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AVIATION CLIMATE FINANCE USING A GLOBAL FREQUENT FLYING LEVY

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EXECUTIVE SUMMARY

Aviation is often considered a "hard to abate" sector; it is growing rapidly but struggling to deploy low-carbon technologies due to their high costs. This paper presents a case under which progressive taxation, namely a frequent flying levy (FFL), can generate revenues for decarbonization while ensuring equitable distribution of the cost burden.

The idea of an FFL is to institute a per-flight tax that increases as a person takes more flights in a year. It has been advocated for in the United Kingdom as a fiscal tool to curb aviation demand and emissions. Research has consistently shown a positive correlation between income and propensity to fly. Varying the levy based on flying frequency allows the FFL to focus the tax burden on wealthier frequent flyers rather than on people who fly only occasionally. The design could also help ensure that people with lower incomes are not priced out of air travel because of climate policy.

The International Civil Aviation Organization estimates that up to $4 trillion in technology investment may be needed to achieve a 1.75 °C-compatible aviation emissions reduction pathway through 2050, or an annual investment of $121 billion. Using income distribution and air traffic data for 175 countries, this study investigates the distributional impacts of raising this revenue in two different ways: a flat per-flight tax (air passenger duty, or APD), or a frequent flying levy. Raising $121 billion of revenue in 2019 would have required a flat $25 tax on each one-way flight or an FFL starting at $9 for a person's second flight to $177 for their twentieth within the same year.

Globally, the inequality of income and the uneven participation in flying is extreme. We conclude that the richest 20% worldwide take 80% of the flights, and the top 2% most frequent flyers take about 40% of the flights. We estimate that a global FFL would generate 81% of revenue from frequent flyers (people who take more than six flights a year) and 67% from high-income countries, versus 41% and 51% under a flat tax. Thus, the levy would shift the tax burden from occasional flyers to frequent flyers, and from lower-income countries to high-income countries, relative to an APD. The shift of burden to high-income countries, in particular, is key to ensuring that aviation decarbonization does not unfairly burden countries with low historical emissions. High-income countries generated about 70% of aviation CO_2 emissions between 1980 and 2019; revenues collected from a global FFL would better track each country's historical emissions than an APD would.

Figure ES-1 shows the geographical redistribution of the tax burden under an FFL compared to a flat levy. The color scale represents the percentage of increase or decrease in country-total tax burden when an FFL is in place compared to if a flat levy is implemented. Under an FFL, some high-income countries, such as Norway and Iceland, would almost double the amount of levy revenue collected compared to an APD, while residents in low-income countries would pay a fraction of the APD charges. The middle-income countries in green shades would see the largest absolute reduction in levy revenue, as levy cost shifted to more affluent countries, shaded in orange and red.

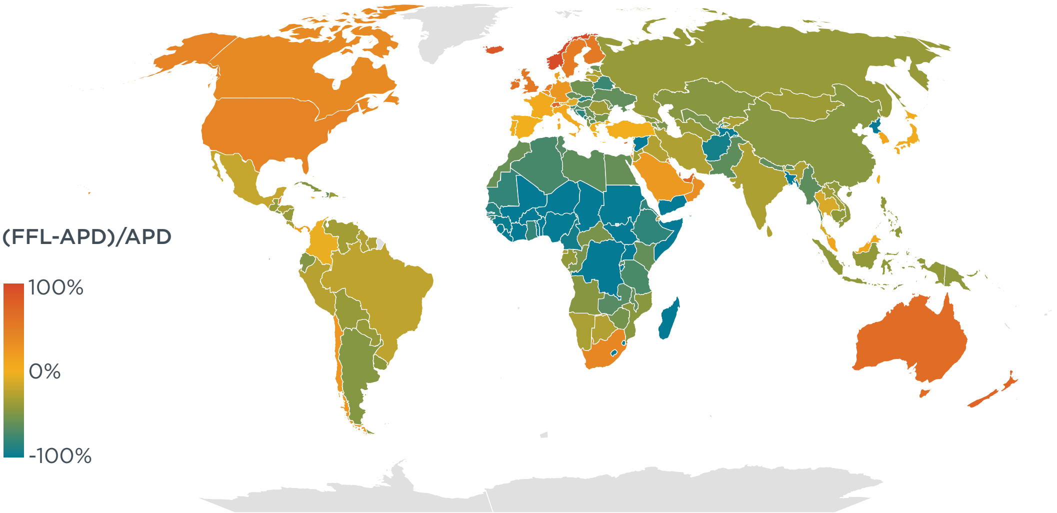

Figure ES-1. Percentage difference in total APD collected and total FFL collected for each country

From the income perspective, both a flat per-flight tax and FFL can be considered progressive, in terms of generating a majority of revenue from higher income brackets. Specifically, a flat per-flight tax generates 81% of revenue from the richest 20% of global population, while an FFL raises virtually all (98%) of its revenue from the richest 20% (Table ES-1). This is because flying activities are currently undertaken by a small subset of the global population, who tend to be in higher income brackets. An FFL could further alleviate the burden on global middle-income brackets compared to a flat levy.

