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Factors determining airline's costs for climate protecting market-based measures

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Abstract

This paper investigates the factors influencing airline's costs for climate protecting market-based measures. It is based on selected results of the interdisciplinary research project AviClim (Including Aviation in International Protocols for Climate Protection). AviClim has investigated how to limit aviation's full climate impact best from an environmental and economic point of view. In this research project, both long-lived CO_2 and short-lived non-CO_2 effects of aviation have been addressed simultaneously and climate protecting scenarios for aviation in the timeframe 2010-2030 have been developed. On this basis, the factors determining aviation's costs for climate protecting measures have been analysed.

Results indicate that the choice of the market-based measure, it's regional scope, the metric chosen for the translation of the non-CO_2 impacts into equivalent CO_2 and the prices for equivalent CO_2 are important factors for airline's costs. An analysis for single flights reveals remarkable differences in specific emissions (tons CO_2 equivalent/flight kilometre). An investigation for groups of airlines differentiated by business model and country of origin indicates that the world regions served by the airlines, the business model, the length and the emission characteristics of the flights are further important factors for the costs of the regulating measure.

Keywords: air transport; climate relevant emissions; market-based measures

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1. Objectives

Aviation is a continuously growing sector. According to forecasts of the International Civil Aviation Organisation ICAO, international aviation is expected to grow by 3 – 5 per cent annually in the next decades, depending on the world region (ICAO, 2013). As aviation's climate relevant emissions are only regulated to a small part currently, air transport's contribution to climate change will be increasing in the next decades. Aviation generates both long lasting effects on climate by emitting CO_2 and rather short term effects by emitting NO_x, H_2O, contrails and contrail cirrus which induce ozone and methane changes. While CO_2 has an atmospheric lifetime up to a millennia, the lifetime of the other climate relevant species ranges from hours to months respectively decades. Different to most sectors, aviation's non-CO_2 effects on climate play an important role and contribute about 2/3 of the total impact on climate in terms of radiative forcing (Lee et al., 2009).

The interdisciplinary research project AviClim (Including Aviation in International Protocols for Climate Protection) has explored the feasibility for including aviation's full climate impact, i.e., both long-lived CO_2 and short-lived non-CO_2 effects, in international protocols for climate protection and has investigated the economic impacts. In particular, the cost, demand, competition and employment as well as the environmental effects have been analyzed. For regulating aviation's full climate impact, three different market-based measures have been designed. The present paper presents selected results of the project and investigates the factors determining aviation's costs for climate protecting measures.

2. Data and methodology

Climate relevant species addressed within AviClim are: CO_2, NO_x, H_2O and contrails. This way, the full climate impact of aviation can be regulated at the same time. In this research project, a climate tax, an open emission trading scheme for regulating all climate relevant emissions from aviation and a NO_x emission charge combined with an open CO_2 trading scheme and operational measures have been investigated alternatively for the regulation of aviation's full climate impact. These market-based measures have been combined with four geopolitical reduction scenarios which differ concerning the international support for these climate protecting measures. In this way, they take the global dimension of the issue and the challenges associated with the international negotiations on climate change into account. Based on the political discussions on EU-, ICAO- and UNFCCC-level in the last years, four scenarios have been considered:

- The first geopolitical scenario assumes that the political measure under consideration will be implemented by the Member States of the European Union (EU27) plus Norway, Iceland and Liechtenstein, but not by the rest of the world. This scenario is called "Greater EU".
- A second scenario which presumes that the US, Canada, South Korea, Japan, Singapore, Russia, Australia, India, China, Brazil and the United Arab Emirates will introduce this political measure in addition to the "Greater EU"-States (EU27, Norway, Iceland, Liechtenstein and Switzerland). This way, the major players and emitters in international aviation will be addressed. Accordingly, this scenario is called "Great Aviation Countries".
- A third geopolitical scenario assumes that all Annex-I Countries of the Kyoto Protocol plus Brazil, Russia, India and China (BRIC-Countries) but none of the other developing countries will implement the climate protecting measure under consideration. This scenario has been named "Annex-I Countries".
- Finally, the scenario "World" is assuming a worldwide implementation of the climate protecting measure under consideration.

As a reference development, a business-as-usual scenario has been developed. In this scenario, the absence of climate protecting measures in aviation other than implemented until 2010, is assumed.

The three market-based measures have been combined with the four geopolitical reduction scenarios. The comparison of the environmental and economic impacts of these different market-based measures and geopolitical scenarios allows for conclusions on the environmental, economic and competitive impacts of the political measures under consideration.

The cost, demand and competition impacts of these political measures as well as the impacts on employment have been estimated by employing economic simulation models. The environmental and climate effects have been investigated by DLR-developed metrics and models, see Schaefer (2012) and Dahlmann (2012) as well as Scheelhaase et al. (2015) for details.

Both long-lived CO_2 and short-lived non-CO_2 species, such as NO_X, H_2O or contrails and associated cirrus, contribute to aviation's full climate impact. The latter depend on flight altitude, geographical location, day time, weather and other factors (e. g. Fichter et al. (2005), Mannstein et al. (2005), Fichter (2009) and Frömming et al. (2012)). Since the life-times of non-CO_2 species differ and their climate impact depends to a great extent on the location of emission, the climate impact induced by aviation's non-CO_2 species is not proportional to the CO_2 emissions. Against this background, the application of a suitable metric is important for the appropriate translation of the non-CO_2 effects into equivalent CO_2. According to Dahlmann (2012), the so-called 'Average Temperature Response' (atr) is an adequate metric for the comparison of aviation's non-CO_2 effects with each other and with CO_2 and the translation of the non-CO_2 effects into equivalent CO_2. Within AviClim, time horizons for the metric atr of 20 and 50 years (atr 20 and atr 50) are investigated. This means the mean changes in near surface temperature averaged over 20 and 50 years, respectively, are taken into account. In this paper, we concentrate on the effects calculated for the metric atr 50.

