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Measuring greenhouse gas emissions from international air travel of a country's residents methodological development and application for Sweden

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ABSTRACT

Global civil aviation accounts for 4–5% of total greenhouse gas emissions and these emissions are increasing. In the absence of sufficiently effective global climate instruments, national instruments might be considered as a complement, in which case some way of allocating emissions from international air travel between countries is needed. The purpose of this paper is to develop an accounting method that reflects one country's greenhouse gas emissions from international air travel, and to apply this methodology to Sweden. The new methodology consists of three parts: the number of international air trips made by the country's residents; the average distance of these trips; and the greenhouse gas emissions per passenger km. For Sweden, data for 1990 to 2014 show an increase in the number of trips by Sweden's population of 3.6% per year, resulting in, on average, one international journey (round trip 5800 km) per capita in 2014. The average distance to the final destination has increased only marginally due to simultaneous growth in both long and short trips. However, global average greenhouse gas emissions per passenger km have decreased by 1.9% per year between 1990 and 2014. Because the increase in the number of their trips has outweighed the decrease in emissions per km, the total emissions from Swedish residents' international air travel have increased by 61% between 1990 and 2014. The total emissions from Swedish residents' air travel, including both CO_2 and non-CO_2-effects, were 11 Mt CO_2 equivalents in 2014, which is the same level as the emissions from Swedish car traffic. This type of reliable data is important when designing policies and for getting public support for new policies.

1. Introduction

Global civil aviation emitted 815 Mt of CO_2 in 2016 (IEA, 2017), which constituted 2.5% of global energy-related CO_2 emissions (IATA, 2017). In addition to this, there are non-CO_2-effects from civil aviation; principally emissions of nitrogen oxides, contrails and aviation-induced cirrus clouds, and these effects are estimated to be almost as significant as the CO_2 emissions themselves in terms of their global warming potential (GWP) 100-year perspective (Azar and Johansson, 2012; David S Lee et al., 2009). If the non-CO_2-effect are also taken into account, this would mean that 4–5% of total energy-related greenhouse gas emissions are due to civil aviation, which is in line with Lee et al. (2010). The climate impact from air travel increased by 40% between 1990 and 2010 (IPCC, 2014a) and will most likely continue to grow (Owen et al., 2010). It has been projected that the aviation industry's share of global emission may rise to 22% by 2050 if no new radical technologies or policies are introduced (Cames et al., 2015).

According to the Intergovernmental Panel on Climate Change (IPCC), total global greenhouse gas (GHG) emissions must decrease by around 60% by 2050 for a credible chance of meeting the 2-degree climate target (IPCC, 2014b, RCP 2.6). The target set by the air transport industry (to reduce total CO_2 emissions by 50% by 2050 compared to 2005) is roughly in line with the IPCC estimates (IATA, 2009). Globally, the number of air travel passengers is predicted to rise by 4% per year in the next 20 years (IATA, 2015a), which can be seen in relation to the anticipated reductions in emissions intensity of around 1–2% per year depending on policy strategies (Macintosh and Wallace, 2009; Owen et al., 2010; Schäfer et al., 2016). Technological efficiency potentials are limited and unlikely to meet the predicted increases in demand (Bows-Larkin, 2015; Peeters et al., 2016).

In 2016, the International Civil Aviation Organization (ICAO), a specialized agency of the UN, reached an agreement to implement a global Carbon Offsetting and Reduction Scheme for International Aviation (CORSIA) system. CORSIA stipulates that airlines are obliged to offset their increases in emissions after 2020 by purchasing credits from projects that reduce emissions outside the aviation sector (ICAO, 2016b). Even if CORSIA were to work perfectly, it would still only partly offset the anticipated rise in GHG emissions (since non-CO_2

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Table 1
Nine options for the allocation of GHG emissions from international aviation. Options 1–8 were presented by the SBSTA (UNFCCC, 1996) (boldface, our emphasis). We also add a ninth option of consumption-based allocation.

1) No allocation.
2) Allocation of global bunker sales and associated emissions to parties in proportion to their national emissions (from all sectors).
3) Allocation according to the country where the bunker fuel is sold.
4) Allocation according to the nationality of the transporting company, or to the country where an aircraft of ship is registered, or to the country of the operator.
5) Allocation according to the country of (a) departure or (b) destination of an aircraft or vessel; alternatively, emissions related to the journey of an aircraft or vessel (c) shared by the country of departure and the country of arrival.
6) Allocation according to the country of departure or destination of passengers or cargo: alternatively, emissions related to the journey of passengers or cargo shared by the country of departure and the country of arrival.
7) Allocation according to the country of origin of passengers or owner of cargo.
8) Allocation to a party of all emissions generated in its national space.
9) Allocation according to the country of residency of the final consumer (consumption-based accounting).

effects and domestic aviation are not included). The additionality of the offsetting projects are also often questioned (Anderson and Bernauer, 2016; Becken and Mackey, 2017). In addition, there are some national and regional policy instruments, such as the European Union Emission Trading System (EU ETS) which covers CO_2 emissions, but not non-CO_2 emissions, from intra-EU flights[1] (European Commission, 2017). Hence, global GHG emissions from aviation are likely to continue to grow, even after the implementation of these policy instruments. Since CORSIA will not be fully implemented until 2027, there is little hope that more radical international policy instruments will be implemented in the next decade. Therefore, national aviation climate policies are worth considering.

