ZEW policy brief

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Turbulence Ahead: Effective and Efficient Climate Policy in Aviation

Decarbonising aviation is a major challenge. It requires not only determined political measures but also strong incentives for the use of sustainable aviation fuels (SAFs). At present, both market-based and regulatory instruments are used to drive decarbonisation – for example the European Emissions Trading System (EU ETS), the EU-wide SAF blending quota and the international compensation system CORSIA (Carbon Offsetting and Reduction Scheme for International Aviation).

A new ZEW study shows: The cost effectiveness of climate policy instruments is determined by the structure of a market and the degree of competition. Under conditions of perfect competition, CO_2 taxes are a cost-effective way to reduce emissions. However, if air carriers have market power, SAF quotas are more advantageous as they stabilise demand while promoting the use of sustainable fuels. The EU's climate policy measures in the aviation sector are useful in reducing emissions, but their global impact is limited. The sharp rise in passenger numbers is driving up the cost of achieving net-zero emissions growth significantly. This underlines the fact that international measures and regulatory incentives for the use of SAFs are indispensable. If the offsetting certificates used under CORSIA fail to achieve genuine emission savings, there is a risk that the industry will continue to rely on fossil aviation fuels, and the decarbonisation of aviation will be delayed.

KEY MESSAGES

- Market structure and competition are of central importance when designing climate policy instruments; in the aviation sector, competition is usually imperfect.
- Under these conditions, SAF quotas are more cost-effective than a CO_2 tax: They set incentives for climate action and reduce distortions in competition.
- The EU's 2035 climate package for the aviation sector (EU emissions trading + SAF quota) curbs emissions at an average cost of 377 euros per tonne of CO_2 avoided; ticket prices rise by 12 per cent. EU emissions trading alone, without SAF quota, delivers minor emission reductions at high costs.
- Even with highly stringent EU measures (CO_2 price of 300 euros in emissions trading and SAF quota of 35 per cent), global aviation emissions are reduced by less than 7 per cent.
- Strong passenger growth calls for global measures: To stabilise global air transport emissions at 2019 levels, they would have to be curbed by 59 per cent worldwide; in the absence of fundamental technological breakthroughs this is only possible with a massive use of SAFs.
- If carbon offsetting (e.g. CORSIA) fails to bring genuine emission reductions, there is a risk of path dependencies that delay transformation and entrench dependence on fossil aviation fuels.

DECARBONISATION OF AVIATION

Decarbonising aviation: Technological and economic challenges and climate policy play a role

Aviation is a sector with particular technological and structural characteristics, which make it especially difficult to decarbonise this industry. It is heavily dependent on fossil aviation fuels and has few options to switch to alternative energy sources, such as electrification. High cost of capital and structural barriers to market entry lead to incomplete competition in many global aviation markets. Moreover, limited airport capacity, slot allocation and high aircraft costs also restrict competition, so that as a rule only a few air carriers compete on a particular route. In the absence of fundamental technological breakthroughs, market-based instruments and targeted incentives for emission reductions and the use of SAFs are crucial to drive decarbonisation effectively and cost-efficiently.

Existing measures focus on Europe

Various climate policy measures are in place to abate emissions from air transport. Important examples are the European Emissions Trading System (EU ETS) and the EU quota for SAFs. The only market-based mechanism with a global scope is the Carbon Offsetting and Reduction Scheme for International Aviation (CORSIA).

The scope of the EU ETS is limited to flights within Europe

The EU ETS covers flights (with origin and destination airports) within Europe. Airlines are required to hold a certificate for each emitted ton of CO_2. As the EU ETS cap will be tightened over time, the expectation is that a higher CO_2 price will be an incentive for emission reductions that is cost-effective for the economy.

The EU SAF quota for all flights from EU airports was introduced in 2025

The EU quota for SAFs was introduced with the ReFuelEU initiative and has been applicable since January 2025. It mandates the use of a gradually increasing blending quota of SAFs for flights departing from European airports, regardless of the destination airport. This means that the quota accelerates the phase-out of fossil fuels for aviation.