Within AviClim, three different price development paths for CO_2 and CO_2 equivalents have been assumed alternatively:

- A 'High Price Path' where prices per ton CO_2 equivalent range from 10 USD in the year 2010 up to 80 USD in the year 2030,
- a 'Low Price Path' where a price development of 10 USD per ton CO_2 equivalent (2010) to 30 USD per ton in 2030 has been assumed and
- a 'Mixed Price Path'. This price path combines low CO_2 equivalent prices for both trading schemes under investigation and high CO_2 equivalent prices for the climate tax and the NO_X charge. This way, the probable advantages of emission trading models which become evident in lower prices for emission permits (as compared to taxes and charges) can be shown more explicitly.

The costs for the market-based measures will increase the production costs of the airlines under the regulatory scheme. Under the simplifying assumption that the airlines will act as profit maximizers, they will try to pass-through the full costs of complying with the regulation scheme. Accordingly, prices for air services will increase. How will demand react? As it is difficult to predict this demand reaction (see Oum et al. (1990), Oum et al. (1992) or Lu (2009), for instance), different price elasticities of demand have been assumed alternatively. The corresponding demand reactions range from an inelastic reaction (quantitative demand for air services remains unchanged as compared to the business-as-usual development); a moderate demand reduction (quantitative demand reduction is under proportionate to the price increase); and a highly elastic reaction (quantitative demand reduction is disproportionate to the price increase by the airlines).

In case demand reacts to the price increase by a quantitative reduction in demand, airlines' revenues will be affected negatively. As a next step, the airlines are expected to change their flight plan (supply side effect). Implicitly, equality of supply and demand has been assumed here. This is plausible after a certain time. These developments will affect employment and air traffic in the timeframe analysed. In case air traffic will decrease as compared to the business-as-usual development, a reduction in fuel consumption, climate relevant emissions and a reduced climate impact from aviation result.

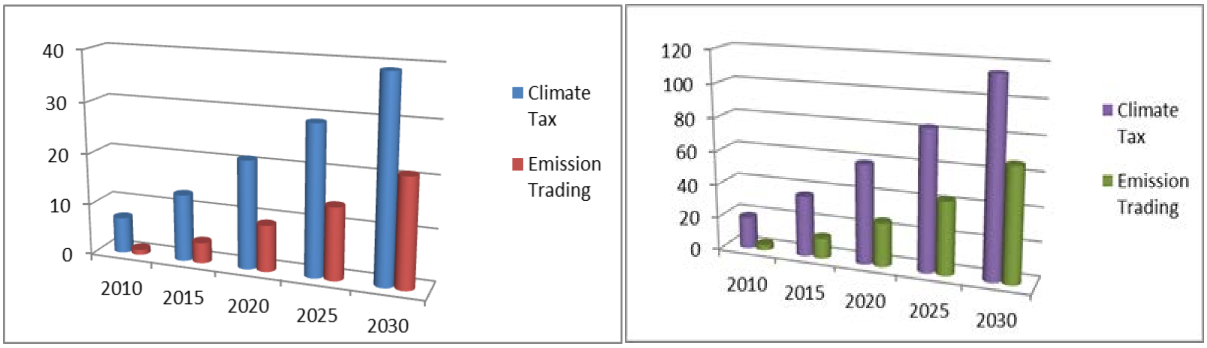
3. Results

The following section provides an overview of AviClim's selected results on the costs and competition impacts of the market-based measures climate tax and emission trading for all climate relevant species. Here, modelling results for the geopolitical scenarios "Greater EU", "Great Aviation Countries" and "World" combined with the "High Price Path" as well as the "Low Price Path" and the metric atr 50 are presented. This selection of market-based measures and scenarios allows for most meaningful results in terms of cost and competitive impacts. Scheelhaase et al. (2014) presents and discusses AviClim's economic and environmental results in full.

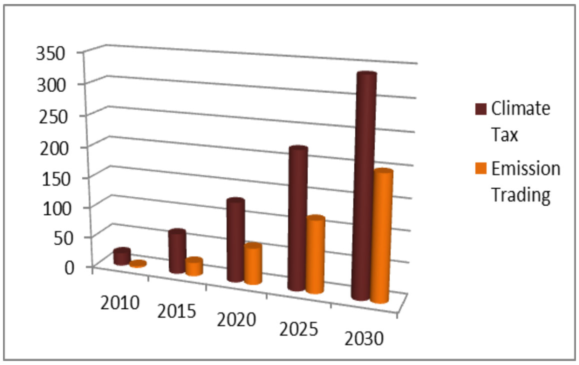
In the next section at first cost impacts for the aviation sector under the respective market-based measure are presented. This is followed by an analysis of the cost and competition impacts on airlines' level.

