus only on the carbon emissions of different aircraft types, as in the case of Flybe, or rank airlines based on their carbon emissions, as in the Atmosfair Airline Index. The calculation of flight-specific carbon dioxide emissions these days is mainly performed and made publically available through the use of carbon calculators. From an air passenger's perspective, the comparison of different aircraft types or the carbon emissions of entire airlines do not provide much relevant information, because the air passenger usually intends to purchase a flight, not an aircraft or an airline. Carbon calculators are in this regard easy-to-use tools for air passengers to measure their flight-related carbon emissions and can certainly make up, at least to some extent, for the absence of flight-specific carbon labels. Unfortunately, current carbon calculators severely lack consistency as different calculators produce different outcomes for the same journey (Miyoshi & Mason, 2009). Table 1 presents an example of this inconsistency by showing the results of various emissions calculators for a one-way flight from New York (JFK) to Helsinki.

Table 1. Results of different emissions calculators for a New York-Helsinki flight

New York (JFK)–Helsinki	ICAO	Climate Care	Atmosfair	Finnair
Distance	6,603 km	6,607 km	6,653 km	6,977 km
CO_2 (kg)/passenger	353.00 kg	910.00 kg	471.00 kg	424.63 kg

Sources: Atmosfair, 2018b; Climate Care, 2018; Finnair, 2018; ICAO, 2018.

As of yet, no consensus exists on how to calculate carbon emissions produced from air transportation. Jardine (2009), however, found that all aviation emissions calculators broadly utilize the same methodology. Nevertheless, while the methodologies applied are similar, there is a huge difference among the data used by the emission calculators. Inputs can range from the use of very simplified data like indicative short-, medium- and long-haul aircraft, as in the case of the DEFRA calculator (DEFRA, 2012), up to the use of actual fuel data, like in case of Finnair's emissions calculator (Finnair, 2018). Table 2 illustrates the range of inputs different emissions calculators utilize.

Besides the differences in data used, the data sources also differ as they can either come from publically available data sources or privately owned ones. Data such as the distance, aircraft type, freight factor, passenger load factor and seating configuration may be publically available, but access to actual fuel consumption figures are normally not. Emissions calculators, therefore, have to typically rely on average fuel data. The only currently known emissions calculator that uses actual fuel data is Finnair's emissions calculator. Although software exists (e.g. Piano-X or FAA's AEDT) that can model the fuel consumption of individual airplanes very precisely, these programs are usually not freely available. For this reason, most of the emissions calculators rely on publically available emissions data that can be found in inventory guidebooks. A commonly used inventory guidebook is the European Environment Agency's (EEA, 2007) EMEP/Corinair, which provides fuel consumption data for the entire flight, including taxing, take-off, climb, cruise, approach and landing for 44 aircraft types over 16 stage lengths. The updated version of EMEP/EEA published in 2016 (EEA, 2016) even distinguishes between more different aircraft types of the same aircraft families (e.g. Airbus A320, A321), and now features altogether 130 aircraft types. Besides many commonly used emissions calculators, numerous studies (e.g. Givoni & Rietveld, 2010; Loo, Li, Psaraki & Pagoni, 2014; Romano, Gaudioso & De Lauretis, 1999; Winther, Kousgaard & Oxbol, 2006) have based their calculations on EMEP/Corinair. A major drawback of the use of inventory guidebooks such as EMEP/Corinair, however, is the lack of information on fuel consumption based on different weights, speeds and flight levels, all of which certainly influences fuel consumption (Filippone, 2008). Nevertheless, even with the lack of actual fuel data or access to expensive modelling software the EEA inventory guidebook still provides a reliable source of fuel data, as Park and O'Kelly (2014) found when they performed a validation analysis of the EMEP inventory compared with more sophisticated fuel burn data sources.

