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Cost Impacts of the Inclusion of Air Transport into the European Emissions Trading Scheme in the Time Period 2012-2020

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Since January 2012, international aviation has been included in the emissions trading scheme of the European Union (EU ETS), in accordance with EU Directive 2009/29 EC. From this year up to (at least) 2020, all flights starting from or landing at European airports are subject to the EU ETS, apart from a few exemptions. In 2012, the CO_2 emission target for aviation is 97 per cent of the historical emissions of the years 2004-2006. From 2013 onwards, this reduction target will be lowered by another 2 per cent. In September 2010, the ICAO Assembly agreed to an exemption clause for market-based measures which could be applied to the EU ETS. Whether this should be the case is a controversial issue on the international political level.
Model-based empirical estimations presented in this study indicate significant impacts of the EU ETS on airline costs, airfares and competition within the airline sector: in the year 2020, more than 50 per cent of the required allowances will have to be purchased by the airlines. Assuming an allowance price of 20 € per tonne of CO_2, the resulting costs for the aviation sector will amount to about 20,502 million € in 2012-2020. In addition, competitive distortions can be expected if the ICAO exemption clause is introduced to the EU ETS.

Keywords: Environment; Aircraft emissions; Airline competition; Air transport policy; Climate change; Environmental economics; Emissions trading; European Commission

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1. Introduction

From the year 2012 up to at least 2020, a number of energy-intense sectors will be subject to ambitious CO_2 reduction goals within the European Union. International aviation will be one of these sectors since, apart from a few exemptions, all flights starting from or landing at any European airport will be included in the EU emissions trading system (EU ETS) from 2012 onwards. In the year 2012, the total quantity of allowances allocated to aircraft operators will be equal to 97 per cent of the historical aviation emissions of the years 2004-2006 (so-called 'cap') (Council of the European Union, 2009a). From 2013 onwards, this reduction target will be lowered by another 2 per cent (Directive 2008/101/EC; Council of the European Union, 2009a). Non-CO_2 impacts of aviation, albeit considered as substantial contributors to the climate-change effect of aviation as shown in Lee et al. (2009), have so far not been included in the EU ETS, due to considerable uncertainties associated with their measurement (de F. Forster et al. 2006).

A number of studies have been published in the recent years on the economic impacts of introducing the EU ETS for air transport, e. g. by Forsyth, Dwyer and Spurr (2007), Boon et al. (2007), Scheelhaase et al. (2010), Schaefer et al. (2010), Anger and Köhler (2010), Forsyth (2011) and Yuen and Zhang (2011). These studies mainly focus on the economic impacts on the air transport sector in the short and medium term respectively. In addition, specific aspects are analysed, such as the impact of the EU ETS on tourism (Forsyth, Dwyer and Spurr (2007)) or the impacts of introducing the trading scheme on full-service network airlines from European versus non-European countries (Schaefer et al. (2010)). Anger and Köhler (2010) compare the main findings of the recent studies on including air transport in the EU ETS. Brueckner and Zhang (2010) analyse the effects of emissions charges on air fares, service quality and the longer-term impacts on aircraft design. Yuen and Zhang (2011) investigate the effects of unilateral greenhouse gas emissions regulation on airline competition and global emissions. The two latter papers follow a theoretical modelling approach.

While most studies in literature tend to focus on short/medium-term impacts of the EU ETS, our paper investigates the effects of the EU ETS on the aviation sector as such up to the year 2020. Unlike most other studies, this will be conducted assuming the current legal framework in detail and by employing a newly-enhanced simulation model. Therefore, the objective of this paper is to investigate the cost impacts of integrating air transport into the EU emissions trading scheme in the time period 2012-2020. In addition, the cost impacts of the possible introduction of the ICAO (International Civil Aviation Organisation) exemption clause to the EU ETS will be investigated for the first time in literature. The findings of this paper are an important input for European and international air transport politics.

In order to investigate these questions, a DLR-developed air traffic and emissions simulation model is employed. This model has been enhanced by a new module simulating the future development of the worldwide fleet and resulting improvements in fuel efficiency. As a result, it can be shown that the impacts of the EU ETS on costs, fares and on competition within the airline sector will be substantial, especially in the longer term. Furthermore, the CO_2 effects will be remarkable: if the European Commission politically succeeds in integrating European as well as non-European carriers into the EU ETS, roughly one third of aviation's global CO_2 emissions will be regulated.

This paper is organized as follows: initially, an overview of the EU legislation on emissions trading for air transport for the period 2012-2020 is provided (section 2). The recent political developments on this subject on ICAO level as well as UNFCCC (United Nations Framework Convention on Climate Change) level are also presented in this section. This is followed by a brief description of our methodology (section 3). Section 4 shows and discusses the main modelling results: the cost and CO_2 impacts of the inclusion of air transport in the EU ETS in the time period 2012-2020 and the cost impacts of the ICAO exemption clause. On this basis, conclusions are drawn regarding the short and longer-term impacts of the EU ETS on competition between EU and non-EU airlines (section 5).

2. Political Background

2.1 EU legislation for the inclusion of air transport in the EU emissions trading scheme (EU ETS)

Two EU Directives make provisions for the inclusion of air transport in the EU ETS: while EU Directive 2008/101/EC (Council of the European Union, 2009a) adopts most regulations for the year 2012, Directive 2009/29/EC (Council of the European Union, 2009b) contains regulations for the period 2013-2020. These Directives apply to the 27 EU Member States and the non-EU States Norway, Iceland and Liechtenstein, which joined the EU ETS in 2008.