3.1 Costs for the airlines under the market-based measure

Under the assumption that the airlines potential to abate climate relevant emissions by technological measures will be already tapped in the business-as-usual scenario, which is reasonable to believe as fuel costs are an important driver today, the costs for the market-based measures will increase the production costs of the airline sector, as mentioned above. AviClim results show that total costs for the airline sector depend to a great extent on the market-based measure, the geopolitical reduction scenario and the CO_2 equivalent prices assumed. The following pictures provide an overview of the costs modelled for the airlines under the respective market-based measure and geopolitical scenario.



Pictures 1 and 2: Cost impacts in the scenarios "Greater EU" (left picture) and "Great Aviation Countries" (right picture) in USD million, Low Price Path. Source: AviClim modelling results. In 2012 prices. Results for the metric atr 50.



Picture 3: Cost impacts in the scenario "World", in USD million, High Price Path. Source: AviClim modelling results. In 2012 prices. Results for the metric atr 50.

As the pictures show total costs for complying with the respective market-based measure increase within the timeframe analysed. This development can be explained by the expected air traffic growth in 2010 – 2030. This leads to rising climate relevant emissions and increasing costs for the climate tax and the emission trading scheme.

With regard to the geopolitical reduction scenario investigated total costs are the highest for the scenario “World”. As a maximum, total costs of about 339 USD million can be expected in the year 2030 (climate tax, High Price Path). Costs calculated for the “Great Aviation Countries” are almost at the level of the results for the “World” scenario. This is because the delta between both reduction schemes is less than 10 per cent of the global flights. In contrast, costs estimated for the airlines under the “Greater EU” scenario are comparably low. Here costs ranging from 1 USD billion (emission trading, Low Price Path) in the year 2010 to 105 USD billion (climate tax, High Price Path) in the year 2030 have been modelled. Overall, these differences in costs are caused by the number and the emission characteristics of the flights under the respective geopolitical reduction scenario.

An analysis of the market-based measure assumed reveals that the emission trading scheme for all climate relevant species causes significantly lower costs than the climate tax. This is the case for all geopolitical scenarios and price paths investigated. The differences in costs are the highest in the beginning of the time period under investigation and diminish partly until 2030. In the “Greater EU” scenario, for example, total costs for the emission trading scheme amount up to 1 USD billion in 2010 while costs for the climate tax are expected to be about 7 USD billion in that year (High Price Path). In the year 2030, however, total costs for complying with the emission trading scheme are expected to be about 57 USD billion and total costs for the climate tax are estimated at 105 USD billion (High Price Path). These differences between the market-based measures can be explained by their fundamental discrepancies in the modes of functioning: While the climate tax charges from the first unit of CO_2 equivalent, under an emission trading scheme 85 per cent of 2010’s emissions are free of charge because for this amount emission permits are allocated for free. Consequently, at the beginning of the timeframe under consideration a relatively small number of permits has to be purchased additionally. This leads to smaller costs as compared to the climate tax. In the course of time the number of required permits rises as air traffic is expected to grow. As a result costs for complying with the emission trading scheme for the airline sector increase until 2030 but stay on a lower level than the costs for the climate tax. Overall, AviClim modelling results indicate that a global emission trading scheme limiting aviation’s full climate impact would be advantageous to minimise airlines’ costs as compared to a climate tax.

At the same time, environmental benefits from the emissions trading scheme are significant: For the scenario “World”, for instance, a reduction in temperature change of up to about 70 per cent in the year 2100 has been estimated as compared to a business-as-usual development. See Scheelhaase et al. (2014) and Scheelhaase et al. (2015) for full environmental results.

3.2 Costs and competitive impacts for airline groups under the market-based measure

As total costs probably will be distributed differently within the airline sector, competitive distortions may be caused by the climate protecting measures. To investigate these questions, different airline groups were created which have been formed in respect to the country of origin and the business model of the airlines under consideration.

1. Geopolitical Scenario “Greater EU”:
    - Top 10 “Greater EU” Full Service Network Carrier (FSNC);
    - Top 10 Non-“Greater EU” Full Service Network Carrier (FSNC);
    - Top 10 “Greater EU” Low Cost Carrier (LCC)/Holiday carrier.
2. Geopolitical Scenario “Great Aviation Countries”:
    - Top 10 “Great Aviation Countries” Full Service Network Carrier (FSNC);
    - Top 10 Non-“ Great Aviation Countries” Full Service Network Carrier (FSNC);
    - Top 10 “Great Aviation Countries” Low Cost Carrier (LCC)/Holiday carrier.
3. Geopolitical Scenario “World”:

- Top 10 “World” Full Service Network Carrier (FSNC);
- Top 10 “World” Low Cost Carrier (LCC)/Holiday carrier.

This grouping was conducted for two reasons: Firstly, an analysis on individual companies’ level would be associated with too many uncertainties since management strategies and market developments play an important role on this level, which are difficult to foresee for external parties. Secondly, an investigation of the total some 250 airlines listed in the global flight schedule OAG (Official Airline Guide (2011 ff.)) would be too time-consuming and probably not lead to very meaningful results as the assignment of the individual airlines to the different airline business models will be questionable in a number of cases.

Regional carriers have been excluded from this analysis because in most cases, these airlines can be characterized as being not very important in terms of ASK (available ton kilometres) offered, RTK (revenue ton kilometres) operated as well as revenues realized and distances operated as compared to the rest of the sector. Also, regional carriers operate their flights mostly within national or close continental boundaries. Against this background distinctive results from a comparison of the economic effects for these groups of airlines cannot be expected.

