Environmental, Employment and Competitive Impacts of Market-Based Measures for the Limitation of Aviation’s Full Climate Impact

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1. Background
2. Objectives of research
3. Modelling approach and main results
4. Conclusions
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In 2005, aircraft-induced CO$_2$ contributed 1.6% to the total radiative forcing (RF). If the non-CO$_2$ climate effects are also considered, aviation’s contribution to total anthropogenic RF is about three times as large, i.e., 4.9% (Lee et al., 2009).
1. Background (2) Political Facts

• Whilst aviation’s carbon dioxide emissions have been regulated in a number of countries by market-based measures (European Union, New Zealand) or will soon be regulated (China, South Korea), this is not the case for most of aviation’s non-CO₂ climate impacts.

• To complicate matters, the international character of aviation renders national approaches relatively ineffective and requires lengthy political negotiations on the international level. Here, both the International Civil Aviation Organisation (ICAO), as well as any supranational/international political institution of great regional importance such as the European Union will have to be involved.

• With regard to estimated average future annual growth rates of 4 – 5 per cent (Airbus, 2012), the implementation of a global scheme for the reduction of international aviation’s non-CO₂ impact on climate change seems to be necessary expeditiously.
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1. Background
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2. Objectives of research

In October 2011, the German Aerospace Center (DLR) started a three-year research project with the **overall goal**:  

*To explore the feasibility for addressing aviation’s CO₂ and non-CO₂ climate impacts (aviation-induced clouds, NOₓ emissions, water vapour emissions, etc.) by regulatory measures and to study the associated economic impacts. Especially the effects of aviation-induced clouds and NOₓ emissions on high altitudes have not been investigated with this goal at this point.*

Within the interdisciplinary research project **AviClim** (Including **Aviation** in International Protocols for **Climate** Protection) three DLR institutes are involved:

Institute of Air Transport and Airport Research, Institute of Propulsion Technology and Institute of Atmospheric Physics.
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1. Background
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4. Conclusions
3. Modelling approach (1): Regulatory measures

Best options for **market-based and operational measures** for the reduction of all climate relevant species from aviation include:

- **Climate tax** on all climate relevant species from aviation;
- **Climate charge** on NO$_X$ emissions plus CO$_2$ emissions trading scheme combined with **climate-optimal flight trajectories** for the minimization of contrails (applied on 50% of flights between 30 and 60°N on an altitude between 9 and 12 km);
- Open **emissions trading** scheme on CO$_2$, NO$_X$, H$_2$O and contrails.

These measures have been selected in respect to economic efficiency, environmental benefits and practicability. They have been combined with **4 scenarios** which differ concerning the level of international support for these climate protecting measures.
3. Modelling approach (2): Scenario overview

- Scenario Greater EU
- Scenario Great Aviation Countries
- Scenario Annex I Countries
- Scenario World
3. Modelling approach (3): Model overview

Forecast emission inventory → CO₂ equivalence factors

CO₂ equivalents → Emission reduction

Emission reduction → Climate impact

Cost, demand and air traffic effects

Employment effects (direct & indirect)

Regulatory measure → CO₂ purchases from other sectors (only ET models)
3. Modelling approach (4): CO₂ prices and metrics

As the future development of prices for CO₂ equivalent is difficult to foresee, three different price development paths have been assumed alternatively:

1. Low Price Scenario: USD 10 (2010) to USD 30 (2030) per ton CO₂ equivalent;
2. High Price Scenario: USD 10 (2010) to USD 80 (2030) per ton CO₂ equivalent;
3. Mixed Price Scenario: USD 10 (2010) to USD 30 (2030) (ET models); respectively USD 80 (2030) (climate tax and NOₓ charge) per ton CO₂ equivalent.

Also, two different metrics for quantifying aviation’s full climate impact have been considered alternatively: Average Temperature Response ‘atr 20’ and ‘atr 50’; ‘atr’ is the mean change in near surface temperature averaged over 20 and 50 years, respectively.
3. Modelling approach (5): Change in revenues

The costs for the market-based measures will lead to a production cost increase of the airlines regulated. Under the assumption that the airlines will try to pass-on the full cost increase to their customers, and will therefore act as profit maximizers, prices for air services will increase.

In general, the demand reaction to this price increase depends on the price elasticities of demand. As empirical data of the price elasticities of demand for air services shows a broad range of possible figures (Oum et al., 1990; Oum et al., 1992; Lu, 2009), three cases of price elasticities \( E_D \) have been analysed alternatively: case 1: \( E_D = 1 \); case 2: \( E_D = -0.8 \); case 3: \( E_D = -2.1 \).
3. Main results (1): Costs impact of political measures in USD billion

Scenario „Greater EU“, atr 50, Low Price Scenario

NO\textsubscript{X} Charge includes CO\textsubscript{2} trading and operational measures.