Table ES-1. Distribution of levy revenue by global income brackets in 2019, APD vs. FFL

Income percentile	Per capita income (USD)	Average annual flights	Share of APD revenue*	Share of FFL revenue*
1st –9th	0-189	0	0.0%	0.0%
10th–19th	190-559	0	0.0%	0.0%
20th–29th	560-849	0	0.0%	0.0%
30th–39th	850-1,229	0	0.1%	0.0%
40th–49th	1,230-1,969	0.03	0.4%	0.0%
50th–59th	1,970-3,149	0.07	1.2%	0.0%
60th–69th	3,150-5,099	0.33	5%	0.1%
70th–79th	5,100-9,199	0.77	12%	2%
80th–89th	9,200-22,999	1.3	19%	9%
90th–94th	23,000-37,099	2.8	63%	90%
95th–99th	>37,100	4.5		

*Sum of the cell values in the column may exceed 1 due to rounding.

Regardless of tax design, the impact of increased cost on travel demand would be moderate, reducing travel by about 7% globally; this is the extreme case where all decarbonization costs are passed on to consumers in 2019, so the actual impact would be even smaller. Demand impact is fairer under an FFL than under a flat levy, as it is concentrated in the top income brackets and the frequent flyers, minimizing the impact on the rest of the world who take occasional trips or have yet to gain access to air travel services.

Linking FFL to flight emissions and exploring ways to simplify the logistics remain as future work. Barriers to implementation include establishing an accurate and privacy-protected flying frequency database, distinguishing business trips from personal trips, and ensuring effective use of the revenue collected.

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INTRODUCTION

Commercial air travel has grown rapidly in recent decades as an increasing share of the global population flies, and as the frequency of travel for many people increases. The fast-growing aviation industry is on its way to becoming one of the biggest contributors to climate change. At its pre-COVID traffic growth rate of about 5% per annum, and assuming fuel efficiency improvement of about 1.5% per year, aviation could use up 12.5% of the remaining carbon budget available to economies worldwide, a budget calculated to prevent the increase in global average temperature from exceeding 1.5 °C (ICAO, 2016; IPCC, 2021).

While the industry and its impact on climate are growing, flying activity is spread very unevenly across the global population. Boeing CEO Dennis Muilenburg commented in 2017 that “less than 20 percent of the world’s population has ever taken a single flight” (CNBC, 2017). Gossling and Trumpe (2020) also estimated that only 10% of the world flew in 2018, and that the top 1% of travelers, in terms of frequency of travel, are responsible for half of the emissions from flying.

The inequality of flying is evident within countries as well. In the US, 12% of people took 66% of all flights, while in the UK 20% of the households took about 75% of the flights (Airlines for America, 2018; Buchs & Mattioli, 2021). In China, 5% of households took 40% of flights and in India just 1% of households took 45% of all the flights (Choong & Wong, 2017). A per-flight tax that escalates with flying frequency would be sensitive to these inequalities by targeting heavy polluters rather than uniformly raising the cost of flying.

In this paper, we present the analysis of a global frequent flying levy[1], focusing on its potential to generate revenue to develop low-carbon aircraft and fuels. Our modeling estimates the frequency of air travel by income bracket within each country using 2019 air traffic and income data. Based on the distribution of flying activities, we constructed an example frequent flying levy that could generate enough revenue to support a net-zero aviation industry. We compared the distributional impacts of FFL to those of a flat per-flight tax (e.g., UK’s APD) that generates the same amount of revenue. We also evaluated the demand response to both types of levies.

The results help us to understand whether a frequent flying levy leads to a more equitable distribution of the cost burden. This includes equity among different income brackets, different countries, and people with different frequencies of flying. The main goal of this study is to illuminate the benefits of segmenting flyers based on frequency when designing aviation taxation; we plan to release future papers with refined analysis to inform more concrete policy recommendations.

1 “Frequent flying levy” is used as an alternative to “frequent flyer levy” in this paper to emphasize that the levy targets frequent flying behavior rather than a certain group of people. For instance, a person identifying themselves as “frequent flyer” may not fly frequently every single year and thus is not always subject to a “frequent flying levy”.

BACKGROUND

Given the impact of flying on the climate, governments and industry will need to invest in fuel efficiency technologies and alternative fuels to keep aviation emissions in check. The challenge is how to pay for these advances in ways that do not make access to flying more unequal than it already is.