The following tables provide an overview of the assignment of individual airlines to the respective airline groups explained above, differentiated by geopolitical reduction scenario. This assignment has been conducted on the bases of empirical passenger data (RPK) for the year 2010 (Airline Business (2011)). This base year had to be chosen because all models used within AviClim’s base upon this year. In this respect, the ranking of the different Top 10 airlines groups is not up to date anymore in some cases. And some of the airlines listed in the following table do not exist as individual companies anymore today. For instance, Continental Airlines and United Airlines merged in 2010/2011 and the brand ‘Continental’ has been abandoned since. On the other hand, an in-depth analysis of the rankings 2009-2013 reveals that the changes in ranking pre-dominantly rest upon position changes within the ‘Top 10 groups’ or company mergers. Against this background the respective Top 10 airlines groups can be characterized as being relatively stable in the timeframe 2009-2013.

Table 1: Geopolitical reduction scenario “Greater EU”: airline groups investigated

Top 10 “Greater EU”- Full Service Network Carrier	Top 10 Non-“Greater EU”- Full Service Network Carrier	Top 10 “Greater EU”- Low Cost Carrier/ Holiday Carrier
Lufthansa, Air France, British Airways, KLM, Iberia, Virgin Atlantic Airways, Alitalia, TAP Portugal, Scandinavian Airlines (SAS) and Finnair.	Delta Air Lines, American Airlines, United Airlines, Emirates, Continental Airlines, China Southern Airlines, Qantas, Cathay Pacific, US Airways and Air China.	Ryanair, easyjet, Air Berlin, Thomson Airways, Thomas Cook Airways (UK), Condor Flugdienst, Air Europa, TUIfly, Monarch Airlines and Aer Lingus.

Source: Own compilation on the basis of Airline Business (2011). Airline assignment on the basis of the country of origin and main business model used. Only airlines with flights under the reduction scheme are taken into account.

Table 2: Geopolitical reduction scenario “Great Aviation Countries”: airline groups investigated

Top 10 “Great Aviation Countries” - Full Service Network Carrier	Top 10 Non-“Great Aviation Countries”- Full Service Network Carrier	Top 10 “Great Aviation Countries”- Low Cost Carrier/Holiday Carrier
Delta Air Lines, American Airlines, United Airlines, Emirates, Lufthansa, Continental Airlines, Air France, China Southern Airlines, British Airways and Qantas.	Thai Airways International, Qatar Airways, Turkish Airlines (THY), Malaysia Airlines, Saudi Arabian Airlines, LAN Airlines, China Airlines, Air New Zealand, South African Airways and Garuda Indonesia Airways.	Southwest Airlines, Ryanair, easyjet, JetBlue Airways (US), Air Berlin, Thomson Airways, AirTran Airways, GOL Linhas Aereas Inteligentes, Thomas Cook Airlines (UK) and WestJet Airlines (Canada).

Source: Own compilation on the basis of Airline Business (2011). Airline assignment on the basis of the country of origin and main business model used. Only airlines with flights under the reduction scheme are taken into account.

Table 3: Geopolitical reduction scenario “World”: airline groups investigated

Top 10 “World” - Full Service Network Carrier	Top 10 “World”- Low Cost Carrier/ Holiday Carrier
Delta Air Lines, American Airlines, United Airlines, Emirates, Lufthansa, Continental Airlines, Air France, China Southern Airlines, British Airways and Qantas.	Southwest Airlines, Ryanair, easyjet, JetBlue Airways (US), Air Berlin, Thomson Airways, AirTran Airways, GOL Linhas Aereas Inteligentes, Thomas Cook Airlines (UK) and WestJet Airlines (Canada).

Source: Own compilation on the basis of Airline Business (2011). Airline assignment on the basis main business model used.

Not surprisingly, the Top 10 groups of the FSNC as well as the LCC/Holiday carrier in the scenarios “Great Aviation Countries” and “World” are identical in ranking and composition, as the last two tables illustrate. An in-depth analyses and comparison of the competitive impacts for the airlines groups under both reduction scenarios is still worthwhile conducting because in the “World” scenario all global flights are subject to the respective market-based measure whereas in the scenario “Great Aviation Countries” only the flights to, from and within these countries are under the respective reduction instrument.

The modelling of the cost impacts of the climate tax and the emission trading scheme for all climate relevant species from aviation has been conducted as follows: At first, the revenue ton kilometres (RTK) of the years 2010-2030 under the respective geopolitical reduction scenario have been calculated for the individual airlines. According to AviClim’s main assumptions, all flights to, from and within the countries participating in the geopolitical scenario are subject to the market-based measure under consideration. At second, the corresponding climate relevant emissions (in tons CO_2, NO_X, H_2O, contrails) for these flights have been estimated.

The costs for the climate tax have then been modelled by weighing the climate relevant emissions under the reduction scenario on the airlines level with the specific metric for CO_2, NO_X, H_2O, contrails, respectively. The metric atr_{50} translates the climate impact of the non-CO_2 species into equivalent CO_2. This metric varies with the flight position p (see below) and the climate relevant species. This way, the different climate relevant species can be directly compared with each other and the total amount added up in tons CO_2 equivalent. As a next step, the total amount of CO_2 equivalent subject to the reduction measure has been multiplied by the assumed price per ton CO_2 equivalent, differentiated by the three price scenarios and years explained above.