Table 2. **Key features of different emissions calculators**

Parameter	DEFRA	ICAO	Finnair
Great circle distance correction	9%	Up to 11%	5% + 20 km
Plane type	3 aircraft types, short, medium and long haul	50 aircraft types, some representatives	Actual aircraft
Fuel burn data	EMEP/Corinair	EMEP/Corinair	Real data
Freight factor	Domestic: 99.8% Short haul: 99.4% Long haul: 88.1%	Wide body: 72.9%–90.3% Narrow body: 91.7%–99.6%	Real data
Load factor	Domestic: 66.4% Short haul: 83.4% Long haul: 81.9%	Wide body: 64.5%–83.6% Narrow body: 67.3%–81.8%	Real data
Seat configuration	Representative from CAA data	Number of economy seats that fit into the aircraft	Real data

Sources: DEFRA, 2012; Finnair, 2018; ICAO, 2015.

Despite the availability of actual flight data (distance, aircraft type, freight factor, passenger load factor and seating configuration) and rather sophisticated fuel data (e.g. EMEP/EEA), many emissions calculators fail to provide users with more than a 'typical' flight because they mainly utilize average data. As Miyoshi and Mason (2009) found, currently available emissions calculators treat all flights in the same way, not distinguishing between the different environmental performances of individual airlines or flights. As mentioned previously, the DEFRA emissions calculator, for example, uses only a few generic types of aircrafts instead of the specific aircraft that is operating the actual flight. This of course has consequences on the fuel burn, which can differ significantly between different aircraft types. Another common way of simplifying the calculations is the use of average passenger and freight load factors which, according to Miyoshi and Mason (2009), are often unrealistically high, as is also shown in Table 2. Finally, most of the emissions calculators fail to distinguish between the different seat layouts which can differ significantly between airlines and certainly can play an important role in terms of the per passenger carbon emissions (Bofinger & Strand, 2013; Park & O'Kelly, 2014). While currently available emissions calculators might be able to provide air passengers with some rough estimations on how much carbon dioxide emissions a typical flight might produce, this type of information would not be enough to make informed choices between different flight options regarding their CO_2 emissions.

THE STUDY

After discussing the various approaches of emissions calculators and the importance of the use of actual data in the calculation of carbon dioxide emissions, I would now like to move on to the empirical part of this chapter. Based on the above presented approach I engaged in carbon dioxide emissions calculations with the aim to show that there are significant differences between the emissions of individual flights. This can, however, only be shown by applying the most accurate calculation method. The purpose of these calculations was to justify the need for carbon labels in the aviation industry, because such labels can only have an impact if significant differences exist between the carbon emissions of individual flights.

For this study carbon dioxide emissions for 67 flight connections operated by 116 different flights connecting three city pairs were calculated. The selected routes covered three geographical markets of short-, medium- and long-haul flights. On the short-haul market, the busiest domestic route in the U.S., from Los Angeles (LAX) to San Francisco (SFO), was chosen. This route was of special interest because the variety of aircrafts used on this route was large. Yet the route is not so short that it is only operated non-stop, providing an opportunity to compare non-stop flights with connecting ones on a short-haul route. All departures between 10 a.m. and 12 p.m. were analyzed, 21 connections in total. For the medium-haul route, the second busiest medium-haul route in the United States, Los Angeles (LAX) to New York (JFK), was selected. This route was chosen over Miami (MIA) to New York (NYC) because of the greater diversity of operators and aircrafts used on the LAX to JFK route. All departures between 6 a.m. and 7 a.m. were analyzed, 26 connections in total. For the long-haul route, I selected Los Angeles (LAX) to London (LHR), which is the third busiest U.S. American international route after New York (JFK) to London (LHR) and Honolulu (HNL) to Tokyo (NRT). This route was chosen over the others because it offers more connecting flights than the other two routes. In addition, the diversity of operators and aircrafts was higher, giving more opportunities to compare different operators and aircrafts. All departures between 5 p.m. and 12 a.m. were analyzed, 20 connections in total. On all three routes all major operators and the most common aircrafts used on these particular routes were analyzed. All direct flights and all connecting flights that were listed on the OAG (Official Aviation Guide) Flight Schedule were taken into consideration.