In the European Union and in Norway, Iceland and Liechtenstein, the EU ETS will cover all flights departing from or arriving at European airports from 2012 onwards. This way, both European and non-European airlines will participate in the EU ETS. Aircraft operators will be obliged to hold and surrender allowances for CO_2 emissions. EU Allowances (EUAs) as well as permits from the Kyoto-based “Clean Development Mechanism” (CERs) and “Joint Implementation” (ERUs) will be accepted for compliance.

The Clean Development Mechanism allows emission-reduction projects in developing countries to earn certified emission reduction (CER) credits. CERs can be traded and sold, and used by industrialized countries to meet some of their targets under the Kyoto Protocol. Joint Implementation, as defined in Article 6 of the Kyoto Protocol, allows a country with an emission reduction or limitation commitment under the Protocol (Annex B Party) to earn emission reduction units (ERUs) from an emission-reduction or emission removal project in another Annex B Party. Both CDM and JI are understood politically as being additional to emission reduction measures within the European Union.

In the year 2012, the total quantity of allowances allocated to aircraft operators will be equivalent to 97 per cent of the historical aviation emissions of the years 2004-2006 (so-called overall “cap”). This “cap” will be lowered by another 2 per cent in 2013. Allowances allocated to aircraft operators will be valid within the aviation sector only. However, it will be possible to purchase additional permits. In 2012, aircraft operators may use emission permits from “Joint Implementation” and “Clean Development Mechanism” for up to 15 per cent of the number of allowances they are required to surrender for this year. In the period 2013 until 2020, the use of these Kyoto instruments will be reduced to 1.5 per cent. This figure was a political compromise agreed upon after long and controversial negotiations. Flights from third countries, which have introduced ‘equivalent’ CO_2 reducing measures, can be excluded from the EU ETS. It will be up to the European Commission to decide whether a third country measure is equivalent (Council of the European Union, 2009b). On this issue, the future conflict potential could be significant.

Exemptions from the EU ETS will be granted for flights performed within the framework of public service obligations (PSO) on routes within outermost regions or on PSO routes with an annual capacity of fewer than 30,000 seats. Also excluded from the EU ETS will be flights performed by commercial air transport operators operating either fewer than 243 flights per four-month period for three consecutive four-month periods (so-called ‘de minimis’ clause) or flights with total CO_2-

emissions of less than 10,000 tonnes per year. The 'de minimis' clause was introduced with the goal of reducing the administrative costs for operators with a low number of flights to and from Europe. Another exemption refers to flights performed under visual flight rules, amongst some other exemptions.

2.2 Recent developments on international level

On the level of the International Civil Aviation Organisation (ICAO), which is the specialized UN agency for international civil aviation, market-based measures for the limitation of CO_2 emissions have been discussed for a number of years. In May 2009, the ICAO GIACC (Group on International Aviation and Climate Change) adopted a 'Programme of Action' with the following main goals: "An annual improvement of the fuel efficiency of 2 per cent over the medium term until 2020. For the long term, the GIACC recommends an aspirational global fuel efficiency improvement rate of 2 per cent per annum from 2021 to 2050" (International Civil Air Transport Organisation ICAO, 2009a). In addition, the ICAO Council should establish a process to develop a framework for market-based measures in international aviation. These goals were agreed upon in the 37th ICAO Assembly in October 2010. Furthermore, the 37th ICAO Assembly agreed on an exemption provision for market-based measures which could be applied to the EU ETS. The cost impacts of this exemption clause are investigated in section 4.3.

Concerning the EC Directives for the inclusion of air transport in the EU ETS, strongly diverting views of non-EU countries were expressed at the ICAO Assemblies in 2007 and 2010. Unlike the EU Member States, most other ICAO contracting states believe that an inclusion of non-EU carriers is only possible on the basis of a mutual agreement. Such mutual agreements do not exist to date. Both parties argue on the basis of the Chicago Convention on Civil Aviation. This controversial issue is still unsolved. In December 2009, the Air Transport Association of America (ATA) and the US airlines American, Continental and United commenced legal action in the UK against the inclusion of aviation in the ETS. The claimants brought the case in the UK because the UK is the administering EU Member State for these airlines. The case was referred to the Court of Justice of the EU (CJEU) (Bisset and Crowhurst, 2011). In December 2011, the Court of Justice of the EU decided that the application of the EU ETS to all airlines is legal (Court of Justice of the EU, 2011).

As of September 2012, in many countries opposed to the EU ETS, countermeasures and restrictions on European airlines are in preparation, such as special taxes and traffic rights limitations. In China, approval for orders of Airbus aircraft worth US$12 billion has been suspended. As a response, in a joint letter Airbus and eight European Airlines called upon the governments of France, Germany, the UK and Spain to stop escalating a possible trade conflict with the countries opposing the EU ETS (Airbus, 2012).

On the level of the United Nations Framework Convention on Climate Change (UNFCCC), the 17th Conference of the Parties (COP17) took place in Durban in November/December 2011. The outcome was the so-called 'Durban Platform for Enhanced Action', in which the need for enhanced action to limit climate change is recognized. However, agreement on immediate action on state level could not be reached. International aviation is not mentioned in the 'Durban Platform' (UNFCCC, 2012).

