Impact of the Russia-Ukraine War on Aviation Carbon Emissions

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Overview

The global aviation industry faces numerous uncertainties in achieving its carbon reduction targets, with geopolitical conflicts being particularly significant. In February 2022, the airspace closure policies triggered by the Russia-Ukraine war profoundly impacted global aviation operations and carbon emissions. This conflict led multiple countries to impose airspace bans on Russian aircraft, while Russia retaliated with countermeasures, restricting flights from 36 nations, including EU member states. These policies forced numerous flights to be canceled or rerouted, significantly affecting flight distances, durations, and operating frequencies.

To examine the impact of airspace closure policies on aviation carbon emissions and social welfare, this study extends its analysis to cover the period from January 2019 to October 2023. Utilizing a propensity score matching with difference-in-differences (PSM-DID) approach, the research systematically evaluates the effects of the war through two dimensions: flight rerouting (Intensive Effect) and flight frequency reductions (Extensive Effect). This study not only uncovers the profound implications of the conflict on the global aviation sector and carbon reduction goals but also provides empirical evidence and policy recommendations to address geopolitical risks, inform climate policy development, and foster regional cooperation.

Methods

To comprehensively assess the multidimensional impacts of the airspace closure policy triggered by the Russia-Ukraine war on global aviation, this study first applies the Propensity Score Matching and Difference-in-Differences (PSM-DID) methods to quantitatively analyze the effects of the war on two key dimensions of the aviation industry: flight rerouting (Intensive Effect) and flight frequency reduction (Extensive Effect). Subsequently, through counterfactual analysis, the study further evaluates the combined impact of the airspace closure policy on global aviation carbon emissions and social welfare.

Specifically, this study uses high-resolution data on global flight fuel consumption and frequency from January 2019 to October 2023, obtained from the OAG flight database and carbon emissions database. First, the propensity score matching method is used to match the experimental group flights (i.e., those affected by the airspace closure policy) with the control group flights (i.e., those not affected), in order to reduce sample selection bias. Then, the Difference-in-Differences method is applied to quantitatively analyze the impact of the airspace closure policy on the two major factors of flight rerouting and flight frequency reduction, assessing their extent of impact on the global aviation industry. In addition, this study conducts heterogeneity analysis on the flight characteristics of different countries and markets, focusing on the differences in the impact of the airspace closure policy based on flight distance, market characteristics, and airline aircraft decisions. Finally, to quantify the overall impact of the war, a counterfactual scenario is constructed assuming that the Russia-Ukraine war did not occur. The carbon emissions and flight operations in this hypothetical scenario are compared with actual observed values to calculate the overall impact of the war on aviation carbon emissions and social welfare..

Results

This study reveals the profound impacts of the airspace closure policies triggered by the Russia-Ukraine war on global aviation carbon emissions and social welfare, primarily through two mechanisms: flight rerouting (Intensive Effect) and flight frequency reductions (Extensive Effect). For the banned countries, flight rerouting led to a 2.39% increase in fuel costs, with a cumulative carbon emission increase of 1,623,737.03 tons of CO_2. Simultaneously, flight frequencies in these countries decreased by an average of 9,364 flights per month. While this reduction resulted in overall carbon emission savings, it came at the cost of significant social welfare losses amounting to -26,504.98 million USD, highlighting the substantial economic disruptions caused by flight cancellations and travel restrictions.

Moreover, the airspace closure policies produced significant spillover effects on non-sanctioned countries such as China, Bahrain, and Bangladesh. In these countries, average fuel consumption rose by 0.95%, with a cumulative carbon emission increase of 404,727.16 tons of CO_2 and a monthly flight frequency reduction of 1,498 flights.

Although some of these countries mitigated the disruptions by enhancing their role as transit hubs and absorbing rerouted flights, their social welfare losses remained significant, totaling -3,832.70 million USD.

Heterogeneity analysis further revealed that long-haul routes (over 5,000 km) experienced fuel cost increases 1.5 to 3 times higher than short- and medium-haul routes. The Asia-Europe and Europe-Australia markets, characterized by higher route densities, showed the most significant increases in fuel consumption and carbon emissions, with monthly flight frequencies decreasing by 6 to 8 flights. Counterfactual analysis revealed that the airspace closure policies led to a 2,028,464.19-ton CO_2 increase in emissions through the Intensive Effect, while the Extensive Effect resulted in a reduction of 30,477,186.63 tons of CO_2, culminating in a net global reduction of 28,448,722.43 tons of CO_2. Of this net reduction, banned countries accounted for 83.77% and non-sanctioned countries for 16.23%. Nevertheless, the total social welfare loss amounted to -35,735.34 million USD, with banned countries bearing 87.34% of the losses and non-sanctioned countries 12.66%. The five countries with the most significant welfare declines—namely the United States, Sweden, China, South Korea, and Hungary—accounted for 43.48% of the total loss.

Furthermore, the study found no significant evidence that the airspace closure policies prompted airlines to transition to lower-emission aircraft models, such as the Airbus A350 or Boeing 787, reflecting the constraints imposed by high costs on airline decision-making.

Conclusions

This study comprehensively evaluates the multifaceted impacts of airspace closure policies triggered by the Russia-Ukraine war on global aviation carbon emissions and social welfare. The findings reveal that these policies profoundly altered the operational patterns of the aviation industry through two primary mechanisms: flight rerouting and reduced flight frequencies. Flight rerouting significantly increased fuel costs and carbon emissions, while reduced flight frequencies, despite lowering overall carbon emissions, imposed substantial economic and social welfare losses. Both sanctioned and non-sanctioned countries were unable to escape the adverse effects of the war. While non-sanctioned countries mitigated some of the impacts by strengthening their roles as transit hubs, the overall declines in social welfare and environmental benefits remained pronounced.

The study also highlights the spillover effects of the conflict and the heterogeneous impacts across different markets and routes. Long-haul routes and high-density routes were most severely affected, with substantial increases in carbon emissions. Routes between Asia and Europe, and Europe and Australia, experienced particularly severe environmental and economic impacts, reflecting the extensive reach of geopolitical conflicts beyond the directly involved countries. These findings underscore that no country emerged as a true "winner" in this global geopolitical conflict, as both directly affected nations and indirectly impacted third-party countries suffered significant losses.

This study emphasizes the widespread impacts and complex challenges posed by geopolitical conflicts. By analyzing the multi-dimensional effects across markets, routes, and nations, it provides a robust foundation for understanding the long-term implications of such conflicts on the aviation industry and global decarbonization goals. It also offers valuable insights for achieving global emission reduction and climate targets.

Based on these findings, the study offers two levels of policy recommendations. 1) Airline-Level Strategies: Airlines should adopt advanced technologies and refined operational strategies to reduce carbon emissions. These include optimizing route planning through big data analytics and modern navigation technologies, enhancing aircraft fuel efficiency with innovations like blended winglets and lightweight cabin designs, and expanding the use of sustainable aviation fuels (SAF). Collaborative joint operations between sanctioned and non-sanctioned airlines could further optimize route networks and provide better transit services, mitigating the adverse effects of airspace closures. 2) National-Level Policies: Governments should implement targeted incentives and supportive policies to facilitate the aviation sector's green transition. These measures include offering tax incentives and subsidies to support the development and adoption of advanced emission-reduction technologies and SAF. Moreover, international cooperation should be strengthened to establish unified industry standards, promote technology and information sharing, and improve airspace management to minimize unnecessary flight distances and emissions.

References

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