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How to improve the global 'Carbon Offsetting and Reduction Scheme for International Aviation' (CORSIA)?

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Abstract

Air transport contributes to anthropogenic global warming by emitting CO_2 and other climate relevant species like NO_x, H_2O and soot, as well as contrails and contrail cirrus. Even though air transport's total contribution to global warming is estimated to be relatively small, this share is expected to increase in the future due to the enormous growth rates in the sector. While we acknowledge that the short-term decline caused by Covid-19 is unprecedented in its extent, we do not expect a structural interruption caused by COVID-19 in the long-term, but a continuation of trends that have been already present before (Scheelhaase et al., 2020). To limit aviation's CO_2 emissions, the 'Carbon Offsetting and Reduction Scheme for International Aviation' (CORSIA) was agreed at the International Civil Aviation Organization (ICAO) Assembly in 2016. CORSIA is the first global scheme for the limitation of aviation's CO_2 emissions. However, criticism has been raised concerning CORSIA's environmental ambitiousness. This paper investigates CORSIA's environmental benefits as well as options for improving the scheme's environmental impact. Based on our emission modelling results for the global airline schedules, recommendations for technical experts and policymakers are provided. Our results indicate that an effective option for improving the scope of CORSIA would be a voluntary inclusion of domestic CO_2 emissions of the ten largest domestic aviation markets (USA, China, Japan, Brazil, India, Indonesia, Russia, Australia and Canada, as well as the EU,). Domestic flights are those within a country including overseas territories, if applicable. This way, in the long run, an additional 50% of CO_2 p.a. could be compensated, without significant added bureaucracy for most airlines, and CORSIA's environmental performance would be improved massively. This approach could be realized relatively easily since the decision on a voluntary inclusion of domestic aviation in CORSIA is at the sovereignty of each state.

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1. Background

Air Transport contributes to anthropogenic global warming by emitting climate relevant species like CO_2, NO_x, H_2O and soot, as well as contrails and contrail cirrus. According to Lee et al. (2009), air transport accounted for about 4.9 per cent of total anthropogenic radiate forcing in the year 2005. Even though air transport's total contribution to global warming is estimated to be relatively small currently, this share is expected to further increase as the sector keeps growing enormously. The leading aircraft manufacturers Airbus (2018) and Boeing (2019) estimate a sectoral global growth in the medium and long term of 4.4 per cent and 4.6 per cent annually, respectively. While we acknowledge that the short-term decline caused by Covid-19 is unprecedented in its extent, we do not expect a structural interruption caused by COVID-19 in the long-term, but a continuation of trends that have been already present before (Scheelhaase et al., 2020). According to recent ICAO (2020b) forecasts, global air transport is expected to return to already 62% - 72 %, of its original growth path by the end of the year 2020, depending on the scenario assumed.

To limit and reduce aviation's CO_2 emissions, the 'Carbon Offsetting and Reduction Scheme for International Aviation' (CORSIA) was agreed at the 39th International Civil Aviation Organization (ICAO) Assembly in 2016 as an important pillar for supporting the ICAO goal of carbon neutral growth in international aviation from the year 2020 onwards (CNG2020) (ICAO, 2016). CORSIA is the first global scheme for the limitation of air transport's CO_2 emissions and the result of decades of difficult negotiations at ICAO level. The European Emissions Trading Scheme (EU ETS) is the only other trading scheme addressing air transport's international CO_2 emissions, but regulating only most flights within the European Economic Area (EU, Norway, Liechtenstein, Iceland) (so-called "reduced scope" of the EU ETS). Originally, almost all flights from or to EEA airports were planned to be subject to the EU ETS ("full scope"), subject to few exemptions. However, against the background of strong international opposition and to ease the – at that point – ongoing CORSIA negotiations at ICAO level (Bartels, 2012 and European Parliament, 2018), the EU's so-called "stop the clock" decision eventually reduced the scheme's scope to intra-EEA traffic (European Union, 2019).

