ASHER RUDOLPH and QING WANG, Dept of Computer Science, Mathematics, and Engineering, Shepherd University, Shepherdstown, WV 25443. Economies of Distance in Commercial Aviation: Emissions Intensity and Marginal Abatement Costs

This study examines the structural drivers, economic implications, and policy feasibility of carbon dioxide (CO_2) emissions in U.S. commercial aviation using large-scale flight-level operational data. Approximately 353,000 domestic commercial jet flights operated during March 2025 were analyzed to evaluate how flight distance influences fuel burn, emissions per mile, and associated operating costs under real-world conditions.

Fuel burn was converted to CO_2 emissions using standardized International Civil Aviation Organization (ICAO) emission factors and normalized by flight distance to measure emissions intensity. A log–log regression reveals a strong inverse nonlinear relationship between distance and CO_2 emissions per mile, with an estimated elasticity of -0.18 and distance explaining over half of observed variation in emissions efficiency. Short-haul flights exhibit disproportionately high emissions intensity due to fuel-intensive taxi, takeoff, and climb phases, while efficiency gains diminish at longer distances.

Extending the physical analysis into an economic framework, fuel burn and emissions were translated into fuel and carbon costs using representative jet fuel prices and carbon pricing benchmarks. Cost-per-mile patterns closely mirrored emissions intensity, and one-way ANOVA testing confirmed statistically significant differences in fuel, carbon, and total cost per mile across short-, medium-, and long-haul categories.

To assess economic feasibility, a marginal abatement cost (MAC) framework simulated uniform operational fuel-efficiency improvements of 1–5 percent. Under a 1% efficiency improvement, the implied abatement value was approximately \$648.78 per metric ton of CO_2 avoided. Because cost savings and emissions reductions scale proportionally with fuel burn, the marginal abatement cost remains stable across flight types under the uniform-efficiency assumption. These results indicate that modest operational efficiency improvements represent a negative-cost abatement opportunity, demonstrating that near-term emissions reductions can be achieved while simultaneously lowering airline operating costs. This research was conducted as part of the 2025 NASA West Virginia Space Grant Consortium at Shepherd University.