Specific assumptions: ET models: 85% of 2010 emissions allocated for free.
3. Main results (2): Costs impact of political measures in USD billion

Scenario „World“, atr 20, High Price Scenario

NO\textsubscript{X} Charge includes CO\textsubscript{2} trading and operational measures.
3. Main results (3): Influence of metrics chosen on costs of climate tax in USD billion in 2030

Different geographical scenarios, Low Price Scenario
3. Main results (4): Competitive impacts for selected airline groups, atr 50, Low Price Scenario

<table>
<thead>
<tr>
<th>Scenario / Group of Airlines</th>
<th>Low Price Scenario, Costs in USD million</th>
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</thead>
<tbody>
<tr>
<td><strong>Emissions Trading all species</strong></td>
<td></td>
</tr>
<tr>
<td>Top 10 &quot;Greater EU&quot; Network Carrier</td>
<td>2010 399 2015 1696 2020 3677 2025 6513 2030 8753</td>
</tr>
<tr>
<td>Top 10 Non-&quot;Greater EU&quot; Network Carrier</td>
<td>2010 152 2015 669 2020 1451 2025 2378 2030 3647</td>
</tr>
<tr>
<td>Top 10 &quot;Greater EU&quot; LCC/Holiday Carrier</td>
<td>2010 141 2015 487 2020 1001 2025 1526 2030 2193</td>
</tr>
<tr>
<td>Top 10 &quot;Great Aviation Countries&quot; Network Carrier</td>
<td>2010 1040 2015 3363 2020 7753 2025 12835 2030 19600</td>
</tr>
<tr>
<td>Top 10 Non-&quot;Great Aviation Countries&quot; Network Carrier</td>
<td>2010 155 2015 816 2020 1862 2025 3143 2030 4777</td>
</tr>
<tr>
<td>Top 10 &quot;Great Aviation Countries&quot; LCC/Holiday Carrier</td>
<td>2010 242 2015 819 2020 1631 2025 2481 2030 3578</td>
</tr>
<tr>
<td>Top 10 &quot;World&quot; Network Carrier</td>
<td>2010 982 2015 4158 2020 8892 2025 14342 2030 21533</td>
</tr>
<tr>
<td>Top 10 &quot;World&quot; LCC/Holiday Carrier</td>
<td>2010 249 2015 843 2020 1680 2025 2145 2030 3693</td>
</tr>
<tr>
<td><strong>Climate Tax</strong></td>
<td></td>
</tr>
<tr>
<td>Top 10 &quot;Greater EU&quot; Network Carrier</td>
<td>2010 2658 2015 5085 2020 8195 2025 12160 2030 15530</td>
</tr>
<tr>
<td>Top 10 &quot;Greater EU&quot; LCC/Holiday Carrier</td>
<td>2010 938 2015 1682 2020 2595 2025 3518 2030 4584</td>
</tr>
<tr>
<td>Top 10 &quot;Great Aviation Countries&quot; Network Carrier</td>
<td>2010 6934 2015 12204 2020 19541 2025 27569 2030 37282</td>
</tr>
<tr>
<td>Top 10 Non-&quot;Great Aviation Countries&quot; Network Carrier</td>
<td>2010 1036 2015 2137 2020 3622 2025 5344 2030 7418</td>
</tr>
<tr>
<td>Top 10 &quot;Great Aviation Countries&quot; LCC/Holiday Carrier</td>
<td>2010 1613 2015 2875 2020 4372 2025 5908 2030 7690</td>
</tr>
<tr>
<td>Top 10 &quot;World&quot; Network Carrier</td>
<td>2010 6546 2015 10683 2020 20020 2025 28252 2030 38225</td>
</tr>
<tr>
<td>Top 10 &quot;World&quot; LCC/Holiday Carrier</td>
<td>2010 1661 2015 2962 2020 4504 2025 5160 2030 7929</td>
</tr>
</tbody>
</table>

LH: 90% RTK under MBM; UA: 18% RTK under MBM
3. Main results (5): Competitive impacts – Percentage of free allocation of emission permits for selected airline groups, atr 50

<table>
<thead>
<tr>
<th>Scenario/Group of Airlines</th>
<th>2010</th>
<th>2015</th>
<th>2020</th>
<th>2025</th>
<th>2030</th>
</tr>
</thead>
<tbody>
<tr>
<td>Top 10 &quot;Greater EU&quot; Network Carrier</td>
<td>85 %</td>
<td>67 %</td>
<td>56 %</td>
<td>49 %</td>
<td>45 %</td>
</tr>
<tr>
<td>Top 10 Non-&quot;Greater EU&quot; Network Carrier</td>
<td>85 %</td>
<td>64 %</td>
<td>52 %</td>
<td>46 %</td>
<td>40 %</td>
</tr>
<tr>
<td>Top 10 &quot;Greater EU&quot; LCC/Holiday Carrier</td>
<td>85 %</td>
<td>71 %</td>
<td>62 %</td>
<td>57 %</td>
<td>53 %</td>
</tr>
<tr>
<td>Top 10 &quot;Great Aviation Countries&quot; Network Carrier</td>
<td>85 %</td>
<td>69 %</td>
<td>58 %</td>
<td>51 %</td>
<td>46 %</td>
</tr>
<tr>
<td>Top 10 Non-&quot;Great Aviation Countries&quot; Network Carrier</td>
<td>85 %</td>
<td>63 %</td>
<td>50 %</td>
<td>43 %</td>
<td>37 %</td>
</tr>
<tr>
<td>Top 10 &quot;Great Aviation Countries&quot; LCC/ Holiday Carrier</td>
<td>85 %</td>
<td>71 %</td>
<td>63 %</td>
<td>58 %</td>
<td>54 %</td>
</tr>
<tr>
<td>Top 10 &quot;World&quot; Network Carrier</td>
<td>85 %</td>
<td>66 %</td>
<td>55 %</td>
<td>49 %</td>
<td>43 %</td>
</tr>
<tr>
<td>Top 10 &quot;World&quot; LCC/ Holiday Carrier</td>
<td>85 %</td>
<td>71 %</td>
<td>63 %</td>
<td>58 %</td>
<td>54 %</td>
</tr>
<tr>
<td>Average</td>
<td>85 %</td>
<td>68 %</td>
<td>57 %</td>
<td>51 %</td>
<td>47 %</td>
</tr>
</tbody>
</table>
3. Main results (6): Revenue impact of climate tax in Scenario “World”, atr 20, Low Price Scenario