Emissions were calculated following the methodology provided by the International Civil Aviation Organization (ICAO, 2015). This methodology is widely adopted by many emissions calculators and has also been utilized by various studies (e.g. Hanandeh, 2013; Lu & Shon, 2012). However, as shown in Table 2, the ICAO Carbon Emissions Calculator relies mainly on average data while I wanted to base my calculations on actual data. My approach therefore differs from the ICAO methodology as I acquired real traffic data from the United States Department of Transportation (USDOT) in order to calculate load factors, passenger to freight factors and number of seats supplied on each flight. In addition, for the fuel data I based my calculations on the revised EMEP/EEA inventory guidebook, meaning I was able to calculate with more accurate data. This approach allowed me to distinguish between different types within aircraft families. I am, however, aware that only real fuel data would result in accurate consumption figures. Nevertheless, comparing my results with that of Finnair's emissions calculator gave me confidence in the accuracy of my calculation method. The Great Circle Distance (GCD) between the origin and destination was also acquired from the USDOT database. I used a correction factor in order to account for stacking, traffic and weather-driven diversion from the GCD. I then added 50 km to flights less than 550 km, 100 km to flights between 550 km and 5,500 km and 125 km to all flights beyond 5,500 km. To calculate carbon dioxide emissions per passenger I used Equation 1 as stated in the ICAO Carbon Emissions Calculator manual Version 8 (May 2015):

$$CO2\ per\ passenger\ =\ 3.16 * \frac{(total\ fuel * passenger\ to\ freight\ factor)}{(number\ of\ seats * passenger\ load\ factor)} \quad (1)$$

The constant of 3.16 represents the number of tons of CO_2 produced when burning one ton of aviation fuel (Dings, Wit, Leurs, Davidson & Fransen, 2003; Sutkus, Baugcum & DuBois, 2001). Cabin seat charts that helped mapping the seat configuration of various aircrafts and the amount of seats in each cabin class were extracted from Seat Guru. All CO_2 emissions were calculated on a per passenger basis.

RESULTS

Figure 1 provides an overview of the total carbon dioxide emissions of all 21 flight connections on the short-haul route from Los Angeles (LAX) to San Francisco (SFO). The figure clearly illustrates that the flight option a passenger chooses can make a huge difference in carbon dioxide emissions. On this route the carbon emissions ranged from 69 kg for the most efficient non-stop flight up to more than five times or 362 kg for the least efficient connecting flight via Dallas/Fort Worth (DFW). Though it seems unsurprising that a connecting flight via Dallas/Fort Worth (DFW) would significantly add to the carbon dioxide emissions, given the longer flight distance, the results also showed relevant differences in the emissions between flights operated through the same routing and even by the same airline.

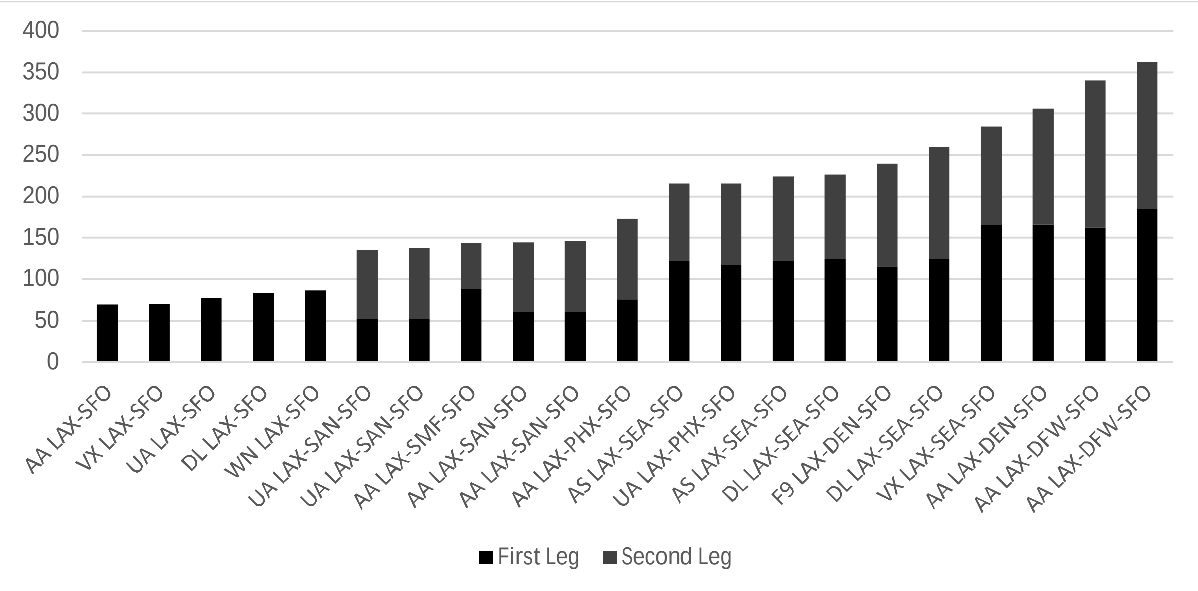

Figure 1. CO_2 emissions (kg)/passenger for flights on Los Angeles to San Francisco route