Aviation decarbonization technologies, such as more fuel-efficient airframes and sustainable aviation fuels (SAF), will cost significantly more than fossil jet fuel. Various groups have estimated the total investments needed for deep decarbonization of the aviation industry through mid-century. In ICCT's Projection of Aviation Carbon Emissions (PACE) model, the total SAF cost premium over conventional jet fuel in a 1.75 °C compatible pathway mounts to $144 billion annually between 2020 and 2050 (Graver et al., 2022). International Civil Aviation Organization (ICAO,2022a) also provides an estimate for total technology costs for achieving a long-term aspirational goal (LTAG) consistent with the Paris Agreement (1.75 °C); the cost of all decarbonization levers (i.e., improved efficiency, fuel switch, and carbon removal) adds up to $4 trillion from 2018 to 2050, which translates to an annual "price tag" of $121 billion. To secure such large amounts of investments will require collaboration of a consortium of public and private actors, including governments, airlines, aircraft manufacturers, fuel suppliers, and airports.

Besides direct investments from industry stakeholders, government policies will be needed to raise the price of fossil jet fuel in order to make clean fuels competitive. A variety of policies could help close the price gap between alternative and fossil jet fuels, including fuel taxes, emission trading systems (ETS), Low Carbon Fuel Standards (LCFS), and ICAO's Carbon Offset and Reduction Scheme for International Aviation (CORSIA). Given the currently large price gap, an economywide carbon price (e.g., imposed through an ETS) is unlikely to be high enough to spur SAF deployment. Out-of-sector offset schemes like CORSIA also do not provide enough incentives for deploying high-cost decarbonization technologies in-sector. What is needed is taxation of aviation fuel or flights, with revenue recycling for clean fuels. This approach is consistent with the "polluter pays" principle, which states that actors causing pollution should pay to mitigate it (EEA, 2020).

A uniform tax on all flying activities, however, can have adverse economic and equity impacts. First, low-income households, while less likely to fly, are more sensitive to price changes and therefore are more likely to be priced out of flying. Those who currently cannot afford to fly will also find it harder to gain access. Second, higher prices can reduce air travel demand and deny the economic benefits of air travel to lower-income countries that need them the most; moreover, these countries have typically contributed the least to historical aviation emissions (EIA, n.d.). Third, a uniform tax might harm people who have infrequent but also inelastic demand for air travel, such as island residents and immigrants. On the other hand, a uniform tax might have little to no impact on the behavior of wealthy individuals, who are also more likely to fly frequently.

It is these potential limitations of a uniform tax that spurred the idea of a frequent flyer levy (FFL), where the per-flight tax increases as an individual takes more flights in a given year. FFL is designed with the highly unequal distribution of flying activities in mind, and it can be a fairer way to manage emissions than a uniform tax. Polls in the UK have shown strong public support for an FFL, with one citing 60% support and the other citing 89% (Coffey, 2021; McDonnell, 2021).

The UK's Climate Change Committee (CCC) acknowledged the potential of a frequent flyer levy as one of the fiscal tools to address the country's aviation emissions (CCC, 2019), and the UK Parliament's citizens' assembly on climate change also recommended an FFL (Climate Assembly UK, 2020). Prior to that, Possible had launched the "A Free Ride" campaign to advocate for introducing an FFL to flights leaving UK airports (A Free Ride, n.d.). The campaign advocates that everyone get one tax-free return flight each year and that revenues be invested into greener alternatives to flying.

Recently, the New Economics Foundation (2021) modeled a UK nationwide FFL that would cap aviation growth at 25% above its 2018 level (which is needed for UK aviation to achieve net zero by 2050) and compared its distributional impact to that of an equivalent Air Passenger Duty (APD). The APD is a fee charged for each passenger leaving UK airports based on the passenger's seat class and the length of the flight (UK, 2022). Economy-class APD for a flight of less than 2000 miles is currently £13, rising to £185 for a premium class passenger flying more than 2000 miles. The modelled FFL started at £0 for the first leisure flight and reached as high as £700 for the tenth business flight. An APD driving the same level of demand reduction would be £41 per flight. The study shows that, under an FFL, the top 20% of population by income will reduce air travel most significantly (about 30%), while the bottom 20% hardly need to curb any of their travel. Under an APD, however, the bottom 20% would reduce flights more than any other income bracket. In other words, this analysis confirms the progressive nature of an FFL; it places more cost burden and associated demand reduction on population groups that fly more often.

The levy can also differ based on the distance of the flight or carbon dioxide (CO_2) emitted from the flight. The concept of "Air Miles Levy" was proposed as a variation of FFL that better captures different levels of emissions among routes (Carmichael, 2019). The author also suggested factoring in the larger per-person emissions generated from flying business or first class. Since frequent flyers are more likely to purchase premium tickets, a frequency-based levy may reduce more emissions by lowering demand specifically for the most carbon-intensive tickets (Gossling and Nilsson, 2010). Buchs & Mattioli (in press) concludes that an Air Miles Levy is the most progressive tax design when compared with a flat per-flight tax and an FFL.