While monitoring and reporting requirements under CORSIA have been in force since January 2019 already, voluntary offsetting is planned to start from the year 2021. The scheme will eventually become mandatory by the year 2027. However, criticism has been raised concerning CORSIA's environmental ambitiousness (see for instance Transport & Environment, 2018; CarbonBrief, 2019 or Fraenkel-Eidse, 2016).

How does CORSIA work and which environmental benefits can be expected for aviation? Are there straightforward options for improving CORSIA, and which amounts of CO_2 could additionally be saved? These questions will be investigated in sections 2, 3 and 4 of this paper. Based on our modelling results, recommendations for policymakers and technical experts will be provided in section 5.

2. How does CORSIA work?

CORSIA is a baseline-and-credit scheme where CO_2 credits can be traded freely on so-called credit markets. The baseline above which emissions have to be compensated or abated is defined as the average total CO_2 emissions of all international flights under the scheme in the years 2019 and 2020. This way, the CNG2020 goal shall be realized. In principle, the airlines have the choice either to purchase credits for the emissions exceeding their individual CO_2 limit or to abate. This decision will be determined by their abatement costs for an additional unit of CO_2 (so-called marginal abatement costs). Thus, CO_2 can be reduced cost-efficiently while a given environmental target shall be met.

While the CO_2 emission monitoring, reporting and verification (MRV) obligations under CORSIA have already started in 2019, offsetting is possible from 2021 onwards. CORSIA consists of three offsetting phases: A Pilot Phase in the timeframe 2021-2023, Phase 1 (2024-2026) and Phase 2 which covers the timeframe 2027-2035. From 2021 until 2026, ICAO contracting states are encouraged to participate on a voluntary basis.

CORSIA follows a route-based approach as only emissions from flights between participating states are subject to offsetting. In other words: emissions from flights between a participating state and a non-participating state, as well as emissions from flights between two non-participating states are not covered by CORSIA. Other exemptions refer to emissions from small aircraft (MTOM below 5.7 tons), small emitters (below 10'000 tons of CO_2 annually) and from flights conducted for humanitarian, medical and firefighting reasons. Military and governmental flights are completely excluded as they do not fall under the Chicago Convention and, hence, are not within the scope of ICAO. MRV under CORSIA is mandatory for all ICAO contracting states, irrespectively of any voluntary or mandatory participation. These obligations started in January 2019 already.

As of July 2020, 88 ICAO contracting states have declared to voluntary participate in CORSIA's offsetting pilot phase. International flights of carriers from these states represent about 76.82 per cent of total international revenue ton kilometres (RTK) (ICAO, 2020a). Most important 'aviation countries', like the EU states, Australia, Canada, South Korea, Japan, the US, Mexico, the UAE, Turkey, Indonesia and Qatar, as well as a notable number of developing countries such as Burkina Faso, Gabon, Zambia or Armenia decided to participate from 2021 onwards. In contrast, the largest countries missing are Russia, India, China and Brazil.

From 2027, all states whose airlines accounted for more than 0.5 of global international RTK in the year 2018 are subject to offsetting under CORSIA. Exemptions only apply to least developed countries, land-locked developing countries as well as small islands. However, voluntary participation will remain possible for any ICAO contracting state.

It is important to note that CORSIA only covers CO_2 emissions from international flights. This is because ICAO is the responsible UN agency for international civil aviation. Emissions from domestic flights are covered by the Kyoto Protocol and the UNFCCC Paris Agreement and hence do not fall under CORSIA. However, emissions from domestic flights could be included in the scheme by the participating states on a voluntary basis. This is because states are encouraged by the UNFCCC to address CO_2 emissions from domestic air transport.