Demand reaction according to cases 1 – 3; case 1 is identical to Business-as-usual development
3. Main results (7): Employment impact, Low Price Scenario

Development of direct and indirect employment in the aviation sector, Scenario “World”, atr 50, Low Price Scenario, moderate price elasticity of demand (case 2), in 1,000 employees

![Graph showing employment impact over time for different scenarios: Business as usual, Climate Tax, Emissions Trading, NOX Charge.]
3. Main results (8): Employment impact, High Price Scenario

Development of direct and indirect employment in the aviation sector, Scenario “World”, atr 50 and atr 20, Climate Tax, High Price Scenario, price elasticities of demand case 2 and case 3, in 1,000 employees.
3. Main results (9): Development of air traffic

Scenario „Great Aviation Countries“, atr 20, Low Price Scenario, Case 2 and Case 3 demand reaction, in per cent compared to Business-as-usual Scenario

NO\textsubscript{X} Charge includes CO\textsubscript{2} trading and operational measures.
3. Main results (10): Change in fuel consumption

Change in global fuel consumption in per cent compared to Business-as-usual Scenario, Case 2 demand reaction, atr 50, in the year 2030

<table>
<thead>
<tr>
<th>Low Price Scenario</th>
<th>„Greater EU“</th>
<th>„Great Aviation Countries“</th>
<th>„World“</th>
</tr>
</thead>
<tbody>
<tr>
<td>Climate Tax</td>
<td>-1.8%</td>
<td>-5.9%</td>
<td>-6.7%</td>
</tr>
<tr>
<td>Emissions Trading</td>
<td>-0.9%</td>
<td>-3.4%</td>
<td>-3.9%</td>
</tr>
<tr>
<td>NO\textsubscript{X} charge</td>
<td>-0.6%</td>
<td>-1.9%</td>
<td>-2.2%</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>High Price Scenario</th>
<th>„Greater EU“</th>
<th>„Great Aviation Countries“</th>
<th>„World“</th>
</tr>
</thead>
<tbody>
<tr>
<td>Climate Tax</td>
<td>-5.1%</td>
<td>-15.8%</td>
<td>-17.8%</td>
</tr>
<tr>
<td>Emissions Trading</td>
<td>-2.7%</td>
<td>-9.2%</td>
<td>-10.4%</td>
</tr>
<tr>
<td>NO\textsubscript{X} charge</td>
<td>-2.4%</td>
<td>-6.5%</td>
<td>-7.4%</td>
</tr>
</tbody>
</table>

NO\textsubscript{X} Charge includes CO\textsubscript{2} trading and operational measures.
3. Main results (11): Development of temperature change

Scenario „Greater EU“, Low Price Scenario, and Scenario „World“, High Price Scenario, demand reaction case 2, metric atr 50, compared to Business-as-usual Scenario temperature development

$\text{NO}_x$ Charge includes $\text{CO}_2$ trading and operational measures.
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4. Conclusions (1)

From an environmental point of view, the limitation of aviation’s both CO₂ emissions and non-CO₂ species seems to be necessary urgently. The climate impact from the non-CO₂ species is in the range of the impacts from CO₂. Depending on the timeframe under consideration, the impact from the non-CO₂ species can even be greater.

AviClim modelling results indicate that under the assumptions explained above, a global emissions trading scheme for the political regulation of both CO₂ and non-CO₂ emissions from aviation would be the best solution from an economic and environmental point of view. The second-best solution would be the combination of both marked-based and operational measures.
4. Conclusions (2)

Under a **global emissions trading scheme**, **costs and impacts on competition** could be minimized and effects on employment are moderate. At the same time, **environmental benefits** are significant. The possibility to purchase emission permits from other sectors (so-called “open emissions trading scheme”) is important for the positive outcome.

Even though the introduction of a global measure would be the best solution, AviClim results show that the introduction of such measures by the “**Great Aviation Countries**” or the “**Annex-I-Countries**” would lead to almost the same environmental and economic results. This approach would probably be much easier to implement on a political level.
Thank you very much for your attention!