While the UK collects social survey data on its residents' air travel behavior, data for other countries remain scarce. The "Elite Status" report released by Possible (Hopkinson & Cairns, 2021) summarizes publicly available data on flying inequalities for various countries. Data sources mainly include consumer surveys and government statistics of varying coverage and quality. Specifically, the report found a few consumer surveys conducted in high-income countries (Australia, Canada, Netherlands, United States, and United Kingdom), in which participants were asked how many times they fly in a year. About half (42–52%) of the population in these wealthier countries reported that they did not fly in the previous 12 months. Meanwhile, the share of frequent flyers (people who take more than 6 flights a year) varied greatly across the surveys, from as low as 3% to as high as 19%.

Even among these surveys, different framings of the question resulted in poor comparability of results. Examples of areas of difference include individual flight versus roundtrips, international travel versus all travel, adults versus all age groups, in the past one year versus two years, and grouping of frequencies (e.g., having 3-5 times as an option rather than 3 times, 4 times, and 5 times), etc. Moreover, the actual flying frequency of travelers in the highest frequency bin (e.g., 6+ flights, 10+flights) is typically unknown. Therefore, the survey results were not standardized enough to extrapolate to the global level, nor even to low- or middle-income countries.

Another key metric of air travel equality is concentration of trips (i.e., 20% of population took 80% of flights). In a report produced by Mastercard (2017), researchers apportioned country-total outbound (international) trips to different income brackets in 17 Asia-Pacific countries, based on data on propensity to travel by income bracket from their consumer surveys. According to the report, the high-income bracket, averaging 14% of total households, took 39% of all trips, while the low-income bracket, averaging 52% of households, took only 21% of trips. The data also suggests that, for example in Indonesia, high income households take 9.6 flights on average, while low-income households take 0.03 flights on average in a year. These data points, however, do not distinguish between flyers and non-flyers within each income band, and therefore the "true" average number of flights taken by those who fly is unknown. We have also not found elsewhere concrete, representative data on the share of non-flyers by income brackets. Nevertheless, the concentration of flights serves as a rather comparable metric across different datasets, which is used to validate modelled distribution of flying activity in this study.

Data on individual flying frequency can be collected by private institutions (e.g., airlines, ticket booking agencies, etc.). A global survey can also gather more comprehensive and standardized data. Due to the resource intensity of these two methods, this study relies on a modeling approach to estimate flight frequency by income band and country, validated by publicly accessible data where available.

According to a meta-analysis of past research, common predictor variables of air travel demand include GDP, population, income, fuel price, and other socio-economic factors (Wang & Gao, 2021). GDP and income are typically the most important predictors. It is therefore reasonable to predict individuals' propensity to travel by air based on their income. Valdes (2015) also found that income elasticity was the most important determinant of air passenger growth in middle income countries in the 2000s, and the elasticity was slightly higher than one. A price elasticity higher than one indicates that air travel is a luxury good, which people consume more of as their income increases. Our study, therefore, developed a methodology to estimate the number of flights an individual takes in a year based on their income.

METHODS

For this study, we developed a method to estimate individuals' annual flying frequency using income and global air traffic data (Figure 1). We then constructed two hypothetical tax schedules, one in the design of FFL and the other a flat tax mimicking UK APD, to analyze the distribution of the cost burden. In addition, we estimated the demand response to these levies based on air travel's price elasticity.