3. Estimated environmental benefits of CORSIA

How ambitious are CORSIA's environmental goals? Which CO_2 savings can be expected from this scheme? These questions have been investigated by Schep et al. (2016), as well as by the authors in former papers (Scheelhaase et al., 2018; Maertens et al., 2019). Schep et al. (2016) matched the environmental impacts of the EU ETS for aviation (in its original and reduced scope) with CORSIA. They assumed that 66 states would voluntary participate in CORSIA's pilot phase and in phase 1, as it was expected in 2016. Schep et al.'s main finding was that on average 81.5 per cent of the growth in international air transport in the timeframe 2021-2035 would be subject to CORSIA's offsetting requirements (Schep et al., 2016). Scheelhaase et al. (2018) also compared the environmental, as well as the competitive effects, of the EU ETS with the impacts of CORSIA. Based on their modelling results and the assumption that 67 states including China would join CORSIA voluntarily, they found that CORSIA's environmental impacts (measured by the share of compensated emissions) would increase over time but stay at relatively low levels of 1.4% in 2021, 9% in 2027 and 16% in 2035, respectively. Hence, the environmental impact of CORSIA would remain below that of the full-scope EU ETS until about the year 2033, while the EU ETS in its reduced scope (as in force since 2013) would achieve CO_2 emission compensation rates of 2 to 4 per cent of global CO_2 in the timeframe 2016 until 2035 (Scheelhaase et al., 2018).

However, neither the findings of Schep et al. (2016) nor those of Scheelhaase et al. (2018) are still topical as the number of voluntary participants has increased to more than 80, however at the expense of China which withdrew its intention to join from scratch. In addition, Scheelhaase et al. (2018) did not model the additional effects of CORSIA becoming mandatory in 2027, but assumed the list of participating states to remain constant until 2039. Hence, an updated assessment was published in Maertens (2019), considering these additional effects (as well as a second scenario assuming only a 20% CORSIA Certified Emission Reductions (CER) effectiveness to actually achieve the promised emission reductions elsewhere).

Based on this and on a CORSIA CER effectiveness assumption of 100%, Figure 1 provides these updated modeling results. The methodological approach applied was already described in full in, e.g., Scheelhaase et al. (2018) but will be briefly summarized in the next section.

As CORSIA offsetting will become mandatory in 2027, we expect the scheme's compensation rate to increase from 6% in 2016 to 11.5% in 2027, to 20% in 2035 and (if extended) up to 23.4% in 2039. However, compared to the environmental benefits derived from the EU ETS in its original (full) scope, the corresponding benefits of CORSIA would stay at lower levels until about 2029 at least.