These modelling steps can be conducted by using the following formula

$$climate\ tax = price * \sum_{p \in Flight} CO_{2\,(p)} + NO_{x(p)} * atr_{50(p)}^{(NO_x)} + H_2O_{(p)} * atr_{50(p)}^{(H_2O)} + dist_{(c)} * atr_{50(p)}^{(Cont)}$$

Where: $NO_{X\ (p)}$ is the amount of NO_X emitted on the different flight altitudes, degrees of longitudes and latitudes (identical with flight position p) at different points in time. The climate relevant species H_2O, CO_2 and contrails are differentiated by the flight position p as well, because these species diversify with the local atmospheric conditions and the actual thrust-setting of the engines. Since the climate impact of CO_2 does not depend on the altitude of emission, it is not necessary to take the flight altitude ($atr_{CO2,p}$) into account for this climate relevant species.

The climate tax has been calculated for all flights and airlines under the respective reduction scenario on a flight-by-flight-basis. The summation of the individual airlines' costs for the Top 10 airline groups analysed equates to their total costs for the climate tax.

The costs for complying with the emission trading scheme have been calculated within three consecutive steps: Starting point was the estimation of the emissions cap for the respective geopolitical reduction scenario. Within AviClim the emissions cap has been set at 2010 levels. This means that aviation's emissions are limited to the amount of CO_2 equivalent emitted in the year 2010. This cap has been calculated in tons of CO_2 equivalent applying the methodology explained above. For all emissions exceeding this cap, permits have to be purchased by the airlines. Since the aviation sector is expected to grow in the timeframe 2010-2030, aviation will be a net buyer on the emission permits market. Furthermore a free allocation of 85% of 2010 emissions has been assumed, this assumption has been inspired by the free allocation rule in the EU-ETS. The remaining 15% of permits have to be auctioned by the airlines. Applying these rules, the amount of climate relevant species under the emission trading scheme and the amount of emissions exceeding the cap can be calculated. For the latter, emission permits have to be purchased. The amount of permits allocated free of charge to the individual airlines will be determined by a so-called benchmark, which has also been inspired by the related regulations in the EU-ETS for aviation. But within AviClim, we decided to abstain from introducing the numerous exceptions within the EU-ETS and to keep the benchmark rules relatively simple. The benchmark applied within AviClim stays constant throughout the whole timeframe analysed, same as the EU-ETS. But it differs between the geopolitical scenarios because the absolute amount of CO_2 equivalent emitted as well as the revenue ton kilometres (RTK) subject to the reduction schemes vary.

The method of calculating the benchmark for aviation has been described in literature, for instance see Scheelhaase et al. (2010) for details. In short, the total amount of CO_2 equivalent of the base year (AviClim: 2010) is weighed with the share of emission permits allocated for free (AviClim: 85%). The result will then be calculated as a ratio of the total revenue ton kilometres (RTK) of the year 2010. This benchmark in turn will be multiplied by the absolute number of RTK submitted by the airline for the year 2010 to calculate the individual amount of permits allocated free of charge. This way, very environmental efficient airlines will get a higher amount of emission permits for free while relatively inefficient aircraft operators will receive a smaller number of permits per RTK. Thus, early movers in terms of efficiency will be rewarded for their past steps.

The benchmark applied within AviClim can be regarded as a measurement for the environmental efficiency of the flights under the reduction scheme. In the geopolitical “Greater EU” scenario the benchmark is 2.817 tons CO_2 equivalent/1,000 RTK, in scenario “Great Aviation Countries” it is 2.940 tons CO_2 equivalent/1,000 RTK and in scenario “World” it is 2.952 tons CO_2 equivalent/1,000 RTK. Here, the existing differences in the environmental efficiency of flights and airlines already show. Apparently the flights to, from and within the countries of the “Greater EU” scenario in the year 2010 are a little more environmental efficient than the other flights analysed here. Whether this can be explained by the environmental efficiency of the airlines or the specific characteristics of the flights under the regulation scheme will be investigated in the following.

The cost impact of the emission trading scheme on the individual airlines can be calculated by subtracting the number of permits allocated free of charge from the absolute amount of CO_2 equivalent emitted. The delta is the number of permits which has to be purchased on the emission permits market. This delta will be multiplied with the assumed price for CO_2 equivalent. The costs for complying with the emission trading scheme on the level of individual airlines result. The summation of the costs of the respective Top 10 groups equates to their total costs for this market-based measure.

The following tables provide an overview of the costs calculated for the different airline groups, market-based measures, geopolitical reduction scenarios and price paths explained above.

Table 4: Absolute costs for the climate tax and the emission trading scheme for different airline groups, in USD million

Scenario/Group of Airlines	**Low Price Path**					**High Price Path**				
Emission Trading all species	**2010**	**2015**	**2020**	**2025**	**2030**	**2010**	**2015**	**2020**	**2025**	**2030**
Top 10 "Greater EU" Network Carrier	399	1696	3677	6513	8753	399	2827	7354	15631	23342
Top 10 Non-"Greater EU" Network Carrier	152	669	1451	2378	3647	152	1116	2902	5707	9727
Top 10 "Greater EU" LCC/Holiday Carrier	141	487	1001	1526	2193	141	811	2002	3662	5849
Top 10 "Great Aviation Countries" Network Carrier	1040	3363	7753	12835	19600	1040	5605	15506	30803	52267
Top 10 Non-"Great Aviation Countries" Network Carrier	155	816	1862	3143	4777	155	1360	3723	7544	12739
Top 10 "Great Aviation Countries" LCC/Holiday Carrier	242	819	1631	2481	3578	242	1365	3261	5955	9540
Top 10 "World" Network Carrier	982	4158	8892	14342	21533	982	6930	17784	34420	57420
Top 10 "World" LCC/Holiday Carrier	249	843	1680	2145	3693	249	1406	3360	4487	9847