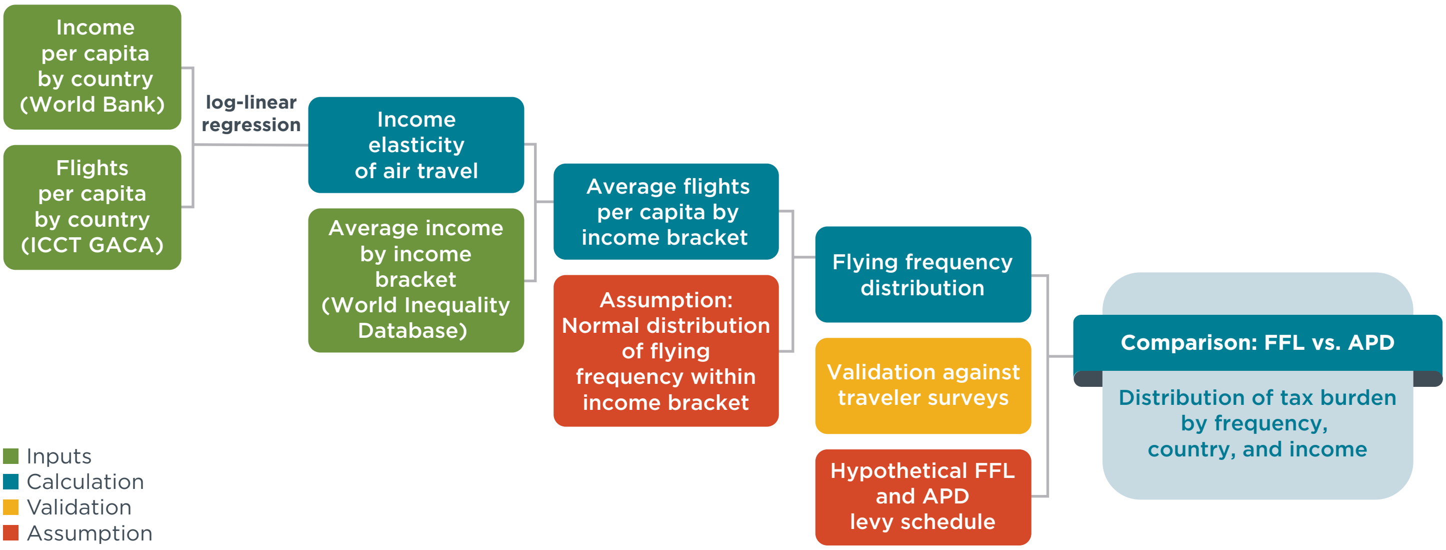

Figure 1. Methodology flowchart

PASSENGER ATTRIBUTION AND INCOME ELASTICITY OF AIR TRAVEL

As mentioned above, income is a major predictor of air travel. While data on individuals' flying frequency and income are not publicly available, we performed a logarithmic linear regression on income per capita and flights per capita for 177 countries in order to quantify the correlation (Figure 2). We used log-log regression because the increase in air travel is not linear with increase of each dollar in income; one dollar is valued differently by people of different income levels. World Bank (n.d.) provides income per capita data. Flights per capita were calculated from flight departure data in ICCT's Global Aviation Carbon Assessment (GACA) Model (Graver et al., 2020) and country population data from the World Bank (n.d.).

For the purpose of this study, we adjusted GACA departure data to better attribute passengers to their country of residence rather than departure airports. Assigning flights to countries based on departure airport assumes that half of the passengers on a flight are from the origin country, and the other half is from the destination country. However, economic development status and the size of the tourism industry often distort this 50:50 proportion.

Therefore, two adjustment factors were applied to GACA country departure data: country GDP (logged) and outbound vs. inbound tourism ratio. The two factors are multiplied together to form a weight for each country. For a flight between country A and B, the total number of passengers is apportioned to each country based on their weights:

$$\text{Passenger}_A = \text{Total Route Passenger}_{A,B} \times \text{Weight}_A \,/\, (\text{Weight}_A + \text{Weight}_B)$$

$$\text{Passenger}_B = \text{Total Route Passenger}_{A,B} \times \text{Weight}_B \,/\, (\text{Weight}_A + \text{Weight}_B)$$

The idea is that wealthier countries and tourism-generating countries will have heavier weights and thus more passengers attributed to them. Both the GDP and tourism ratio data are from the World Bank (n.d.). Together, the two adjustment factors attribute fewer flights to residents of lower income countries and/or to countries that have a lot of visiting tourists (Table A1). Transit passengers, who are often from a third country, are not addressed in this approach. Countries with large transfer hubs may be assigned extra passengers.