3. Methodology

The simulation model employed in this study to analyse the cost impacts of the EU ETS is a chain of software tools covering aircraft flight simulation, air traffic simulation and forecast scenarios. A schematic of the automated tool chain is presented in Figure 1. It calculates transport performance (in terms of revenue passenger-kilometres and tonne-kilometres), fuel consumption and emissions of air traffic in a bottom-up approach, i.e. starting from a database of flight movements and calculating emissions for each flight. As will be described below, this approach is followed both for historical analyses and for the emissions forecast. More details on the tool chain and its individual modules are found in Schaefer (2012).

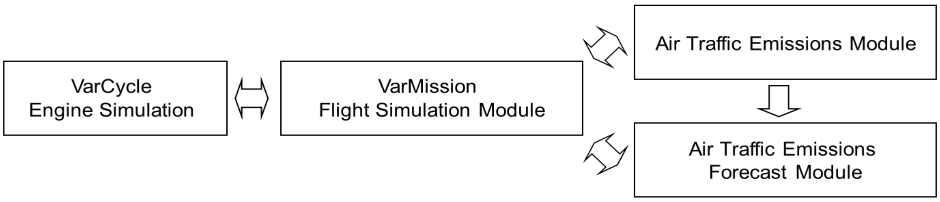

Figure 1. Schematic of model architecture

Source: Schaefer (2012).

VarMission is an aircraft performance tool developed at the DLR Institute of Propulsion Technology. It is capable of calculating fuel burn and CO_2 emissions of aircraft on flight mission level. Using the BADA database of aircraft models hosted by EUROCONTROL (EUROCONTROL, 2011), VarMission covers a broad range of large transport aircraft. Besides BADA, aircraft models from other sources and in different formats can be used with this module. Simulation models for the most important aircraft types of the near future have been developed at DLR and are used to supplement BADA for this study. This includes models of the Boeing 787-800 and 747-8, the Airbus A350XWB-900 and the Airbus A320 NEO (New Engine Option) family. The models of these aircraft types are based on estimations of their characteristic weights (e.g. empty weight, maximum take-off weight) and aerodynamic properties, while fuel flow is obtained from engine models simulated by DLR's VarCycle engine performance software. Aircraft types without available simulation models are represented by the most similar available model for the purpose of emissions calculation. As will be described below, VarMission is used by the Air Traffic Emissions Module and the Air Traffic Forecast Module to estimate fuel burn and emissions for each flight from a database of flight movements.

The Air Traffic Emissions Module employed in this study is based on worldwide flight schedules compiled by the Official Airline Guide (OAG, 2000-2010), supplemented by a DLR-developed schedule for cargo flights that are not contained in OAG. Initially, the flight schedules are converted into a database of flight movements. An engine type and a load factor are assigned to each flight from the movements data, using statistics on engines from the ASCEND fleets database (ASCEND, 2011) and load factor data from ICAO (ICAO, 2009b). Provided with this information, the module relies on VarMission to estimate fuel burn and emissions for each flight. As details on the flight trajectories are not available from the flight schedules, VarMission initially assumes "standard" trajectories without horizontal or vertical inefficiencies. In a following step, inefficiencies from Air Traffic Management (ATM) are accounted for, which influence fuel burn and emissions of global air traffic. For this purpose, the Air Traffic Module assumes flight inefficiencies from ATM including ground-based taxi delays as well as horizontal and vertical flight inefficiencies as estimated by a report from the Civil Air Navigation Services Organization (CANSO, 2008). A schematic of the Air Traffic Emissions Module is shown in Figure 2.

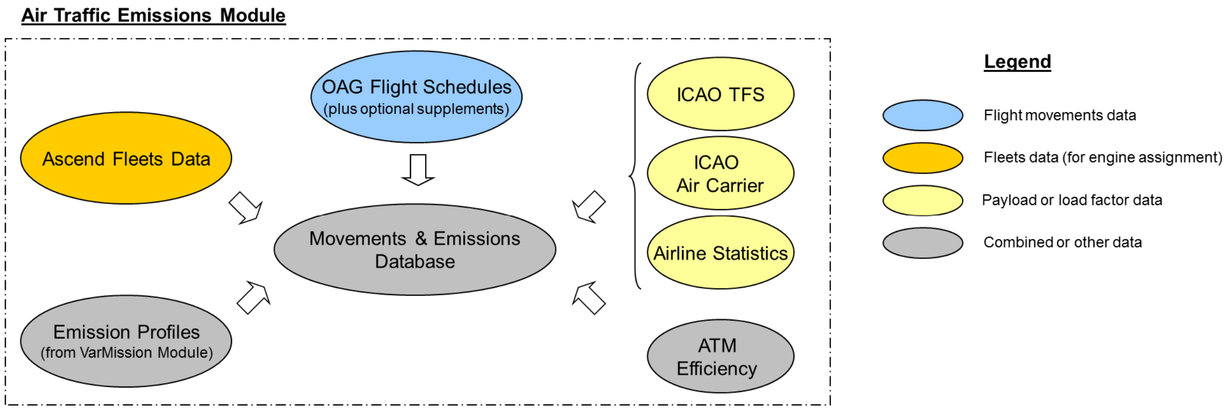

Figure 2. Schematic of the Air Traffic Module

Source: Schaefer (2012).