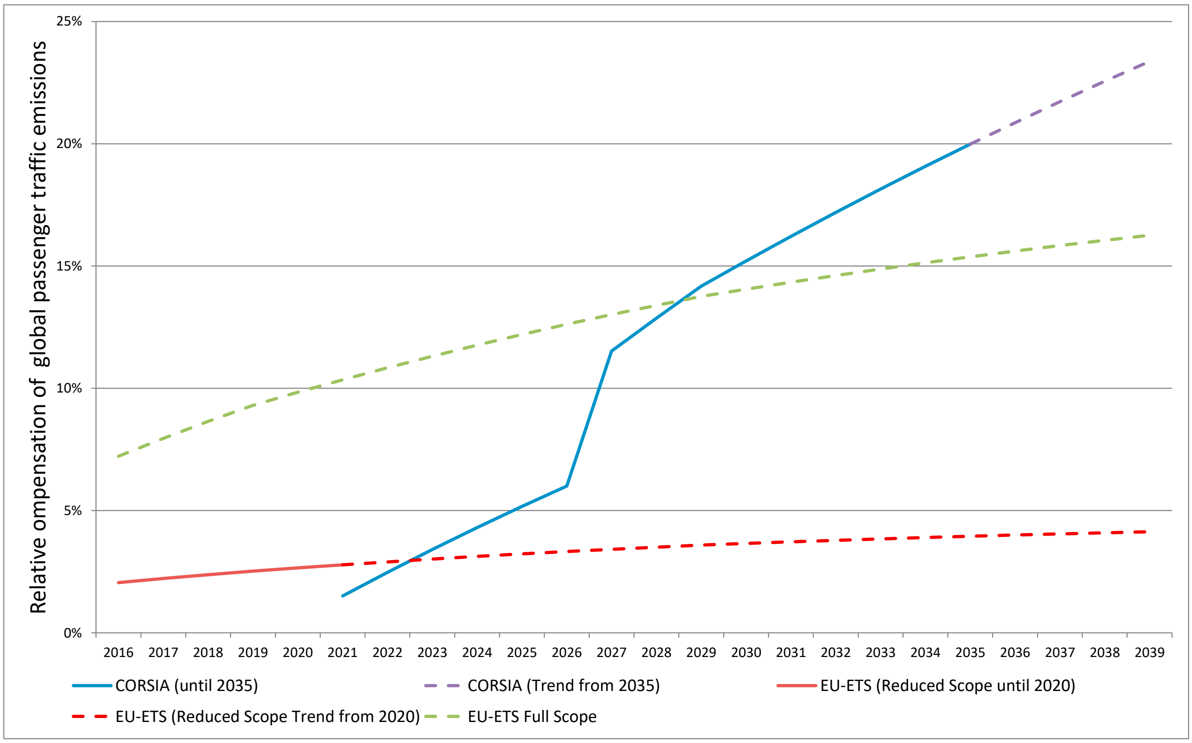

Fig. 1. Emission compensation in percentage of global passenger traffic emissions ICAO CORSIA (CER effectiveness assumption of 100%) and EU ETS. Source: DLR modelling results.

4. Options for improving CORSIA and associated environmental benefits

As shown above, CORSIA's environmental benefits could be more ambitious, e.g. in defining a more ambitious, earlier baseline above which emissions would have to be offset. However, CORSIA's rules and regulations are the result of very difficult and time-consuming negotiations on ICAO level. Against this background and despite the discussion on the actual environmental effectiveness of the CORSIA CERs, CORSIA can definitely be regarded as a successful step towards greening aviation. Nevertheless, it is possible to improve CORSIA's environmental benefits without having to re-start the global negotiation process on CORSIA's rules and regulations all over again. A consideration of domestic aviation by large 'aviation countries' would offer significant CO_2 savings, and such an approach could be achieved relatively easily on a voluntary basis, since it is at the sovereignty of each state to introduce CORSIA for domestic operations. Domestic flights are those within a country including overseas territories, if applicable.

However, costs for monitoring, reporting and verification (MRV) for this approach should not be forgotten. As CORSIA's MRV rules and regulations have to be implemented anyway to handle the international flights, additional costs for handling domestic operations would be rather small. And in some countries, especially in the EU, airlines and competent authorities have to comply with the MRV rules and regulations of the EU ETS since 2012 anyway - for both domestic and intra-European flights.

In this paper, we present and model some options for including domestic aviation in CORSIA, which will be explained in detail below. Basis for our modelling of aviation emissions as presented in figure 1 is a methodology already applied in Scheelhaase et al. (2018) and Maertens et al. (2019). First, the DLR's 4D RACE emission tool is applied to the 2016 passenger schedules as published by Innovata to model route- and aircraft-specific CO_2 emissions estimates for that year. In a second step, we apply ICAO FESG's region-(pair)-specific "Central scenario" (ICAO, 2014) growth rates to each route and increase the number of frequencies accordingly to obtain future (i.e. 2017-2039) schedules and emissions. For the latter, we also consider an average autonomous fuel efficiency increase of 1.2% p. a. We acknowledge that this approach implies the route structure to remain constant as the inauguration of new routes is not modelled. From a global emissions perspective, it is, however, less important whether frequencies on an existing route (e.g. Frankfurt to London) increase or new flights on a similar route within the same geographical route-group are inaugurated (e.g. Amsterdam to Munich).

According to our modelling results, the list of countries with the largest CO_2 emissions from domestic air traffic includes both developed countries and developing or emerging ones (whereby we handle the EU as one country). Table 1 presents the top 10 CO_2 emitting countries from domestic aviation in 2016. The list includes both developed countries like USA, Japan, Australia, Canada and the EU States, as well as the BRIC States (Brazil, Russia, India and China) and Indonesia. These countries altogether were responsible for about 87 per cent of global domestic CO_2 emissions from air transport. However, domestic CO_2 emissions from aviation only account for about 36 per cent of total global CO_2 emissions from aviation. In other words: international flights are responsible for about two thirds (circa 64 per cent) of all CO_2 emissions caused by air transport.