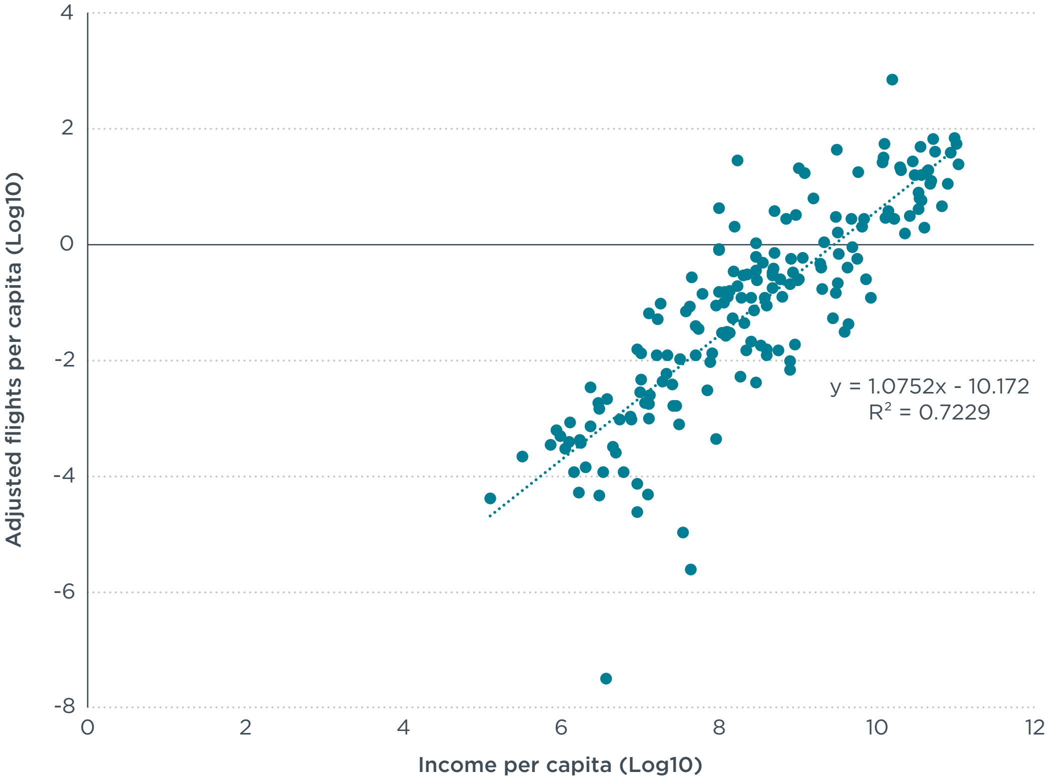

Figure 2. Linear regression of income per capita (logged) and flights per capita (logged)

The statistical test shows a significant linear relationship between income per capita and flights per capita ($p<0.05$):

$$\text{Ln(flights per Capita)} = 1.0752 \times \text{Ln(income per Capita)} - 10.172 \ (n=178, R^2=0.7229)$$

The slope 1.0752 can also be interpreted as the income elasticity of commercial air travel. It is within the range of typical income elasticities found in the literature (InterVISTAS, 2007; Valdes, 2015).

It is important to distinguish “flight” in the sense of a scheduled flight (e.g., a flight from London to New Delhi that carries 250 passengers) versus a plane trip taken by an individual. Distinction should also be made between a one-way “flight” and a “roundtrip”, or simply a “trip”. For the rest of the paper, “flight” strictly refers to a one-way plane trip taken by a single traveler (or in aviation jargon, an “enplanement”), rather than the alternative meanings mentioned above.

INCOME DISTRIBUTION AND DERIVED AVERAGE FLYING FREQUENCY

We sourced income distribution data from World Inequality Database (n.d.). The database provides data on the share of total national income, by each percentile of the adult population for 175 countries, which covers 99.5% of the enplanements in

2019.[2] Based on each decile's share of national income and the total national income data from World Bank, we calculated the average income of each decile, plus the 99th percentile. We then derived the average number of flights taken each year by people in each income bracket using the formula below:

$$\text{Flying frequency}_i = [1 + (\text{average income}_i - \text{income per capita}) / \text{income per capita} \times \text{income elasticity}] \times \text{flights per capita}$$

The income elasticity of 1.0752 obtained from the regression was applied to the difference between the average income of a bracket (i) and the national average income, which translates an increase of income into an increase of flights. While individuals' income elasticities may vary, we assumed 1.0752 to be the average elasticity. We also assumed that populations with income below a certain threshold ($875) do not fly at all; this is based on validating the total number of flights estimated from income against the actual total enplanements in 2019.[3] Estimated enplanements are within 0.1% of the actual after accounting for non-flyers. We also chose to estimate frequency based on income elasticity and national average income and flights, rather than directly using the linear regression equation, in order to best approximate real-world enplanements. It is one of the few ground truthing data points we have.

The concentration of flights by income bracket was validated where possible against the Mastercard data discussed in the Background section. The estimated distributions largely line up with the surveyed data, with the exceptions of Singapore and Thailand (Table B1). Possible reasons for the exceptions are discussed in Appendix B.

Finally, in order to summarize the distribution of flying by income globally, we sorted all income brackets into a global percentile rank; each country's income brackets consist of ten deciles, so there are a total of 1750 deciles for the 175 countries in this analysis (Table ES-1). We compared our calculated global income percentiles to Political Calculations' (2016) estimate of global individual income rank. The income thresholds for the 50th through 80th percentiles closely align, with less than a 10% difference. Our data estimated lower income thresholds for below-median percentiles (e.g., we estimated $190 annual income for the 10th percentile while Political Calculations estimated $550 for the 10th percentile) and a higher threshold or the 90th percentile ($23,000 vs. $11,550). Using this distribution may assign fewer flights to the lowest and highest 10% income brackets, but the estimated level of inequality would only be lower, not greater, in this case.

DISTRIBUTION OF FLYING ACTIVITY BY FREQUENCY

In order to model the impact of an FFL, the average annual number of flights for each income bracket needs to be translated into a distribution by flying frequency (i.e., percentage of population who fly once, twice, … twenty times a year). We assumed normal distribution of flying frequency within each bracket around the average value. The standard deviations of the distributions were adjusted for each income decile so that total modelled enplanements approximate the actual 2019 level of enplanements. All probabilities for values less than zero are combined into the probability for zero (i.e., not flying at all in a year). The total activity modelled is within 1% of actual 2019 data, while variations between modelled total and adjusted GACA departure data exist for individual countries. Reconciling the country-level variation is challenging without data informing how distribution of flying frequency around the mean varies by country.