Scenario/Group of Airlines	**Low Price Path**					**High Price Path**				
Climate Tax	**2010**	**2015**	**2020**	**2025**	**2030**	**2010**	**2015**	**2020**	**2025**	**2030**
Top 10 "Greater EU" Network Carrier	2658	5085	8195	12160	15530	2658	8474	16390	29184	41414
Top 10 Non-"Greater EU" Network Carrier	1013	1960	3173	4530	6230	1013	3267	6345	10871	16612
Top 10 "Greater EU" LCC/Holiday Carrier	938	1682	2595	3518	4584	938	2804	5190	8444	12224
Top 10 "Great Aviation Countries" Network Carrier	6934	12204	19541	27569	37282	6934	20340	39082	66167	99419
Top 10 Non-"Great Aviation Countries" Network Carrier	1036	2137	3622	5344	7418	1036	3561	7245	12826	19782
Top 10 "Great Aviation Countries" LCC/Holiday Carrier	1613	2875	4372	5908	7690	1613	4792	8745	14180	20507
Top 10 "World" Network Carrier	6546	10683	20020	28252	38225	6546	17805	40040	67804	101933
Top 10 "World" LCC/Holiday Carrier	1661	2962	4504	5160	7929	1661	4936	9008	10896	21145

Source: AviClim modelling results. In 2012 prices. Results for metric atr 50.

Table 5: Specific costs for the climate tax and the emission trading scheme for different airline groups, in USD/RTK

Scenario/Group of Airlines	**Low Price Path**					**High Price Path**				
Emission Trading all species	**2010**	**2015**	**2020**	**2025**	**2030**	**2010**	**2015**	**2020**	**2025**	**2030**
Top 10 "Greater EU" Network Carrier	0.005	0.016	0.028	0.041	0.045	0.005	0.027	0.056	0.098	0.120
Top 10 Non-"Greater EU" Network Carrier	0.005	0.017	0.029	0.037	0.046	0.005	0.028	0.057	0.090	0.122
Top 10 "Greater EU" LCC/Holiday Carrier	0.005	0.015	0.026	0.034	0.042	0.005	0.026	0.052	0.081	0.111
Top 10 "Great Aviation Countries" Network Carrier	0.006	0.015	0.027	0.038	0.045	0.006	0.024	0.053	0.091	0.119
Top 10 Non-"Great Aviation Countries" Network Carrier	0.005	0.018	0.032	0.042	0.050	0.005	0.030	0.063	0.100	0.134
Top 10 "Great Aviation Countries" LCC/Holiday Carrier	0.006	0.017	0.028	0.036	0.045	0.006	0.028	0.056	0.087	0.120
Top 10 "World" Network Carrier	0.005	0.018	0.030	0.040	0.049	0.005	0.030	0.061	0.096	0.130
Top 10 "World" LCC/Holiday Carrier	0.006	0.017	0.029	0.032	0.046	0.006	0.029	0.057	0.066	0.122
Average	0.005	0.017	0.029	0.037	0.046	0.005	0.028	0.057	0.089	0.122
Scenario/Group of Airlines	**Low Price Path**					**High Price Path**				
Climate Tax	**2010**	**2015**	**2020**	**2025**	**2030**	**2010**	**2015**	**2020**	**2025**	**2030**
Top 10 "Greater EU" Network Carrier	0.032	0.049	0.063	0.077	0.080	0.032	0.081	0.126	0.184	0.213
Top 10 Non-"Greater EU" Network Carrier	0.033	0.049	0.061	0.071	0.078	0.033	0.082	0.125	0.171	0.209
Top 10 "Greater EU" LCC/Holiday Carrier	0.036	0.053	0.068	0.078	0.087	0.036	0.088	0.136	0.187	0.232
Top 10 "Great Aviation Countries" Network Carrier	0.039	0.053	0.067	0.081	0.085	0.039	0.088	0.134	0.196	0.226
Top 10 Non-"Great Aviation Countries" Network Carrier	0.030	0.047	0.061	0.071	0.078	0.030	0.078	0.123	0.171	0.208
Top 10 "Great Aviation Countries" LCC/Holiday Carrier	0.041	0.059	0.075	0.086	0.096	0.041	0.098	0.150	0.207	0.257
Top 10 "World" Network Carrier	0.036	0.046	0.068	0.078	0.086	0.036	0.076	0.137	0.188	0.230
Top 10 "World" LCC/Holiday Carrier	0.042	0.061	0.077	0.076	0.098	0.042	0.101	0.154	0.160	0.262
Average	0.036	0.052	0.068	0.077	0.086	0.036	0.087	0.136	0.183	0.230

Source: AviClim modelling results. In 2012 prices. Results for metric atr 50.