Figure 2 shows the carbon dioxide emissions of the 26 studied flight connections between Los Angeles (LAX) and New York (JFK). On this route the emissions of the different flight connections also varied considerably. They ranged from 271 kg of carbon dioxide emissions per passenger on the most efficient non-stop flight up to 642 kg for the least efficient connection with a stop in San Francisco (SFO). Interestingly, this figure also shows a huge difference in the carbon dioxide emissions between the most efficient flight and the second least efficient flight as both are non-stop, flying the exactly the same route and even with the same type of aircraft (Airbus A321). The carbon emissions of the second least efficient flight are, at 559 kg, more than twice as high as those of the most efficient flight.

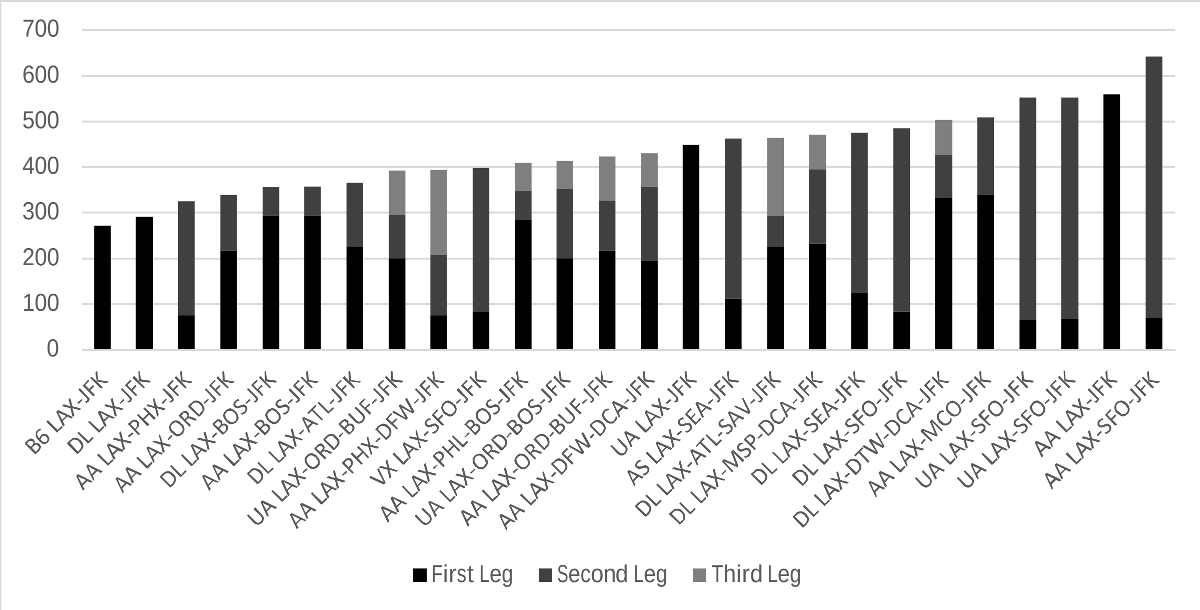

Figure 2. **CO_2 emissions (kg)/passenger for flights on Los Angeles to New York route**

Figure 3 reveals the carbon dioxide emissions of the remaining 20 studied flight connections that operated on the Los Angeles (LAX) to London (LHR) route. Again here the range of carbon dioxide emissions between the most efficient and the least efficient flight option were vast, ranging from 571 kg to 1,152 kg of carbon dioxide per passenger. In addition, significant differences in the emissions can also be found even among flights that are operated on the same route and by the same airline. For example the two daily British Airways (BA) flights, both operated non-stop, differ significantly, as the first flight releases only 776 kg of carbon dioxide emissions per passenger while the second produces 902 kg per passenger.