The first global market-based scheme: CORSIA

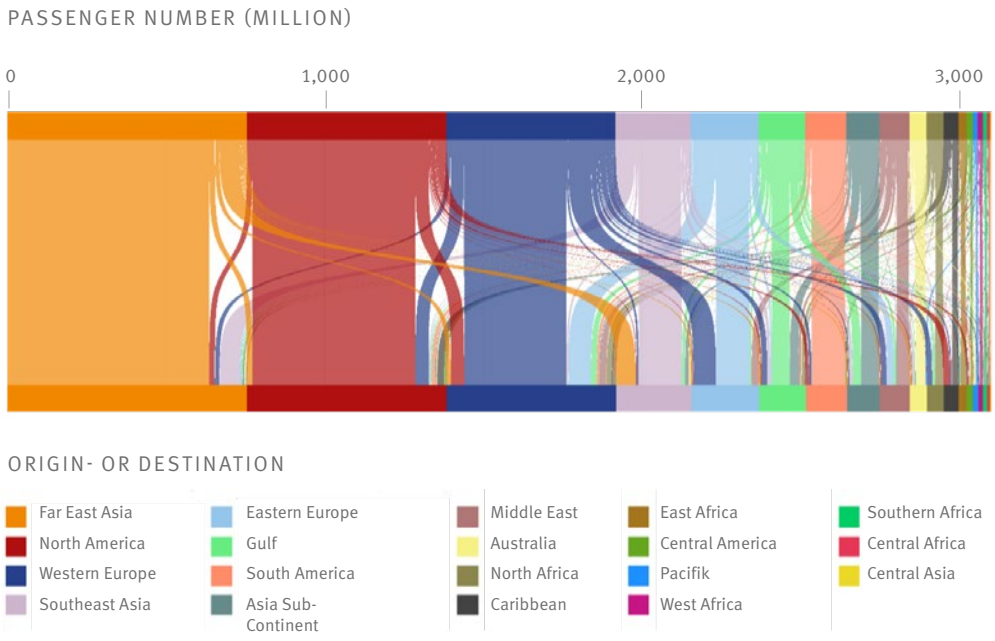
CORSIA is presently the only global scheme that requires airlines to offset emissions exceeding 85 per cent of the 2019 level. However, this initiative has only limited effect as enforcement is weak and the climate impact of many offsets, with predominantly low CO_2 offset prices, is doubtful.

GLOBAL CLIMATE POLICY INSTRUMENTS FOR THE AVIATION SECTOR

Economic simulation model of global aviation markets

A new ZEW study investigates the impact of climate policy on aviation emissions, ticket prices and welfare. An approach is used that combines economic theory and quantitative-empirical simulation analyses. It includes the development of a comprehensive economic model of the air transport markets, which depicts the worldwide network of hub and non-hub airports, in which full-service network carriers (e.g. Lufthansa, Air France, United Airlines) and low-cost carriers (e.g. Ryanair, easyJet, Wizz Air) compete with each other regarding direct flight services and transfer traffic, the competitive conditions being imperfect. Airlines choose between conventional jet fuels (CJFs) and SAFs and adjust both their flight volumes – and thus indirectly their ticket prices – and their fuel mix in order to respond cost-effectively to fuel prices, demand for transport services and different climate policy regulations. The model is calibrated using detailed booking data on ticket prices and passenger flows from 2019 (obtained from the SABRE database), which cover 96 per cent of global flights. The model is therefore the first to enable an economic evaluation of the effects the various regulatory approaches to decarbonising aviation have on global markets and emissions. Global air traffic is concentrated in East Asia, North America and Western Europe, while Africa and Central Asia account for a smaller share (see Figure 1).