The Air Traffic Forecast Module predicts fuel burn and emissions of air traffic until the year 2020. Using a common database structure with the Air Traffic Emissions Module, the model applies regional traffic growth rates from the Airbus Global Market Forecast 2011-2030 (GMF; Airbus, 2011) to given flight movements for the base year 2010. A flight movements sample covering the month of September is currently used for the forecast, in order to limit the database size[1]. A fleet forecast model simulates the future development of the worldwide fleet composition based on historical fleet statistics, typical aircraft retirement curves, assumptions on new aircraft types and aircraft and engine market shares. In a year-by-year forecast based on Airbus (2011), traffic growth and fleet rollover are simulated and applied to the base year flight movements. Similar to the approach in the Air Traffic Emissions Module, VarMission aircraft models are finally employed to determine fuel burn and emissions of each flight. Furthermore, moderate improvements of load factors and ATM efficiency are assumed by the forecast model: an average passenger load factor of 80% and an average weight load factor of 68% are assumed for the year 2020. Regarding air traffic management, targets for future ATM efficiency set by CANSO (CANSO, 2008) are assumed to be met. Figure 3 presents a schematic of the Air Traffic Forecast Module.

Simplifications are made in the aforementioned model, which lead to an underestimation of fuel burn and emissions compared to reality. Most importantly, standard atmospheric conditions according to the International Standard Atmosphere (ISA) are assumed for flight simulation, neglecting the effects of wind and local temperature deviations. The resulting underprediction of fuel burn and emissions was estimated at 2-4% on average according to Schaefer (2012). In addition, effects from airframe and engine deterioration with time (aircraft aging) are not simulated, which may result in an additional underestimation of fuel consumption in the order of 1-3%. Furthermore, airlines sometimes tanker fuel on certain routes in order to take advantage of fuel price differences between origin and destination airports. Fuel tankering, which occurs mostly on short-distance flights, also contributes to higher fuel burn and emissions in real-world air traffic. In total, an underestimation of fuel consumption and emissions in the order of 5-10% can be expected for model results.

[1] In the forecast, yearly results are up-scaled from September results assuming respective ratios of the year 2010.

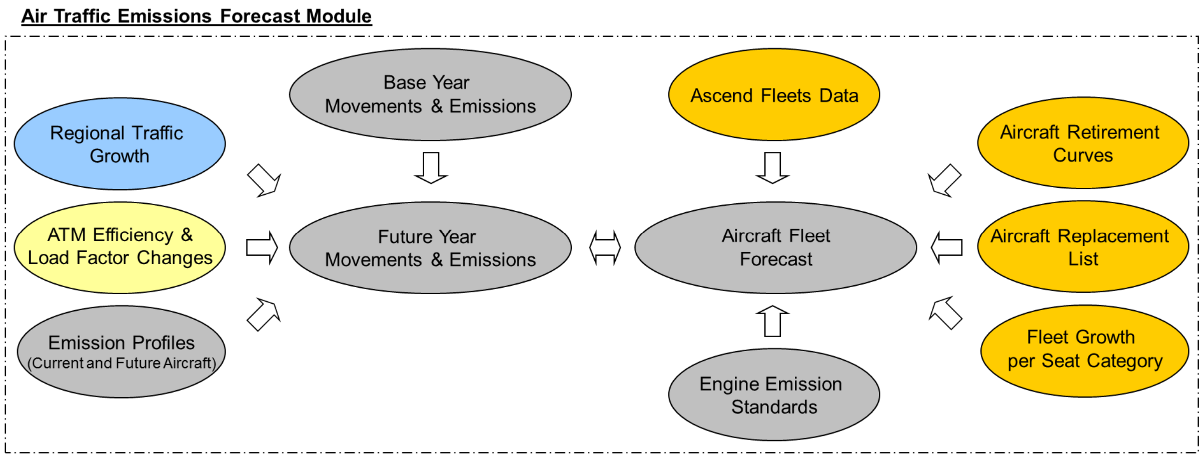

Figure 3. Schematic of the Air Traffic Forecast Module

Source: Schaefer (2012).

4. Modelling results

4.1 CO_2 emissions and transport performance

The historical CO_2 emissions' of the years 2004-2006 are the bases for the EU ETS cost estimations. To calculate transport performance, fuel burn and CO_2 emissions for scheduled aviation in the past, the Air Traffic Module has been used. Flight schedules provided by the Official Airline Guide (OAG, 2000-2010) for the years 2000 and 2003-2010 plus a self-developed cargo flight plan for European airports have served as primary sources of flight movement data. Table 1 summarizes the main results.

Table 1. Historical transport performance und CO_2 emissions of flights to and from European Airports

Year	RTK in billion (modelled)	CO_2 emissions in million tonnes (modelled)
2004	178.1	170.1
2005	198.1	184.0
2006	209.0	191.7
2007	226.4	202.9
2008	229.8	208.6
2009	209.7	196.4
2010	224.8	204.0

Source: DLR model results.

According to our model, the historical CO_2 emissions of the years 2004-2006 are 181.9 million tonnes, on average. If the European Commission politically succeeds in integrating European and non-European airlines into the trading schemes, roughly a third of global aviation's CO_2 emissions will be regulated, according to our simulation.

Interestingly, our estimations of the historical emissions differ noticeably from the estimates published by the European Commission in March 2011: the Commission decided these emissions to be 219 million tonnes on the basis of EUROCONTROL data and information on actual fuel consumption voluntarily provided by about 30 aircraft operators (Commission of the European Communities, 2011). An in-depth analysis of our estimates revealed that these differences can only partly be explained by a lack of data on flight movements, weather conditions, APU fuel use and other information not publicly available. This issue must remain unsolved until more quantitative data concerning this highly political figure is published by the European Commission. As of September 2012, this has not yet been the case.