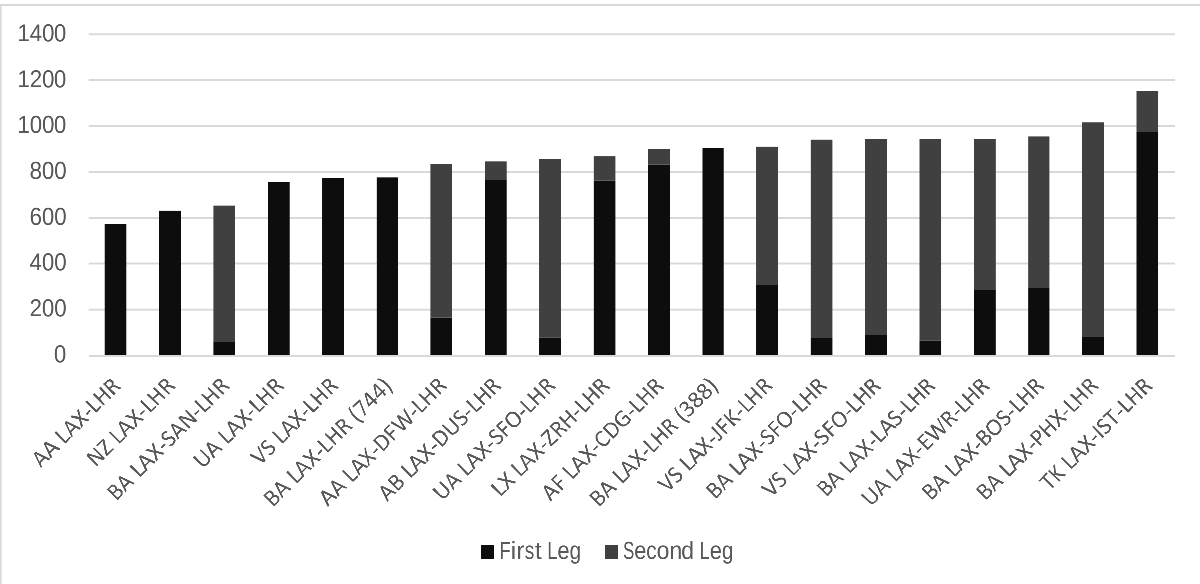

Figure 3. **CO_2 emissions (kg)/passenger for flights on Los Angeles to London route**

Although these carbon dioxide figures might appear abstract for the reader as well as when displayed on a carbon label, their significance becomes more obvious once those figures are brought into perspective with the often-discussed goal of keeping global warming below 2 degrees Celsius. According to the German Advisory Council on Global Change (2009), to achieve this climate goal, each human being would only be allowed an annual climate budget of 2,300 kg of carbon dioxide. However, only one-fourth or 575 kg could be spent on mobility. Once this number is set into contrast with the carbon dioxide emission figures presented above, choosing a more efficient flight over a less efficient one in order to travel from the same origin to destination becomes certainly relevant. In case of the long-haul route from Los Angeles (LAX) to London (LHR) only the most efficient one-way flight doesn't exceed the annual climate budget for the mobility of any individual. Providing air passengers with carbon labels, where the emissions are set in contrast to the annual climate budget, might also help build more awareness. As their consumption behavior and impact on climate change is brought into a broader perspective, this could motivate air passengers to act more responsibly in actively selecting a less polluting flight.