FIGURE 1: MATRIX OF PASSENGER FLOWS BETWEEN ORIGIN AND DESTINATION AIRPORTS IN THE REGIONS



Two climate policy measures: Taxes versus regulations

Two climate policy instruments are compared:

- CO_2 tax: increases the cost of emissions from fossil aviation fuels and gives air carriers the choice between adjusting the number of their flights and (partially) substituting CJFs with SAFs.
- SAF quota: requires airlines to blend a prescribed percentage (in relation to total aviation fuel used) of SAF into the fuel mix.

In a perfectly competitive market, the CO_2 tax is the most cost-effective instrument

A comparison of the global variants of these two approaches to climate policy regulation reveals the following: In a perfectly competitive market, a CO_2 tax is the most cost-effective instrument for achieving a given reduction in emissions. It enables airlines to choose the efficient way to abate emissions (see Figure 2), either by reducing passenger numbers and/or the number of flights or by (partially) switching to SAFs. The average welfare costs per tonne of CO_2 avoided are lower than with an SAF quota. In contrast, an SAF quota mandates airlines to use a specified minimum share of SAFs, thereby limiting the possibilities for cost-effective emission reduction through an adjustment of the fuel mix and leading to higher welfare costs. This follows a well-known logic: A CO_2 externality is internalised in the decisions of airlines, aviation fuel providers and passengers via the direct pricing of CO_2 emissions, which is cost-effective from an economic perspective.

Under imperfect competition, an SAF quota is superior to a CO_2 tax

When airlines offer their transport services (tickets) under imperfect competition, the results change fundamentally. Even without climate policy measures, the effect of incomplete competition is that air travel demand and supply are well below and prices well above the levels that would be seen in a perfect market. A CO_2 tax which is passed on to passengers mainly through higher ticket prices not only increases prices but has the additional effect of curbing demand for tickets. This leads to high welfare losses. In contrast, the quota, which prescribes a proportion x = quantity of SAF/ total quantity of aviation fuels, is equivalent to an implicit tax on the total quantity of aviation fuels and an implicit subsidy for SAFs. This implicit subsidy component acts as a partial compensation for the insufficient number of flights or passengers caused by imperfect competition and reduces overall welfare costs (see Figure 3).

The average welfare costs associated with a 25 per cent reduction of emissions are 480 EUR/tCO_2 with an SAF quota, i.e. around 40 per cent less than under a global CO_2 tax. In this scenario, ticket prices rise by only eight per cent instead of 63 per cent.

FIGURE 2:
AVERAGE WELFARE COSTS OF EMISSION REDUCTION UNDER PERFECT COMPETITION

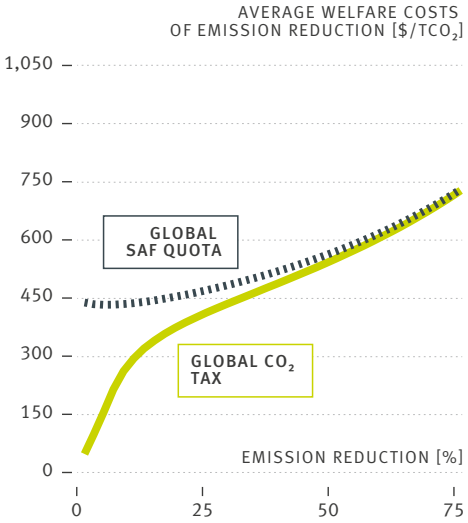
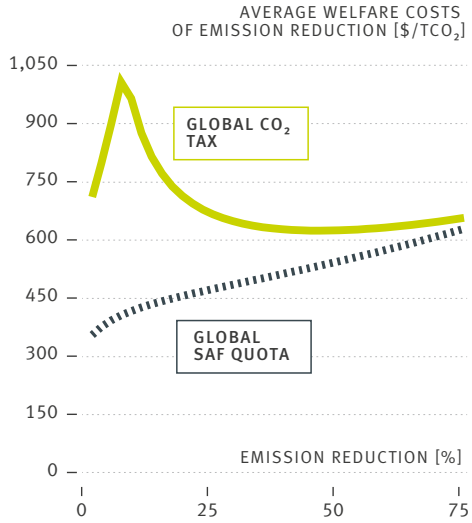


FIGURE 3:
AVERAGE WELFARE COSTS OF EMISSION REDUCTION UNDER IMPERFECT COMPETITION



It is clear from the results that if market power is neglected, this can strongly distort the evaluation of climate policy measures both in absolute and relative terms. With a CO_2 tax, the estimated welfare costs under imperfect competition are 1.6 to 15.6 times higher than under conditions of perfect competition, depending on the stringency of the policy.