According to our model, about 176.5 million emission permits will be created for the aviation sector (97 per cent of the historical emissions) in the year 2012, with each owner of one allowance having the right to emit one tonne of CO_2. 85 per cent of all allowances will be issued for free while the remaining 26.5 million permits will be auctioned. Assuming a future allowance price of 20 / 40 € per tonne of CO_2, governments of the EU Member States will receive between 529 and 1,059 million € from the auctioning in 2012 alone. From 2013 onwards, the amount of allowances created for the aviation sector will be lowered by another 2 per cent due to the reduction of the 'cap'. According to EU legislation, a special reserve of 5.2 million tonnes has to be subtracted. Airlines with an extraordinary growth may apply for this special reserve. This results in a yearly amount of 172.8 million emission permits in the period 2013-2020.

To estimate future air transport performance, fuel burn and CO_2 emissions, the Air Traffic Forecast Module is used. The model simulates traffic growth and fleet rollover and estimates future CO_2 emissions from aviation. The main results are presented in Table 2.

Table 2. Development of EU ETS for aviation key determinants in the timeframe 2012-2020, in million tonnes

Year	CO_2 emissions from aviation	Allowances created for aviation	Free allocation of allowances*	Auctioned allowances	Allowances purchased from other sectors
2012	222.6	176.5	150.0	26.5	46.1
2013	232.2	172.8	146.9	25.9	59.4
2014	242.0	172.8	146.9	25.9	69.2
2015	251.9	172.8	146.9	25.9	79.1
2016	261.5	172.8	146.9	25.9	88.7
2017	271.0	172.8	146.9	25.9	98.2
2018	280.3	172.8	146.9	25.9	107.5
2019	289.7	172.8	146.9	25.9	116.9
2020	299.1	172.8	146.9	25.9	126.3

Source: DLR model results. * *2013-2020: including the special reserve.*

4.2 Impacts on airlines' costs

An important factor for the cost impact of the EU ETS on airlines is the delta between the amount of allowances issued for free and the amount of allowances needed for maintaining operations in the future. Table 2 provides an overview of the expected development of these figures in the timeframe 2012 to 2020. The amount of allowances which have to be purchased increases constantly due to the assumed sectoral growth rates. In 2020, more than 50 per cent of the allowances needed by the airlines will have to be purchased.

By multiplying the number of purchased allowances by an assumed permit price, the cost impact of the EU ETS can be estimated. Table 3 shows the cost impacts at an assumed permit price of 20 € per tonne of CO_2, Table 4 presents the cost impacts at an assumed permit price of 40 € per tonne of CO_2.

Table 3. Cost impacts of the EU ETS for aviation, 20 € per tonne, in million €

Year	Value of total allowances needed	Value of allowances created for aviation	Value of free allowances*	Auction revenues for EU Member States	Value of allowances to be purchased
2012	4,452	3,529	3,000	529	1,452
2013	4,644	3,456	2,938	518	1,706
2014	4,840	3,456	2,938	518	1,902
2015	5,038	3,456	2,938	518	2,100
2016	5,230	3,456	2,938	518	2,292
2017	5,420	3,456	2,938	518	2,482
2018	5,606	3,456	2,938	518	2,668
2019	5,794	3,456	2,938	518	2,856
2020	5,982	3,456	2,938	518	3,044
Total	47,006	31,181	26,504	4,677	20,502

Source: DLR model results. * *2013-2020: including the special reserve.*

Table 4. Cost impacts of the EU ETS for aviation, 40 € per tonne, in million €

Year	Value of total allowances needed	Value of allowances created for aviation	Value of free allowances*	Auction revenues for EU Member States	Value of allowances to be purchased
2012	8,904	7,058	6,000	1,059	2,904
2013	9,288	6,913	5,876	1,037	3,412
2014	9,680	6,913	5,876	1,037	3,804
2015	10,076	6,913	5,876	1,037	4,200
2016	10,460	6,913	5,876	1,037	4,584
2017	10,840	6,913	5,876	1,037	4,964
2018	11,212	6,913	5,876	1,037	5,336
2019	11,588	6,913	5,876	1,037	5,712
2020	11,964	6,913	5,876	1,037	6,088
Total	94,012	62,362	53,008	9,354	41,004

Source: DLR model results. * *2013-2020: including the special reserve.*

Previous work conducted by the authors revealed that the cost impacts of the EU ETS will affect some groups of airlines more than others (see Schaefer et al., 2010 and Scheelhaase et al., 2010 for a full description). Particularly the European network carriers will suffer from a competitive disadvantage under the EU ETS in comparison to their competitors based outside the EU. On average, the share of allowances to be acquired by these EU-based carriers will be significantly higher than for non-EU airlines. This can be explained by the fact that EU-based full service network carriers will have to operate their relatively inefficient short-haul feeder flights under the EU ETS, while most other carriers from outside the EU operate only long-haul flights with high load factors to and from Europe, which are generally more fuel-efficient than short-haul flights. With these empirical findings, earlier works based on theoretical models (e.g. Brueckner and Zhang, 2010 and Yuen and Zhang, 2011) were widely supported.

The cost increases presented in Tables 3 and 4 may have demand side effects as the aircraft operators could decide to pass-on the additional costs to the passengers in the form of higher ticket prices and/or freight rates. However, we refrained from modelling the demand side effects because these effects are determined by the price elasticities of demand which show a broad range of possible values in literature (e. g. Brons, 2002 and Gillen, 2004). Therefore, possible reactions of the demand side and of the airlines facing these reactions cannot be presented here. For this reason, the numbers given in this paper may be lower in reality.