Tab. 1. Top 10 CO_2 emitters from domestic aviation in 2016. Source: DLR modelling results.

Domestic aviation market	**CO_2, million tons**
USA	105.59
China	55.20
EU	13.00
Japan	9.48
Brazil	9.11
India	9.04
Indonesia	8.77
Russia	8.55
Australia	7.24
Canada	6.38

We have modelled the environmental impacts of different options (table 2) for including domestic air traffic in CORSIA, differentiated by the state groups "Large CO2 domestic aviation emitters - developed countries", "Large CO2 domestic aviation emitters – developing/emerging countries" and "Top 10 CO2 emitters from domestic aviation (incl. EU)". All three options assume that CORSIA will be introduced for international flights as described in section II of this paper. In addition, Option A assumes a voluntary application of CORSIA for domestic flights by the developed countries USA, Japan, Australia, Canada and the EU Member States from 2020 onwards ("G7 + other EU + Australia domestic"). In contrast, Option B assumes that Brazil, Russia, India, China and Indonesia would introduce CORSIA for their domestic operations on a voluntary basis ("BRIC + Indonesia domestic"). Option C combines Options A and B and thus assumes that the CO2 emissions from domestic flights of all countries presented in table 1 would become subject to CORSIA offsetting from the year 2021 onwards ("G7 + other EU + Australia + BRIC + Indonesia domestic"). Figure 2 visualizes selected modelling results for these options, while key data is provided in tables 3 and 4.

Tab. 2. Overview of options for including domestic air traffic in CORSIA. Source: Own compilation.

Route Group	International traffic between participating CORSIA states	G7 (Canada, France, Germany, Italy, Japan, UK, USA)	Other EU	BRIC (Brazil, Russia, India, China)	Indonesia
Reference CORSIA as planned (int'l only)	X	---	---	---	---
Option A Large CO_2 domestic aviation emitters - developed countries	X	X	X	---	---
Option B Large CO_2 domestic aviation emitters – developing/emerging countries	X	---	---	X	X
Option C Top 10 CO_2 emitters from domestic aviation (incl. EU)	X	X	X	X	X

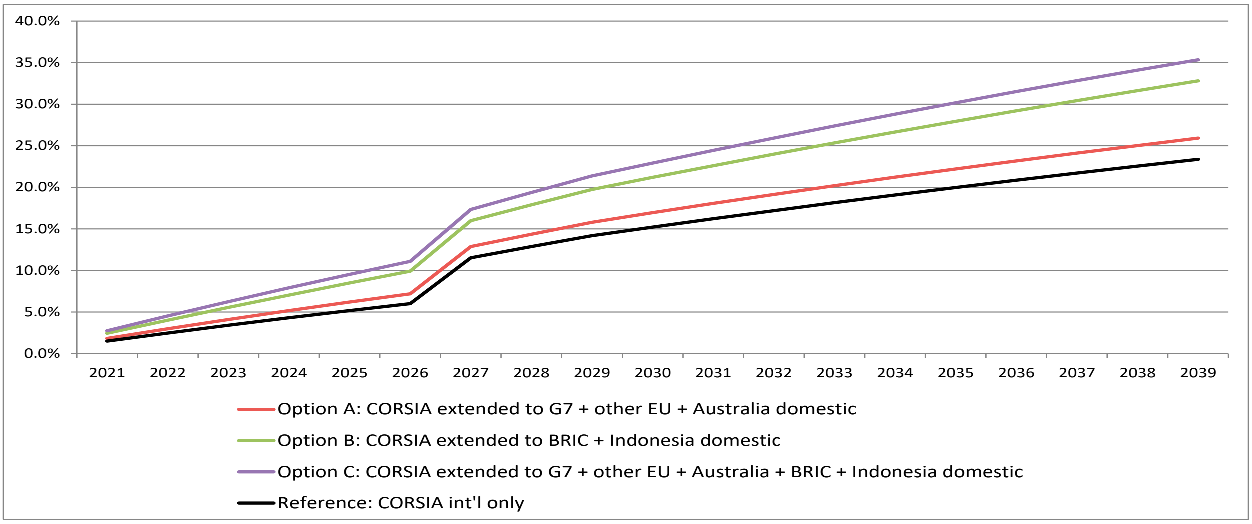

Fig. 2. Emission compensation in percentage of global passenger traffic CO_2 emissions – Options A, B and C (CER effectiveness assumption of 100%). Source: Own modelling results.