2 The data assumes an equal split of income among adults in the same household.

3 A total of 4.78 billion passengers were accounted for in ICCT's 2019 GACA dataset, while the International Air Transport Association (2020) estimates 4.5 billion passengers in 2019.

The shares of flyers for each country are slightly higher than those estimated by Gossling and Trumpe (2020) (Figure B2). This is possibly because the income share data is of equal-split adults instead of the entire population of countries. We validated the concentration of flying activity by frequency against real-world survey data for countries where available (Appendix C).

LEVY SCHEDULE AND DEMAND RESPONSE

The taxation schedules in this study were constructed to generate the same amount of total revenue. APD is flat across all flights, and FFL increases linearly starting from the second and continuing through the twentieth flight. We chose the $121 billion annual figure, undiscounted, from ICAO's LTAG feasibility study because it encompasses all decarbonization levers and costs to all stakeholders. In this study, we model an extreme scenario where all funding needs will be covered by revenues generated from a per-flight taxation scheme. The levy amount, therefore, is illustrative rather than prescriptive. The study aims to assess the distributional impacts of two different tax designs, which are only comparable if the total revenue is the same.

In order to investigate distribution of levy revenue by country, the World Bank (n.d.) lending group classification is used to categorize countries. All world countries are assigned as high income country, upper-middle income country, lower-middle income country, or low income country based on their income per capita.

Lastly, to estimate the demand response to increased taxation, we applied the global average price elasticity of air travel (-0.6) from the InterVISTAS consultant report (2007) commissioned by IATA. This price elasticity means that for a 100% increase in ticket price worldwide, demand for tickets will decrease by 60%. When analyzing demand response by N^{th} flight, we used the average price elasticity (-0.6) for the first flight and decreased it by 1% for subsequent flights; the price elasticity used for the twentieth flight was -0.5. This is because people who fly frequently are generally wealthier and have less elastic demand. When calculating demand response by income bracket, we used the average price elasticity (-0.6) for the 80^{th} – 89^{th} percentile and adjusted the elasticity up and down by 5% for each income bracket. Lower income groups' demand for flying is more elastic, and they were assigned a price elasticity value lower than -0.6; conversely, the 90^{th} percentile's demand for flying is less elastic, and they are assigned a price elasticity value greater than -0.6.

While price elasticity of air travel also varies by geographic markets, trip purpose, and flight distance, it is not possible to segment the flight estimates by these characteristics with the data we have. For the same reason, we use a global average ticket price of $200 as baseline.[4] We used this average ticket price and the average levy per flight to calculate the percentage of ticket price increase. The percentage of ticket price increase multiplied by price elasticity results in the percentage of demand reduction.

4 The average is calculated from 2019 global economy-class fare data purchased from RDC Aviation Ltd, weighted by RPK of each airline-route combination.

RESULTS AND DISCUSSION

In this section, we present our estimated global distribution of flying activity and the level of per-flight taxation needed to raise revenue for deep decarbonization. The results also compare the revenue distribution of a flat APD and an FFL by frequency, country, and income. For the purpose of this study, “frequent flyer” is defined as those who fly more than six times (i.e., three roundtrips) a year, and countries are classified based on World Bank lending groups.

DISTRIBUTION OF FLIGHTS

Flying is highly skewed to more economically developed countries (Figure 3). High income countries host about 16% of the global population but are responsible for half (51%) of all flights taken. Upper middle-income countries are rather proportional, at 35% of both population and flights globally. Meanwhile, the 40% of global population in lower middle-income countries only took 13% of the flights. Low-income countries, constituting 9% of the global population, take almost no flights (0.4% of global enplanements). High income countries’ large share of flying activity today reflects their historical growth, whereas air transport services and infrastructure in the rest of the world are still catching up.