Also, the impacts of the EU ETS on route networks will be limited. This is can be explained as follows: an additional stop immediately outside the borders of the EU would, on the one hand, significantly shorten the distance flown under the EU ETS and hence minimize the emissions for which allowances must be surrendered. On the other hand, however, the disadvantages for airlines getting involved in this kind of strategy are substantial: journey times would increase, reducing the attractiveness of services for time-sensitive high-yield passengers and resulting in a potential loss in revenues. Moreover, intermediate stops also come at a cost. For instance, an intermediate landing in Istanbul with an Airbus A340-600 en-route to a destination in South East Asia would cost an airline 3000 € in airport charges alone (DHMI, 2012), plus costs for ground handling as well as the additional costs for cockpit and cabin crews - in the case of maximum working hours being exceeded as result of the stopover. Such a strategy would only be beneficial to airlines from a financial perspective if carbon prices are higher than reasonably expected for the foreseeable future.

4.3 Competitive impacts of different exemption clauses

In October 2010, the 37th ICAO Assembly agreed to an exemption provision for market-based measures, amongst others, as mentioned above. This exemption clause differs noticeably from the one applied in the current EU ETS framework (so-called EU de minimis clause, see section 2). According to Article 15, ICAO Resolution A37-19, the ICAO Assembly *"Resolves on a de minimis threshold of international aviation activity, consistent with the guiding principles in the Annex, of 1 per cent of total revenue tonne kilometres to MBMs (Market-Based Measures) as follows:*

a) commercial aircraft operators of States below the threshold should qualify for exemption for application of MBMs that are established on national, regional and global levels; and

b) States and regions implementing MBMs may wish to also consider an exemption for other small aircraft operators." (ICAO, 2010).

An application of the ICAO exemption clause in the current EU ETS has been under discussion both on ICAO and EU level since October 2010. If this clause is applied, which cost and competition impacts can be expected? To investigate this question, the ICAO provisions have to be substantiated. In line with the explanation given by ICAO (ICAO, 2011a), two different interpretations of the ICAO exemption provision are possible:

Interpretation a): All individual states whose commercial operators account for less than 1 per cent of global international traffic in terms of revenue tonne kilometres (RTK) will be exempted.

Interpretation b): All individual commercial aircraft operators who account for less than 1 per cent of global international traffic in terms of revenue tonne kilometres will be exempted (ICAO, 2011a).

As a first step, we investigated the empirical distribution of the global international air traffic revenue tonne kilometres (RTKs) according to both interpretations of the ICAO exemption clause. For this purpose, ICAO data for the year 2010 (ICAO, 2011b) was analysed. The results show a strong disparity: assuming interpretation a), almost 60 per cent of the global international RTKs can be assigned to only 10 states/territories (USA, Germany, United Arab Emirates, UK, Republic of Korea, China, France, Hong Kong, Singapore and Japan). Only 24 of all 190 ICAO Contracting States/territories can then be assigned more than 1 per cent of the global RTKs. Results for interpretation b) show a strong disparity as well. According to the latter interpretation, only 29 aircraft operators would have to fulfil the EU ETS obligations while all other airlines would be exempted. Tables 5 and 6 provide an overview of these results.

Table 5. States Ranking according to the share of global international air traffic revenue tonne kilometres (RTK) in 2010

Rank	State/Territory	RTK (million)	% Share
1	United States	59,641	14.34
2	Germany	28,489	6.85
3	United Arab Emirates	28,347	6.81
4	United Kingdom	23,053	5.54
5	Republic of Korea	20,724	4.98
6	China	18,871	4.54
7	France	17,837	4.29
8	Hong Kong	16,189	3.89
9	Singapore	14,788	3.55
10	Japan	14,470	3.48
11	Netherlands	13,845	3.33
12	Republic of Ireland	9,225	2.22
13	Canada	8,017	1.93
14	Qatar	7,723	1.86
15	Russian Federation	7,614	1.83
16	Spain	7,424	1.78
17	Thailand	7,359	1.77
18	Australia	6,721	1.62
19	Turkey	6,139	1.48
20	Malaysia	6,137	1.48
21	India	5,990	1.44
22	Switzerland	5,299	1.27
23	Luxembourg	5,234	1.26
24	Italy	4,383	1.05
25-190	Other	72,466	17.42
1-190	Total	415,985	100.00

Source: ICAO (2011b) and own calculations.

Table 6. Airlines Ranking according to the share of global international air traffic revenue tonne kilometres (RTK) in 2010

Rank	Airline	State	RTK (million)	% Share
1	Lufthansa	Germany	20,231	4.86
2	Emirates	United Arab Emirates	20,013	4.81
3	Air France	France	15,400	3.70
4	Korean Air	Republic of Korea	14,856	3.57
5	Cathay Pacific	Hong Kong SAR	14,468	3.48
6	Delta	United States	13,585	3.27
7	British Airways	United Kingdom	11,801	2.84
8	KLM	Netherlands	11,408	2.74
9	Singapore Airlines	Singapore	10,240	2.46
10	American	United States	9,666	2.32
11	United	United States	8,995	2.16
12	Qatar Airways	Qatar	7,723	1.86
13	Thai Airways	Thailand	7,652	1.84
14	Federal Express	United States	7,469	1.80
15	Ryanair	Ireland	7,370	1.77
16	Continental	United States	6,996	1.68
17	Qantas	Australia	6,959	1.67
18	Air Canada	Canada	6,506	1.56
19	JAL	Japan	6,369	1.53
20	Air China	China	6,169	1.48
21	Asiana	Republic of Korea	5,689	1.37
22	Malaysian Airlines	Malaysia	5,543	1.33
23	Etihad	United Arab Emirates	5,482	1.32
24	Iberia	Spain	5,354	1.29
25	United Parcel	United States	5,342	1.28
26	THY	Turkey	4,967	1.19
27	Cargolux	Luxembourg	4,901	1.18
28	Virgin Atlantic	United Kingdom	4,532	1.09
29	Swiss	Switzerland	4,237	1.02
Other			156,060	38.00
Total			415,985	100,00

Source: ICAO (2011b) and own calculations.