As expected, Option C will lead to the largest CO2 compensation rates. While the CO2 compensation rate will be relatively low (2.8 per cent) at the beginning of the timeframe analyzed, about 35 per cent of global passenger traffic CO2 emissions would have to be compensated in the year 2039 (figure 2 and table 3; assuming an extension of CORSIA beyond the year 2035). In absolute terms, 1'239 million tons of CO2 would then fall under CORSIA (table 3), whereof 538 million tons would have to be compensated by purchasing offsets (table 4). Compared to the regular ICAO CORSIA regime which only addresses CO2 emissions from international flights, almost 50% more CO2 would hence be compensated under Option C (table 4). In other words: Including the domestic CO2 emissions of the ten largest domestic emitters (considering the EU Member States as one 'state') would significantly increase the environmental benefits of CORSIA.

Tab. 3. Coverage and compensation rate by option (CER effectiveness assumption of 100%). Source: Own modelling results. CR = Compensation Rate.

Year	Worldwide emissions	CORSIA int'l (Reference)			Option A			Option B			Option C		
		Coverage	Share	CR	Coverage	Share	CR	Coverage	Share	CR	Coverage	Share	CR
	Mt CO_2	Mt CO_2	%	%	Mt CO_2	%	%	Mt CO_2	%	%	Mt CO_2	%	%
2021	887.0	316.6	35.7%	1.5%	468.4	52.8%	1.8%	439.1	49.5%	2.4%	590.9	66.6%	2.8%
2022	916.2	325.9	35.6%	2.5%	479.5	52.3%	3.0%	454.3	49.6%	4.0%	607.9	66.3%	4.5%
2023	946.6	335.5	35.4%	3.4%	491.0	51.9%	4.1%	470.0	49.7%	5.6%	625.6	66.1%	6.2%
2024	978.2	345.3	35.3%	4.3%	502.8	51.4%	5.2%	486.4	49.7%	7.0%	643.8	65.8%	7.9%
2025	1011.0	355.5	35.2%	5.2%	515.0	50.9%	6.2%	503.3	49.8%	8.5%	662.8	65.6%	9.5%
2026	1045.2	366.0	35.0%	6.0%	527.5	50.5%	7.2%	520.9	49.8%	9.9%	682.4	65.3%	11.1%
2027	1080.6	561.9	52.0%	11.5%	725.4	67.1%	12.9%	724.3	67.0%	16.0%	887.9	82.2%	17.3%
2028	1117.5	581.2	52.0%	12.9%	746.8	66.8%	14.4%	751.5	67.3%	17.9%	917.1	82.1%	19.4%
2029	1155.8	601.2	52.0%	14.2%	769.0	66.5%	15.8%	779.8	67.5%	19.7%	947.5	82.0%	21.4%
2030	1187.6	618.0	52.0%	15.2%	787.6	66.3%	16.9%	803.2	67.6%	21.2%	972.8	81.9%	22.9%
2031	1220.5	635.3	52.1%	16.2%	806.8	66.1%	18.1%	827.4	67.8%	22.6%	998.9	81.8%	24.4%
2032	1254.4	653.1	52.1%	17.2%	826.5	65.9%	19.1%	852.4	68.0%	24.0%	1025.8	81.8%	25.9%
2033	1289.3	671.4	52.1%	18.1%	846.8	65.7%	20.2%	878.1	68.1%	25.3%	1053.5	81.7%	27.4%
2034	1325.4	690.2	52.1%	19.1%	867.6	65.5%	21.2%	904.7	68.3%	26.6%	1082.1	81.6%	28.8%
2035	1362.6	709.6	52.1%	20.0%	889.0	65.2%	22.2%	932.2	68.4%	27.9%	1111.6	81.6%	30.2%
2036	1400.9	729.6	52.1%	20.9%	911.1	65.0%	23.2%	960.5	68.6%	29.2%	1142.0	81.5%	31.5%
2037	1440.4	750.2	52.1%	21.7%	933.8	64.8%	24.1%	989.8	68.7%	30.4%	1173.3	81.5%	32.8%
2038	1481.3	771.5	52.1%	22.6%	957.1	64.6%	25.0%	1020.0	68.9%	31.6%	1205.6	81.4%	34.1%
2039	1523.4	793.3	52.1%	23.4%	981.1	64.4%	25.9%	1051.2	69.0%	32.8%	1238.9	81.3%	35.3%