EU CLIMATE POLICY FOR AVIATION

Limited effect of EU climate policy on global air transport emissions

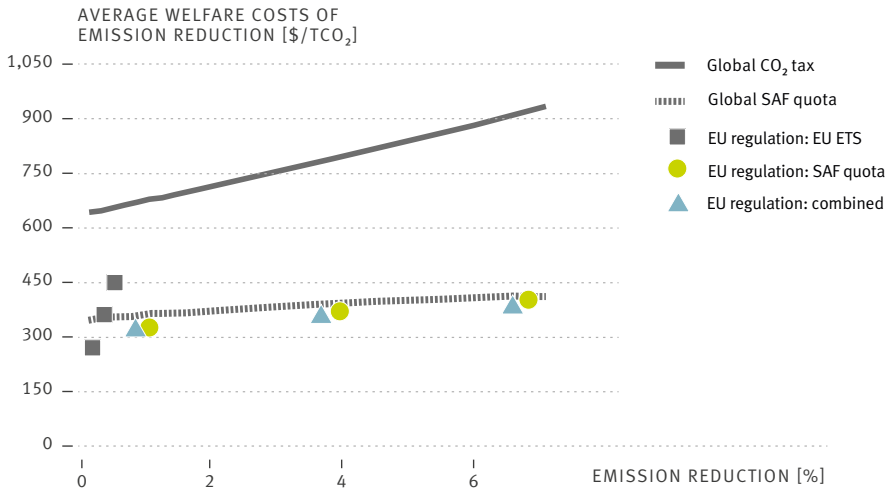
Even ambitious EU measures only have a limited effect on global aviation emissions. By 2035, the EU ETS as well as the EU SAF quota, or a combination of both, would curb global emissions by less than five per cent:

- The EU ETS (at 200 EUR/tCO_2) only achieves a global reduction of 0.4 per cent (Figure 4, dark grey square).
- A 20 per cent EU SAF quota leads to a decrease of 3.8 per cent (Figure 4, light blue triangles).
- By combining both measures, emissions can be abated by 3.9 per cent (Figure 4, green circle).

The costs of the EU ETS increase strongly when reduction targets are raised

The welfare costs associated with the EU ETS increase markedly when stricter emission reduction targets are introduced. This is due to the regionally limited scope of the EU ETS, which only regulates flights within the EU: A stricter emissions cap therefore has a strong impact on costs and demand within the EU, resulting in higher costs compared to global measures with a broader scope.

FIGURE 4: AVERAGE WELFARE COSTS OF EMISSION REDUCTION ($/TCO$_2$) BY EU CLIMATE POLICY



The relative cost-effectiveness of climate policy instruments (CO_2 tax versus SAF quota) also applies when the EU's climate policy in the aviation sector is analysed. Under imperfect competition conditions, the EU SAF quota proves to be cost-effective compared to the EU ETS. A CO2 price of 100 EUR/tCO_2 in the EU ETS would increase ticket prices for regulated flights by around six per cent. In contrast, an SAF quota of 20 per cent, which would result in nine times higher emission reductions, would only cause ticket prices to rise by less than five per cent.