If the ICAO exemption clause is introduced to the EU ETS, considerable economic and CO_2 impacts can be expected. This refers to the competition between airlines and to a likely carbon leakage:

Competitive distortions will arise when an airline or a group of airlines has to bear higher operating costs while their competitors on certain routes or city-pairs will not have to suffer from cost increases. Under the EU ETS, operating costs will rise due to the obligation to purchase CO_2

allowances. Ceteris paribus, this will lead to a decrease in operating results for those carriers under the EU ETS. Table 7 shows estimations of the costs associated with fulfilling the EU ETS regulations for the airlines of the 24 states subject to the EU ETS (interpretation a)). Table 8 presents the costs for the 29 individual airlines subject to the EU ETS according to interpretation b) of the ICAO exemption clause.

Table 7. CO_2 emissions and associated costs for airlines under the EU ETS according to interpretation a) of the ICAO exemption clause in the year 2020

CO_2 in million t	Percentage of allowances to be purchased at auction and on market	Allowances to be purchased at auction and on market in million t	Costs for allowances to be purchased in million € (20 €/t CO_2)	Costs for allowances to be purchased in million € (40 €/t CO_2)	Costs for allowances per RTK in € (20 € per t CO_2 /40 € per t CO_2)
237.85	0.51	121.04	2420.8	4841.6	0.0074/0.0148

Source: DLR model results.

Table 8. CO_2 emissions and associated costs for airlines under the EU ETS according to interpretation b) of the ICAO exemption clause in the year 2020

CO_2 in million t	Percentage of allowances to be purchased at auction and on market	Allowances to be purchased at auction and on market in million t	Costs for allowances to be purchased in million € (20 €/t CO_2)	Costs for allowances to be purchased in million € (40 €/t CO_2)	Costs for allowances per RTK in € (20 € per t CO_2 /40 € per t CO_2)
152.31	0.51	77.51	1550.2	3100.4	0.0072/0.0144

Source: DLR model results.

In absolute terms, airlines under the EU ETS will have to bear additional operating costs of about 2420.8 million € p. a. (according to interpretation a) of the ICAO exemption clause) or 1550.2 million € (interpretation b), under the assumption of an allowance price of 20 €/t CO_2 in the year 2020. An analysis of the change in unit operating costs (costs per RTK) reveals that the airlines under the EU ETS will have to cope with a cost increase of 0.74 or 0.72 € Ct. per RTK, at an allowance price of 20 €/t CO_2. In relation to the total operating costs per RTK of about 10 – 12 € Ct. in the year 2006 (International Air Transport Association, 2006), the EU ETS would lead to an increase in unit operating costs of 6.7 per cent (interpretation a) of the ICAO exemption clause) or 6.5 per cent (interpretation b)). Ceteris paribus, this will lead to a decrease in operating results of the airlines under the EU ETS. Obviously, interpretation a) of the ICAO exemption clause will lead to a larger financial burden than interpretation b). This can be explained by a lower ratio of CO_2 per RTK of the world's most successful 29 airlines in terms of RTK in the year 2010 (ICAO exemption clause interpretation b)). It shows that this group of airlines operates more energy-efficiently on average than the group of airlines according to interpretation a) of the ICAO exemption clause.

The increase of unit operating costs for the airlines under the EU ETS will cause competitive distortions because most carriers under the EU ETS compete with carriers exempted on certain routes or city-pairs. This is the case with, for instance, Lufthansa: in 2010, Lufthansa served airports in 87 countries. According to interpretation a) of the ICAO exemption clause, carriers from 64 of these 87 countries would be excluded from the EU ETS. In the majority of cases, airlines from these 64 countries are competing on route level with Lufthansa. Roughly 20 per cent of Lufthansa's total ASKs are offered on such routes on which airlines excluded by the ICAO exemption clause are

Lufthansa's competitors according to our calculations on country-pair level. If the ICAO exemption clause interpretation b) is applied, competitive disadvantages for the carriers under the EU ETS will be even more likely as competitors from the same country would be exempted as well. Again, this is the case for Lufthansa. As an example: while Lufthansa would have to comply with the EU ETS rules, amongst others, airberlin, Germany's second-largest airline and Lufthansa's direct competitor on a number of domestic, continental and intercontinental routes respectively city-pairs, would be exempted. The same discriminating situation applies to a number of other airlines in the world. At the end of the day, airlines included in the EU ETS will suffer from competitive disadvantages compared to their competitors excluded from the EU ETS. As a result, competitive distortions are likely.