Tab. 4. Amount and share of (additionally) compensated emissions by option (CER effectiveness assumption of 100%). Source: Own modelling results.

Year	Worldwide emissions	Amount and share of (additionally) compensated emissions									
		CORSIA reference	Option A			Option B			Option C		
	Mt CO_2	Mt CO_2	Mt CO_2	Delta	Delta%	Mt CO_2	Delta	Delta%	Mt CO_2	Delta	Delta%
2021	887.0	13.4	16.1	2.8	21%	21.7	8.3	62%	24.4	11.0	83%
2022	916.2	22.6	27.3	4.6	20%	36.8	14.2	63%	41.5	18.8	83%
2023	946.6	32.2	38.8	6.5	20%	52.6	20.4	63%	59.1	26.9	83%
2024	978.2	42.1	50.6	8.5	20%	68.9	26.8	64%	77.4	35.3	84%
2025	1011.0	52.2	62.7	10.5	20%	85.9	33.6	64%	96.3	44.1	84%
2026	1045.2	62.7	75.2	12.5	20%	103.5	40.8	65%	116.0	53.2	85%
2027	1080.6	124.5	139.0	14.5	12%	172.7	48.2	39%	187.2	62.8	50%
2028	1117.5	143.8	160.4	16.6	12%	199.9	56.1	39%	216.5	72.7	51%
2029	1155.8	163.8	182.6	18.7	11%	228.2	64.3	39%	246.9	83.1	51%
2030	1187.6	180.6	201.2	20.6	11%	251.6	71.0	39%	272.2	91.6	51%
2031	1220.5	197.9	220.4	22.5	11%	275.8	77.9	39%	298.3	100.4	51%
2032	1254.4	215.7	240.1	24.4	11%	300.8	85.1	39%	325.2	109.5	51%
2033	1289.3	234.0	260.3	26.4	11%	326.5	92.6	40%	352.9	118.9	51%
2034	1325.4	252.8	281.2	28.4	11%	353.1	100.3	40%	381.5	128.7	51%
2035	1362.6	272.2	302.6	30.4	11%	380.6	108.3	40%	411.0	138.7	51%
2036	1400.9	292.2	324.7	32.4	11%	408.9	116.7	40%	441.3	149.1	51%
2037	1440.4	312.8	347.4	34.5	11%	438.2	125.3	40%	472.7	159.8	51%
2038	1481.3	334.1	370.7	36.6	11%	468.4	134.3	40%	505.0	170.9	51%
2039	1523.4	355.9	394.7	38.8	11%	499.6	143.6	40%	538.3	182.4	51%

Interestingly, assuming 100% CER effectiveness, both Options A and B would regulate almost the same amount of CO2 emissions in the year 2027 when CORSIA for international air traffic will become mandatory: In absolute terms, under Option A about 725 million tons and under Option B circa 724 million tons CO2 would be addressed by CORSIA in that year (table 3). However, due to stronger growth rates in the emerging countries, in the long run (2028 – 2039), Option B would lead to larger amounts of CO2 emissions regulated by CORSIA. For instance, in the year 2039, under Option B about 69% per cent of total global CO2 emissions from aviation would be addressed while this share will just amount to 64 per cent if the CO2 emissions from domestic aviation of the developed countries were included instead (Option A) (table 3).