The tables show that both the absolute cost impact and the specific costs implied by the climate protecting measure differ quite clearly from each other with regard to the geopolitical reduction scenarios analyzed. In absolute numbers the highest cost impact can be expected for airlines based in one of the countries supporting the respective climate protecting measure. The climate tax, for instance, will lead to additional costs for the Top 10 FSNC from a "Greater EU"-Country of about 15.53 USD billion in the year 2030 (Low Price Scenario). Their competitors from outside the "Greater EU" countries will have to bear additional costs of about 6.23 USD billion in the same year and scenario. This discrepancy is caused by the fact that the predominant number of flights operated under this geopolitical reduction scenario is performed by airlines based in one of the "Greater EU" countries while flights from their competitors from outside the "Greater EU" – with very few exceptions - are only operated to and from Europe. For instance, in this geopolitical scenario about 90% of Lufthansa's RTKs will be operated under the climate protecting measure while United Airlines only has to comply with the climate protecting instrument under consideration for 18% of its' RTKs operated. This leads to the conclusion that a competitive disadvantage can be expected for those aircraft operators whose country of origin is supporting the respective climate protecting measure and which operate flights to and from other world regions.

An analysis of the specific costs (USD/RTK) shows a heterogeneous picture: On the one hand, the specific costs implied by the market-based measures are lower for some airlines based in a "Greater EU" or a "Great Aviation Country", as compared to their competitors from outside the respective geopolitical regulation scheme. This is especially true for the costs caused by the emission trading scheme for the years 2015-2030. On the other hand, for the climate tax a partly opposing trend can be noticed. For instance, the specific costs for the Top 10 FSNC based in one of the "Great Aviation Countries" will increase by 0.085 USD per RTK due to the climate tax in the year 2030, while the specific costs for the Top 10 FSNC from outside this group of countries only rise by 0.078 USD/RTK.

Apart from the absolute and specific costs, the average specific emissions, i. e. tons CO_2 equivalent per 1,000 RTK, are a decisive factor for the airlines' financial burden implied by the market-based measure under consideration. Beyond that the percentage of free allocation of emission permits in relation to the required number of permits on the airlines' level is an essential variable for the costs especially caused by the emission trading model. Table 6 presents the specific emissions und their development in the timeframe investigated as well as the development of the percentage of free allocation of emission permits in relation to the required number of permits for the different airline groups investigated.

As illustrated by table 6, the specific climate relevant emissions are expected to decrease within the timeframe 2010-2030. This is the case for all groups of airlines investigated: On average the specific climate relevant emissions will decrease from 3.65 t CO_2 equivalent per 1,000 RTK in the year 2010 to about 2.93 tons CO_2 equivalent/1,000 RTK in 2030. Here the influence of autonomous technological efficiency gains on the environmental performance of the aviation sector shows.

Table 6: Development of the specific emissions (tons CO_2 equivalent/1,000 RTK) and of the free allocation of emission permits in relation to the required number of permits (in per cent) in the timeframe 2010-2030

	Specific emissions (t CO_2 equivalent/1000 RTK)					**Percentage of free allocation of emission permits**				
Scenario/Group of Airlines	**2010**	**2015**	**2020**	**2025**	**2030**	**2010**	**2015**	**2020**	**2025**	**2030**
Top 10 "Greater EU" Network Carrier	3.42	3.44	3.33	3.15	2.83	85 %	67 %	56 %	49 %	45 %
Top 10 Non-"Greater EU" Network Carrier	3.30	3.25	3.14	2.91	2.69	85 %	64 %	52 %	46 %	40 %
Top 10 "Greater EU" LCC/Holiday Carrier	3.63	3.55	3.39	3.12	2.88	85 %	71 %	62 %	57 %	53 %
Top 10 "Great Aviation Countries" Network Carrier	3.74	3.52	3.38	3.11	2.86	85 %	69 %	58 %	51 %	46 %
Top 10 Non-"Great Aviation Countries" Network Carrier	3.26	3.30	3.22	2.97	2.73	85 %	63 %	50 %	43 %	37 %
Top 10 "Great Aviation Countries" LCC/ Holiday Carrier	4.07	3.94	3.77	3.47	3.26	85 %	71 %	63 %	58 %	54 %
Top 10 "World" Network Carrier	3.62	3.59	3.45	3.17	2.92	85 %	66 %	55 %	49 %	43 %
Top 10 "World" LCC/ Holiday Carrier	4.18	4.05	3.87	3.62	3.30	85 %	71 %	63 %	58 %	54 %
Average	3.65	3.58	3.44	3.19	2.93	85 %	68 %	57 %	51 %	47 %

Source: AviClim modelling results. In 2012 prices. Results for the metric atr 50.

Not surprisingly, a comparison of the specific climate relevant emissions of the different groups of airlines reveals wide differences. Especially those groups of carriers operating very fuel efficient (LCC and Holiday carrier) have significantly higher specific climate relevant emissions than other groups of airlines at the beginning of the timeframe analyzed. The Top 10 LCC/Holiday carrier based in one of the “Greater EU” countries for instance, emit about 3.63 tons CO_2 equivalent per 1,000 RTK in the year 2010 while the Top 10 FSNC from one of the “Greater EU” countries cause about 3.42 tons CO_2 equivalent per 1,000 RTK. These differences can be explained by the technologically given “trade-off” between fuel (and thus CO_2) optimization of aircraft engines on the one hand side and a NO_X (and other climate relevant species) optimization of these engines on the other side. Today’s engines can technologically be only optimized in one or the other way. By a step-wise introduction of innovative engine technology which allows for the reduction of both CO_2 and non-CO_2 emissions at the same time in the timeframe analyzed, the differences between the specific emissions of the LCC/Holiday carriers and the other airline groups investigated diminish. In the year 2030 for instance, the Top 10 FSNC based in one of the “Greater EU” countries are expected to emit about 2.83 tons CO_2 equivalent per 1,000 RTK and the Top 10 LCC/Holiday carrier from one of the “Greater EU” countries will cause circa 2.88 tons CO_2 equivalent/1,000 RTK.