EU climate policy in the aviation sector: Low avoidance costs for the economy and moderate increase in ticket prices due to the EU SAF quota

Since 2012, European air transport has been regulated by the EU ETS. The introduction of the SAF quota in 2025 has led to an overlap between the two measures. Contrary to the common theory that regulatory overlap means higher costs, our study shows that by combining the measures, better results may be achieved under conditions of imperfect competition. This is due to the cost-effectiveness of the EU SAF quota, which is a new addition to the instrument mix. By 2035, the combination of both measures will reduce emissions at a welfare cost of 377 EUR/tCO_2 on average, while ticket prices will only increase by twelve per cent. This is considerably less than would be the case with a climate policy that relies exclusively on CO_2 pricing via the EU ETS.

FAR-REACHING DECARBONISATION OF GLOBAL AIR TRANSPORT

The decarbonisation of air transport poses considerable challenges even with today's passenger numbers. For the coming years, passenger volume is expected to grow very dynamically, which will increase the pressure. A growing middle class and ongoing globalisation act as catalysts: Passenger numbers are expected to rise by 3.1 to 4.0 per cent annually and thus likely to grow at least 143 per cent by the year 2050.

Is decarbonisation possible with rising passenger numbers?

Even if climate policy measures were globally coordinated and applicable in all countries, a stabilisation of emissions on the level of 2019 – as projected in the "Net-Zero Growth" path – would lead to high costs.

And at what cost?

- A global CO_2 tax of 856 EUR/tCO_2 would result in average welfare costs of 950 EUR/tCO_2.
- A global SAF quota of 53 per cent would cause average welfare costs of 760 EUR/tCO_2.
- With either policy measure, SAF use would rise considerably. However, a CO2 tax would have a more negative effect on passenger demand than an SAF quota (minus 16 versus minus 11 per cent).

What can be achieved with CORSIA as a global measure?

Another emission reduction approach – related to CO_2 pricing – is the international compensation system CORSIA. The key question here is whether the offsets under CORSIA actually bring about real reductions in emissions. Three scenarios are analysed in the study, each of which combines the CORSIA system with future EU climate measures in aviation:

- Effective CORSIA offsetting certificates: There are actual emission reductions through offsets[1]; the price of the certificates is 110 EUR/tCO_2. This leads to average welfare costs of 113 EUR/tCO_2, a 65 per cent reduction in emissions and a three per cent reduction in demand.
- Ineffective CORSIA offsets: The offsetting payments do not generate actual emission reductions. Associated average welfare costs increase to 505 EUR/tCO_2, emissions are curbed by 15 per cent only, and there are only minor incentives to use SAFs.
- CORSIA tax: In this scenario, the offsets are replaced by a global CO2 tax for all flights that are not subject to the EU ETS. To achieve net-zero growth (reduction by 59 per cent), a tax of 964 EUR/tCO_2 would have to be imposed. Here, the average welfare costs would come to 858 EUR/tCO_2.

If the offsets fail to generate genuine emission reductions, there is a risk that CORSIA may strengthen the sector's ties with fossil fuels and thus delay the decarbonisation of aviation.

CONCLUSION

SAF quota as an efficient and cost-effective climate policy instrument for decarbonising aviation

Efficient climate policy in aviation needs to factor in the incomplete competition between air carriers – with the resulting market power of many carriers – and the global interconnectedness of the sector. Under realistic competition conditions, an SAF quota is a cost-effective instrument: It not only reduces emissions but at the same time mitigates competition-related distortions. Regionally implemented measures such as the EU ETS and the EU SAF quota make an important contribution to emission reduction, but their influence on the global dynamics of air transport is limited. Successful decarbonisation of the sector thus needs to consider international strategies and robust incentives to boost sustainable aviation fuels. A key challenge remains: ensuring that global measures are credible. If offsetting programmes like CORSIA fail to achieve real emission reductions, there is a risk of path dependencies, which will delay the necessary transformation and entrench the reliance on fossil fuels. Global regulation approaches need to be developed further with ambition, and they must come with clear quality standards for offsets as well as a strong focus on SAFs to achieve the long-term goal of climate-neutral aviation.

1 Emissions are compensated by financing external projects that lead to CO2 reductions or removals elsewhere. Air carriers are thus able to maintain their flight operations without directly curbing emissions.

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Imprint

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