CONCLUSION

Aviation in its current form provides many benefits for our society and economic system. However, it is also facing the threat of regulatory restrictions due to its immense growth. Together with growth comes an increase in carbon dioxide emissions, which are a major contributor to climate change. The aviation industry therefore needs to find new ways to reduce its emissions. Behavioral change is currently seen as the measure with the greatest mitigation potential. One instrument that could trigger behavioral change is carbon labelling. Carbon labels could provide air passengers with the opportunity to compare flights not only based on ticket prices, flight schedules or airlines but also allow them to take the climate impact of a flight option into account. Carbon labelling, however, only makes sense if there are significant differences in the carbon emissions between individual flights. The results of this study clearly indicated the existence of such differences. However, these differences must be made visible to air passengers with the help of a carbon label if the labels are to encourage passengers to change their behavior by actively selecting less polluting flights. The currently available carbon labels are not able to show these differences and neither are carbon calculators, because they do not show the differences in the carbon dioxide emissions of individual flights. Current carbon calculators can only provide information on a so-called typical flight, which will not serve those air passengers who want to be able to compare the carbon emissions of individual flights. In order to make the differences between individual flights visible we need to engage in more sophisticated carbon emissions calculations by utilizing real data. Only by performing such calculations was I able to show that carbon emissions between individual flights operating on the exact same route can actually differ tremendously. There were even significant differences between flights that were operated by the same airline or with the same type of aircraft. These differences became especially relevant once they were contrasted with the often-discussed climate goals of keeping global warming below 2 degrees Celsius. Flying to the same destination but selecting a less polluting flight can result in a huge reduction of an individual air passenger's impact on climate change. However, air passengers need to be provided with the right information at the right time in order to take this aspect into consideration. A carbon label could give air passengers the opportunity to act more responsibly in their air travel behavior because their behavior would now be brought into the broader perspective of climate change.

The use of carbon labels could hereby become very beneficial. While a carbon label might trigger behavioral change among air passengers, helping them to more actively select less polluting flights, it might also motivate airlines to improve their performance, which could then be made visible through a carbon label. Especially those airlines who show the highest carbon dioxide emissions per seat would need to improve as otherwise they might be driven out of the market. This market mechanism could help the aviation industry enter a more sustainable growth path and avoid regulatory restriction.

REFERENCES

Adler, N. & Gellman, A. (2012). Strategies for managing risk in a changing aviation environment. *Journal of Air Transport Management, 21*, 24-35.

Anderson, L., Mastrangelo, C., Chase, L., Kestenbaum, D. & Kolodinsky, J. (2013). Eco-labelling motorcoach operators in the North American travel tour industry: analysing the role of tour operators. *Journal of Sustainable Tourism, 21 (5)*, 750-764.

Archer, D. (2005). Fate of fossil fuel CO_2 in geologic time. *Journal of Geophysical Research, 110*, 2156-2202.

Atmosfair. (2018a). Airline Index. https://www.atmosfair.de/en/atmosfair_airline_index

Atmosfair. (2018b). Calculate Flight Emissions. https://www.atmosfair.de/en/offset/flight/

Bofinger, H. & Strand, J. (2013). Calculating the Carbon Footprint from Different Classes of Air Travel. The World Bank, Development Research Group Environment and Energy Team.

Bratt, C., Hallstedt, S., Robert, K., Broman, G. & Oldmark, J. (2011). Assessment of eco-labelling criteria development from a strategic sustainability perspective. *Journal of Cleaner Production, 19*, 1631-1638.

Brenton, P., Edwards-Jones, G. & Jensen, M. (2009). Carbon Labelling and Low-income Country Exports: A Review of the Development Issues. *Development Policy Review, 27 (3)*, 243-267.

Brewer, G. & Stern, P. (2005). *Decision Making for the Environment: Social and Behavioral Science Research Priorities*. Washington, DC: National Academic Press.

Buckley, R. (2002). Tourism Ecolabels. *Annals of Tourism Research, 29 (1)*, 183-208.

Button, K. (2007). Airlines: Sustainable development in a transatlantic context. In: Rietveld, P., Stough, R. (Eds.) *Institutions and sustainable transport: Regulatory reform in advanced economies*. Cheltenham: Edward Elgar.

Climate Care. (2018). Carbon Calculator. https://climatecare.org/calculator/

Cohen, S. & Higham, E. (2011). Eyes wide shut? UK consumer perception of aviation climate impacts and travel decisions to New Zealand. *Current Issues in Tourism, 14*, 323-335.

Cowper-Smith, A. & de Grosbois, D. (2011). The adoption of corporate social responsibility practices in the airline industry. *Journal of Sustainable Tourism, 19 (1)*, 59-77.