The percentage of free allocation in relation to the required number of allowances is also an important factor, as mentioned above. This is because this percentage determines the number of permits to be purchased by the airlines for maintaining their operations. In 2010, this percentage is 85 per cent regardless of the business model of the airlines and the geopolitical scenario assumed, due to AviClim’s main assumptions for the emission trading scheme. Since the number of permits allocated for free stays constant in the timeframe 2010-2030 and the number of flights as well as the climate relevant emissions caused rise in this period, the number of emission permits required by the airlines increases. Correspondingly, the percentage of free allocation in relation to the required number of permits decreases. On average, this percentage decreases from 85 per cent in the year 2010 to about 46.8 per cent in 2030. In other words: In the year 2030, the airline sector has to purchase emission permits for more than half of it's climate relevant emissions.

An analysis by airline business model reveals some distinctive differences: From 2015 onwards, the Top 10 LCC/Holiday carrier groups have the highest percentage of free allocation in relation to the required permits, as compared to both Top 10 groups of FSNC in the respective scenario. This is the case in all geopolitical reduction scenarios investigated. Further remarkable is that the percentage of free allocation of emission permits is always higher for FSNC based in a country supporting the market-based measure than the corresponding percentage of the competing FSNC from outside the geopolitical reduction scenario. In the year 2020, FSNC based in one of the "Great Aviation Countries" will receive free emission permits for about 57.7 per cent of their climate relevant emissions in that year, for instance. In contrast, their competitors from outside the "Great Aviation Countries" will only get a free allocation of emission permits of about 50.4 per cent in 2020.

These finding can be attributed to two main reasons: Firstly, the growth rates of air traffic in the timeframe analyzed. In the medium term these growth rates differ clearly depending on the world region: The European and North American air traffic markets are expected to be relatively mature. In contrast for the Asian market noticeable growth is forecasted (Airbus, 2013). Accordingly, the absolute amount of climate relevant emissions will develop unevenly in the future, depending on the world region. As the airlines serve these world regions differently, this will influence their share of free emission permits in relation to the number of required permits.

Secondly, the specific climate relevant emissions (tons CO_2 equivalent/1,000 RTK), i. e. the emission characteristics of the flights under the emission trading scheme play an important role. The smaller the specific climate relevant emissions of the flights, the better for the free allocation rate of permits. AviClim modelling results show that especially on long-haul flights the ratio tons CO_2 equivalent/flight kilometer is relatively disadvantageous as compared to short- and medium-haul flights. This is mainly because NO_X emitted on high altitudes (i. e. cruise levels) has an increased climate effectiveness (Lee et al. (2010) and Lee et al. (2009)). Consequently, short- and medium-haul flights of LCC/Holiday carrier and FSNC as well as feeder and de-feeder flights of FSNC operated within the geographical boundaries of the respective geopolitical scenario are treated in favor by their flight length.

According to these findings the rate of free allocation of emission permits will be lower for FSNC from outside the geopolitical reduction scenario as compared to their competitors based in a country supporting the emission trading scheme. Remarkably, this can be interpreted as a competitive disadvantage for airlines whose country of origin does not support climate protecting measures in aviation actively. If this presumably small competitive advantage compensates the disadvantage caused by the absolute financial burden of the market-based measure for airlines based in a country supporting this measure remains to be seen.

4. Conclusions

Modelling results indicate that a global emission trading scheme limiting aviation's full climate impact would be advantageous to minimize airlines' costs as compared to a climate tax. At the same time, competitive distortions can be avoided. If a global emission trading scheme for aviation turns out to be not agreeable, the second best approach would be an implementation in the "Great Aviation Countries". This is because the delta between both reduction schemes is less than 10 per cent of the global flights.

An analysis for different groups of airlines reveals that in absolute numbers the highest cost impact can be expected for airlines based in one of the countries supporting the respective climate protecting measure. This leads to the conclusion that a competitive disadvantage can be expected for those aircraft operators whose country of origin is supporting the respective climate protecting measure and which operate flights to and from other world regions.

An in depth-analysis of the specific emissions and the rate of free allocation of permits shows that the world regions served by the airlines under consideration as well as the length and the emission characteristics of the flights are important factors for the economic impacts of the market-based measures. Also the airline business model is a distinctive determinant for the costs and competitive effects. LCC and Holiday carrier are treated in favor by the emission trading scheme on short and medium-haul flights. FSNC based in a country supporting the respective market-based measure will gain a competitive advantage as compared to their competitors from outside the geopolitical reduction scenario. This is because the share of free allocation of emission permits will always be lower for the latter. This is remarkable since these results for the limitation of aviation’s full climate impact are contrary to the respective findings for an emission trading scheme for the limitation of CO_2 alone (see Scheelhaase et al. (2010), for instance). If this presumably small competitive advantage compensates the disadvantage caused by the absolute financial burden of the market-based measure for airlines based in a country supporting this measure remains to be seen. All in all, the best option would be the implementation of the market-based measure on a global level.

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