In addition, the actual compensation rates differ between Options A and B. While they would increase for Option A from 1.8% in 2021 to 12.9% in 2027 and 25.9% in 2035, Option B always leads to a higher share of CO2 compensation (2021: 2.4%; 2027: 16%, 2039: 32.8%) (table 3).

These developments can be explained by the different growth rates expected for the selected groups of countries in the medium and long term. According to Boeing (2019), Airbus (2018) as well as ICAO (2014), an annual growth rate of about 3 – 4 per cent can be expected for the developing/emerging countries analyzed under Option B while the corresponding growth rates for the G7-States, the other EU States and Australia will remain at around 2.5 per cent per annum, or even lower (e.g. 1.6 per cent post-2020 for Japan domestic and 2.2 per cent for North America domestic in the ICAO FESG Central scenario) in the medium and long run.

5. Recommendations

Our modelling results show that addressing both developed countries and developing/emerging countries will be very important for the environmental outcome of any CO2 regulatory measure in aviation. While the developed countries are expected to emit larger amounts of CO2 in the short term, this will change in the medium and long run as the traffic growth in the developing/emerging countries will be disproportionately higher. Even though in our modelling we have assumed autonomous efficiency gains of 1.2 per cent p. a., the relatively high growth in air traffic is expected to overcompensate the fuel and CO2 savings induced by these efficiency gains.

Furthermore, CO2 emissions not only from international, but also from domestic air traffic should be regulated. Compared to the ICAO CORSIA regime which only addresses CO2 emissions from international flights, about 50% more CO2 could be compensated if the CO2 emissions of the ten largest domestic emitters were included (USA, China, EU, Japan, Brazil, India, Indonesia, Russia, Australia and Canada). In other words: Addressing the domestic CO2 emissions of these aviation markets would significantly increase the environmental benefits.

CO2 emissions from domestic operations could be included in CORSIA on a voluntary basis relatively easily, as such a decision would be at the sovereignty of each state. Thus, lengthy and difficult negotiations on ICAO level could be avoided. Moreover, such an approach would minimize transaction costs for airlines under the scheme as the rules and monitoring, reporting and verification (MRV) regulations would then be identical for all flights. However, in this paper we just assumed the willingness of the top 10 largest domestic emitters to voluntary include their CO2 emissions from domestic air transport in CORSIA. How realistic this assumption is in reality remains to be seen. It will be up to the policymakers. After all, as described in section 2 of this paper, many of the top 10 domestic CO2 emitting countries already agreed to voluntary participate in CORSIA for international flights, albeit not the BRIC states. Against this background, a voluntary inclusion of domestic CO2 emissions in CORSIA by the BRIC countries does not seem likely from today's point of view. However, an alternative approach would be the inclusion of domestic aviation in national emission trading schemes as, for instance, China plans (see for instance IETA, 2016 and ICAP, 2019).

Table 5 summarizes the pros and cons of including domestic CO2 emissions in CORSIA.

Tab. 5. Advantages and disadvantages of including domestic aviation's CO_2 emissions in CORSIA as compared to CORSIA only for international flights.

Advantages/Disadvantages (compared to existing CORSIA scheme)	
CO_2 emission limitation	++ (CORSIA international flights plus flights from top 10 CO_2 emitters incl. EU)
MRV effort for airlines and competent authorities	**0n (no significant additional effort)**
Chances to be implemented on a national level	will depend on the individual country's CO_2 reduction policy

Other approaches for increasing the environmental benefits of ICAO's CORSIA could be to define a (much) more ambitious CO2 compensation goal, for instance by limiting aviation's international CO2 emissions on the level of the year 2000 – instead of the year 2019/2020 – or by applying a simple discount factor to the CORSIA baseline (e.g. 50% of average 2019/2020 emissions instead of 100%). For comparison: in the EU ETS for aviation, air transport's CO2 emissions are capped at the level of 95 per cent of average 2004-2006 aviation emissions. Another option would be to define much more strict criteria for eligible offsets under CORSIA. However, both approaches would require long and difficult negotiations on the ICAO level.

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