Cutter, S., Mitchell, J., Hill, A., Harrington, L., Katkins, S., Muraco, W., DeHart, J., Reynolds, A. & Shudak, R. (2002). Attitudes towards reducing greenhouse gas emissions from local places. In: Association of American Geographers Global Change in Local Places (GLCP) Working Group (Eds.) *Global Change and Local Places: Estimating, Understanding, and Reducing Greenhouse Gases*. Cambridge: Cambridge University Press.

Daley, B. (2010). *Air Transport and the Environment*. Wey Court East: Ashgate.
Davison, L., Littleford, C. & Ryley, T. (2014). Air travel attitudes and behaviours: the development of environment-based segments. *Journal of Air Transport Management, 36*, 13-22.

De Boer, J. (2003). Sustainability labelling schemes: The logic of their claims and their functions for stakeholders. *Business Strategy and the Environment, 12*, 254-264.

DEFRA. (2012). Guidelines to Defra / DECC's GHG Conversion Factors for Company Reporting: Methodology Paper for Emission Factors, July 2012.

Dings, J., Wit, R., Leurs, B., Davidson, M. & Fransen, W. (2003). External Costs of Aviation. Berlin: German Federal Environmental Agency.

Dubois, G. & Ceron, J. (2006). Tourism/leisure greenhouse gas emissions forecast for 2050: Factors for change in France. *Journal of Sustainable Tourism, 17*, 17-37.

EEA. (2007). *EMEP/CORINAIR Emissions Inventory Guidebook - 2007*. Brussels: EEA.

EEA. (2016). *EMEP/EEA Air Pollutant Emissions Inventory Guidebook - 2016*. Brussels: EEA.

Filippone, A. (2008). Analysis of Carbon-Dioxide Emissions from Transport Aircraft. *Journal of Aircraft, 45*, 185-197.

Finnair. (2018). Finnair Emissions Calculator. https://www.finnair.com/ee/gb/emissions-calculator

Flybe. (2018). Compare Flybe's fleet. http://www.flybe.com/pdf/eco_labels_make_own.pdf

Gallastegui, I. (2002). The use of eco-labels: A review of the literature. *European Environment, 12*, 316-331.

German Advisory Council on Global Change. (2009). *Solving the climate dilemma: The budget approach*. Berlin: WBGU.

Givoni, M. & Rietveld, P. (2010). The environmental implications of airlines' choice of aircraft size. *Journal of Air Transport Management, 16*, 159-167.

Gössling, S., Peeters, P., Ceron, J-P., Dubois, G, Pattersson, T. & Richardson, R. (2005). The eco-efficiency of tourism. *Ecological Economics, 54 (4)*, 417-434.

Gössling, S., Broderick, J., Upham, P., Ceron, J.-P., Dubois, G., Peeters, P. & Strasdas, W., (2007). Voluntary Carbon Offsetting Schemes for Aviation: Efficiency, Credibility and Sustainable Tourism. *Journal of Sustainable Tourism, 15*, 223-248.

Gössling, S. & Peeters, P. (2007). It does not harm the environment! An analysis of industry discourses on tourism, air travel and the environment. *Journal of Sustainable Tourism, 15 (4)*, 402-417.

Gössling, S. & Buckley, R. (2016). Carbon labels in tourism: persuasive communication? *Journal of Cleaner Production, 111*, 358-369.

Grankvist, G., Dahlstrand, U. & Biel, A. (2004). The Impact of Environmental Labelling on Consumer Preference: Negative vs. Positive Labels. *Journal of Consumer Policy, 27*, 213-230.

Green, J. (2003). Civil aviation and the environmental challenge. *The Aeronautical Journal*, 281-299.

Grunert, K. & Wills, J. (2007). A review of European research on consumer response to nutrition information on food labels. *Journal of Public Health, 15*, 385-399.

Hanandeh, A. (2013). Quantifying the carbon footprint of religious tourism: the case of Hajj. *Journal of Cleaner Production, 52*, 53-60.

Hillman, M. (2004). *How we can save the planet*. London: Penguin Books.

Houe, R. & Grabot, B. (2009). Assessing the compliance of a product with an eco-label : From standards to constraints. *International Journal of Production Economics, 121*, 21-38.

ICAO. (2015). Carbon Emissions Calculator Methodology Version 8, May 2015.