A carbon leakage is the indirect effect of emission reduction policies or activities in the trading scheme(s) under consideration which leads to a rise in emissions elsewhere (Intergovernmental Panel on Climate Change, 1996). In some cases, global emissions could be even higher compared to the situation before the introduction of market-based measures. This can be explained as follows:

If the ICAO exemption clause was introduced to the EU ETS, some strategies would, from an airline point of view, appear promising as a means of absconding from the EU ETS requirements. For instance, airline groups could, to a certain extent, shift operations from airlines under the EU ETS to airlines being excluded from these regulations. This strategy is possible both within a corporate group and within an airlines alliance, by code-share agreements. If the ICAO exemption clause interpretation a) is applied, the Lufthansa group, for example, could either shift intra-European flights from Lufthansa to its subsidiaries Brussels Airlines or Austrian Airlines or serve destinations like Frankfurt - Johannesburg by code-share agreement with South African Airways. As carriers from Belgium, Austria and South Africa will be excluded from the EU ETS, this strategy could be advantageous for Lufthansa. Another option would be the foundation of new subsidiary companies in countries excluded from market-based measures. This way, air transport services could be shifted to countries/airlines excluded from the EU ETS. Against this background, a considerable carbon leakage can be expected. A quantitative estimation of the carbon leakage due to the ICAO exemption clause, however, is a complicated issue since airlines' strategic options to abscond from the EU ETS requirements are numerous, as indicated above. Therefore, we decided to refrain from modelling the carbon leakage in full. What can be estimated, however, is the amount of CO_2 emissions not covered by the EU ETS if the ICAO exemption clause is applied. Table 9 presents these estimations. Evidently, at least 20 to 50 per cent of the CO_2 emissions originally covered by the EU ETS would not be regulated any more if the ICAO exemption clause was introduced, depending on the interpretation of the exemption clause.

Table 9. CO_2 emissions not covered by the EU ETS if the ICAO exemption clause is applied

Year	Base case: CO_2 emissions covered by the EU ETS in million tonnes	CO_2 emissions not covered if ICAO exemption clause a) applied in million tonnes	CO_2 emissions not covered if ICAO exemption clause b) applied in million tonnes	CO_2 emissions not covered if ICAO exemption clause a) applied in per cent	CO_2 emissions not covered if ICAO exemption clause b) applied in per cent
2010	204.40	40.24	100.64	19.73	49.33
2020	299.13	61.28	146.82	20.49	49.08

Source: DLR model results.

From both a cost and CO_2 perspective, the best solution would be the introduction of a unified and globally applied ETS for aviation. This way, competitive distortions and carbon leakages could be avoided to the best possible extent. A second-best option would be the harmonizing of provisions of different emissions trading schemes. This may become crucial since the introduction of a number of emissions trading schemes tackling climate change both on a national as well as on a supranational level is foreseeable within the next decade. Up to now, detailed plans for mandatory or voluntary national emissions trading systems influencing aviation have been worked out by New Zealand, Australia, the US and Canada (for discussion, see Scheelhaase, 2011).

5. Conclusions

In this paper, we estimated the cost effects of the inclusion of the aviation sector in the European emission trading system (EU ETS) in the short term as well as in the longer term. For this purpose, a newly-enhanced simulation model is employed which enables the estimation of air transport's performance and CO_2 emissions up to the year 2020. Also, the cost impacts of the ICAO exemption clause for market-based measures such as the EU ETS are investigated for the first time. Our main conclusions are as follows:

If the European Commission politically succeeds in integrating European and non-European carriers into the EU ETS as intended, about one third of global aviation CO_2 emissions will be regulated. Even though the Court of Justice of the EU ruled in favour of the European Commission in December 2011, many countries opposed to the inclusion of non-European airlines in the EU ETS.

Apart from very few exceptions, all passenger airlines will need to purchase allowances for their flight operations in addition to those allocated for free. Moreover, a continuous increase in costs can be expected due to aviation growth. In the year 2020, more than 50 per cent of the required allowances will have to be purchased.

Even though about 1,175 million allowances will be allocated for free, the aviation sector will have to buy allowances for approximately 20.5 to 41 billion € in the timeframe 2012 to 2020 at an assumed allowance price of between 20 € and 40 €. This is because aviation emissions growth will outpace any foreseeable autonomous efficiency gains. Interestingly, our estimations of the historical emissions of the aviation sector under the EU ETS differ noticeably from the estimations published by the European Commission in March 2011. While the European Commission decided the historical emissions of the years 2004-2006 to be 219 million tonnes CO_2, our modelling results are about 20 per cent lower. These differences can only be partly explained by a lack of data on flight movements, APU fuel use and other not publicly available information. The amount of the historical emissions directly influences airlines' costs for purchasing emission allowances.

An analysis of the exemption provision laid out in ICAO Resolution A37-19, as agreed in October 2010, revealed that this clause has significant potential to distort competition in the airline sector if applied to the EU ETS. Furthermore, roughly 20 to 50 per cent of the CO_2 emissions originally covered by the EU ETS would not be regulated any more, depending on the interpretation of the ICAO exemption clause. Furthermore, airline groups may shift operations to airlines excluded from the EU ETS. As of September 2012, a possible application of the ICAO exemption to the EU ETS is under discussion on the political level.

This leads to the conclusion that from the perspective of competition policy, a unified and globally applied ETS would be the best solution. This way, earlier findings of Scheelhaase et al. (2010), Schaefer et al. (2010) as well as Yuen and Zhang (2011) can be supported. A second-best approach could be the linking of different regional ETSs. This approach could at least partially create a level playing field. Nevertheless, if the consideration of comparable measures in the EU ETS, as envisaged in the current legal EU framework, is practically adopted, we expect fundamental problems in the compatibility and comparability of the EU ETS with measures adopted elsewhere. This will lead to competitive distortions in the aviation sector.

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