Essential to well-grounded national policy decisions is the availability of data on trends and absolute levels of GHG emissions from aviation (Gössling et al., 2016). Emissions from domestic flights are included in the national greenhouse gas inventories reported to the United Nations Framework Convention on Climate Change (UNFCCC), but the emissions from international aviation (and shipping) are not accounted for by any country. According to the Kyoto protocol the emissions from international aviation (and shipping) can instead be reported separately to UNFCCC (IPCC, 2006; Wood et al., 2010). As such, emissions from international aviation are not included in the national totals, and neither UNFCCC nor ICAO communicate this clearly. Considering that aviation emissions are predominately from international travel, a large share of aviation emissions are essentially made “invisible”. The lack of visibility of these emissions can be a contributing factor to the fact that there are no policies on the horizon that will decrease the absolute emission levels. For global climate policies, there is no need for emissions allocations to specific countries. Awaiting sufficiently effective global climate instruments, national instruments might be considered as a complement, in which case some way of allocating emissions from international air travel between countries is needed.

The purpose of this paper is twofold: (1) to develop an accounting method that reflects a country's GHG emissions from international air travel; and (2) to assess the GHG emissions from international air travel for Sweden between 1990 and 2014. Our calculations are made available in a Microsoft Excel file via this paper's supplementary information, with the aim of facilitating similar assessments for other countries as well as for the purpose of making improvements to the methodology.

[1] EU ETS covers countries within the European Economic Area (EEA), which consists of all EU-members as well as Iceland, Liechtenstein and Norway. Since the abbreviation EEA is less well-known EU is used instead in this paper.

2. Methodological development and data

This section describes different options for the allocation of GHG emissions to different countries along with the method developed (2.1) and the application and data sources used for the case of Sweden (2.2).

2.1. Allocation options for GHG emissions from international air travel

Previous research has pointed out the difficulties in identifying coherent system boundaries and collecting data for assessing national emissions from aviation and tourism (Gössling, 2013; Perch-Nielsen et al., 2010). While some studies cover the whole tourism sector, including air and land-based travel, accommodation, etc., this paper focus on air-travel alone. How allocation of emissions from international aviation should be allocated to different individual countries is far from obvious. This issue has been discussed since the 1990s and there are many potential options, e.g. based on where the jet fuel is sold, in which territory the emissions occur or where the final consumer lives. In this paper, the emissions are allocated to the country where the passengers are residing. Our choice is based on an analysis of nine options in relation to a set of five criteria.

The options that are considered are the eight options presented by the UNFCCC Subsidiary Body of Scientific and Technological Advice (SBSTA) (see Table 1). In addition to these original eight options we have added the option of allocation to the country of residency of the *final consumer*, i.e. a consumption-based allocation. Allocations based on the residency of the passenger (Option 7) or of the final consumer (Option 9) are identical regarding air travel for private purposes (vacations, etc.) since the passenger is also the final consumer. For business travel, however, these options differ. For the consumption-based option, emissions from business trips would be allocated to the country of residency of the final consumer of the product that the company produces. For example, if an employee at Volvo in Sweden makes a business trip abroad, then the emissions from this trip would be allocated to the various countries in which the buyers of Volvo cars live.

The five criteria for choosing an allocation option used in this study were sensitivity, additivity, non-leakage, validity, and reliability (inspired by Kander et al., 2015; Wood et al., 2010). Our assessment concludes that Option 7 (allocation based on residency of the passenger) is the one that is the most suitable. Below is a summary of our analysis of the different options in relation to the criteria.

Sensitivity implies that an emissions accounting system should be responsive to factors that countries can influence. Options 1 and 2 are ruled out based on this criterion. An assessment of the other options would depend on which specific policy instruments are considered, all the other options can however be said to satisfy this criterion.

Additivity implies that the sum of all national emissions should be equal to global emissions. Provided accurate measurements are available, this criterion would be fulfilled by all allocation options except Options 1 and 8 (since a lot of aviation occurs over international waters).

Non-leakage implies that countries should not be able to reduce their emissions in a way that increases global emissions. As an example, fuel tax in one country might lead to extra fuel being carried, resulting in additional emissions. Carbon leakage could be a problem for several of the options, but we see no such risks for Options 7 and 9.

Validity refers to that the allocation should accurately reflect a country's GHG emissions from international air travel. Option 3 – allocation based on in which country the fuel is sold – is one way in which the countries can calculate the emissions that they report to UNFCCC (IPCC, 2006). The validity with this option is problematic since it allocates large emissions to countries with large transit airports, and low emissions to countries without transit airports even if its residents are frequent air travellers.

Reliability - Option 7 (allocation based on the residency of the passenger) and Option 9 (allocation based on residency of the final