ICAO. (2018). Carbon Emissions Calculator. https://www.icao.int/environmental-protection/CarbonOffset/Pages/default.aspx

Janic, M. (2004). An application of the methodology for assessment of the sustainability of the air transport system. *Journal of Air Transportation, 9 (2)*, 40-82.

Jardine, C. (2009). *Calculating the carbon dioxide emissions of flights. Environmental Change Institute*. Oxford: Oxford University Centre of the Environment.

Kollmuss, A. & Agyeman, J. (2002). Mind the Gap: why do people act environmentally and what are the barriers to pro-environmental behavior? *Environmental Education Research, 8 (3)*, 239-260.

Lee, D., Fahey, D., Forster, P., Newton, P., Wit, R., Lim, L., Owen, B. & Sausen, R. (2009). Aviation and global climate change in the 21st century. *Atmospheric Environment, 43 (22-23)*, 3520-3537.

Loo, B., Li, L., Psaraki, V. & Pagoni, I. (2014). CO_2 emissions associated with hubbing activities in air transport: an international comparison. *Journal of Transport Geography, 34,* 185-193.

Lu, J.-L. & Shon, Z. (2012). Exploring airline passengers' willingness to pay for carbon offsets. *Journal of Transportation Research Part D, 17,* 124-128.

Macintosh, A. & Wallace, L. (2009). International aviation emissions to 2025: Can emissions be stabilised without restricting demand? *Energy Policy, 37*, 264-273.

Miyoshi, C. & Mason, K. (2009). The carbon emissions of selected airlines and aircraft types in three geographic markets. *Journal of Air Transport Management, 15,* 138-147.

Morris, J. (1997). *Green Goods?: Consumers, Product Labels and The Environment, Studies on the Environment 8*: IEA.

Owen, B., Lee, D. & Lim, L. (2010). Flying into the Future: Aviation Emissions Scenarios to 2050. *Environmental Science & Technology, 44*, 2255-2260.

Park, Y. & O'Kelly, M. (2014). Fuel burn rates of commercial passenger aircraft: variations by seat configuration and stage distance. *Journal of Transport Geography, 41*, 137-147.

Preston, H., Lee, D. & Hooper, P. (2012). The inclusion of the aviation sector within the European Union's Emissions Trading Scheme: What are the prospects for a more sustainable aviation industry? *Environmental Development, 2,* 48-56.

Rex, E. & Baumann, H. (2007). Beyond ecolabels: What green marketing can learn from conventional marketing. *Journal of Cleaner Production, 15,* 567-576.

Rogers, H., Lee, D., Raper, D., Foster, P., Wilson, C. & Newton, P. (2002). The impacts of aviation on the atmosphere. *The Aeronautical Journal, 106*, 521-546.

Romano, D., Gaudioso, D. & De Lauretis, R. (1999). Aircraft emissions: a comparison of methodologies based on different data availability. *Environmental Monitoring and Assessment, 56,* 51-74.

Rothengatter, W. (2010). Climate change and the contribution of transport: Basic facts and the role of aviation. *Transportation Research Part D, 15 (1),* 5-13.

Sgouridis, S., Bonnefoy, P. & Hansman, R. (2011). Air transportation in a carbon constrained world: Long-term dynamics of policies and strategies for mitigating the carbon footprint of commercial aviation. *Transportation Research Part A, 45*, 1077-1091.

Stern, P. (2000). Toward a coherent theory of environmentally significant behavior. *Journal of Social Issues, 56 (3)*, 407-424.

Sutkus, D., Baugcum, S. & DuBois, D. (2001). *Scheduled Civil Aircraft Emissions Inventories for 1999: Database Development and Analysis. NASA/CR-2001-211216.* Washington, DC: NASA.

Thøgersen, J., Haugaard, P. & Olesen, A. (2010). Consumer responses to ecolabels. *European Journal of Marketing, 44 (11)*, 1787-1810.

Upham, Dendler & Bleda, (2011) Carbon labelling of grocery products: public perceptions and potential emissions reductions. *Journal of Cleaner Production, 19 (4)*, 348-355.

Winther, M., Kousgaard, U. & Oxbol, A. (2006). Calculation of odour emissions from aircraft engines at Copenhagen Airport. *Science of the Total Environment, 366*, 218-232.

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