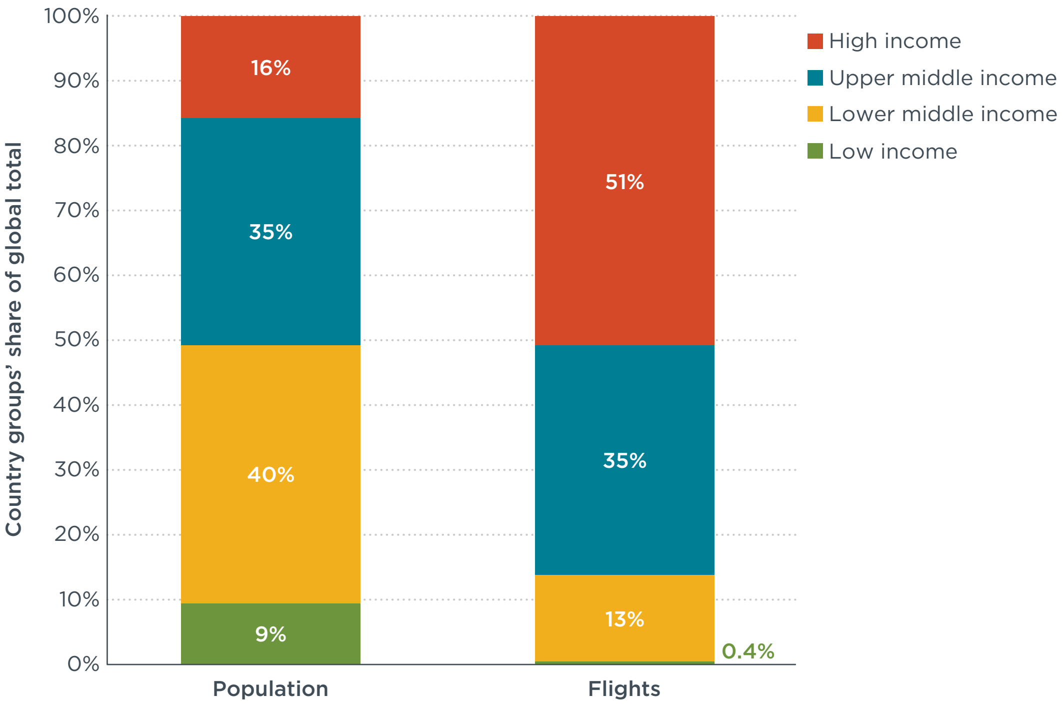

Figure 3. Distribution of flying activity by country income groups, 2019

The difference in aviation industry growth can also be seen through the distribution of flying activity within each country group (Figure 4). For high-income countries, about half of the people fly, and frequent flyers (about 10% of population) are responsible for about half (51%) of flights. In upper middle-income countries, only about 25% of the population fly, and the top 6% of flyers by frequency took 50% of the flights. Moreover, only about 12.5% of the people in lower middle-income countries fly in a given year, with the top 4% most frequent flyers taking about half (48%) of the flights. On average, only 2% of residents in low-income countries fly (Table B1).

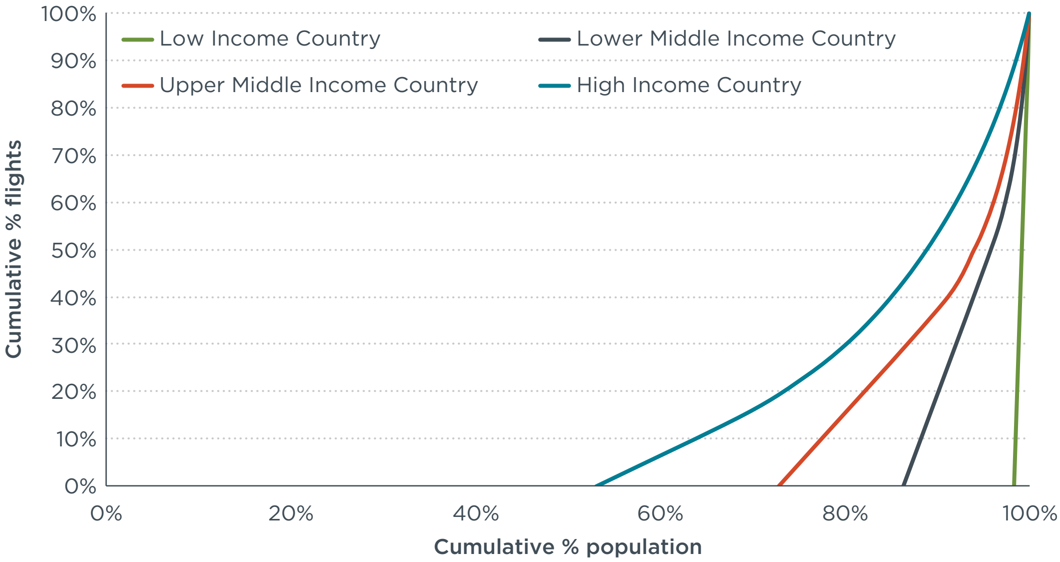

Figure 4. Concentration of flights by flying frequency for each country income group

LEVY SCHEDULE AND OVERALL DISTRIBUTION

Based on the modelled distribution of flying frequency, the levy amounts needed to generate $121 billion revenue in a year under APD vs FFL design are presented in Figure 5. The APD will be a flat $25 for any flight a person takes. The FFL, on the other hand, is modelled as zero for a person's first flight in a year and $9 for their second flight, escalating linearly to $177 for the twentieth flight. The rolling average of FFL per flight also increases linearly, and it exceeds the flat APD after a person's sixth flight in a year. The average FFL per flight would only be $14 for people who take two roundtrips a year but as high as $89 for those who fly 20 times a year.

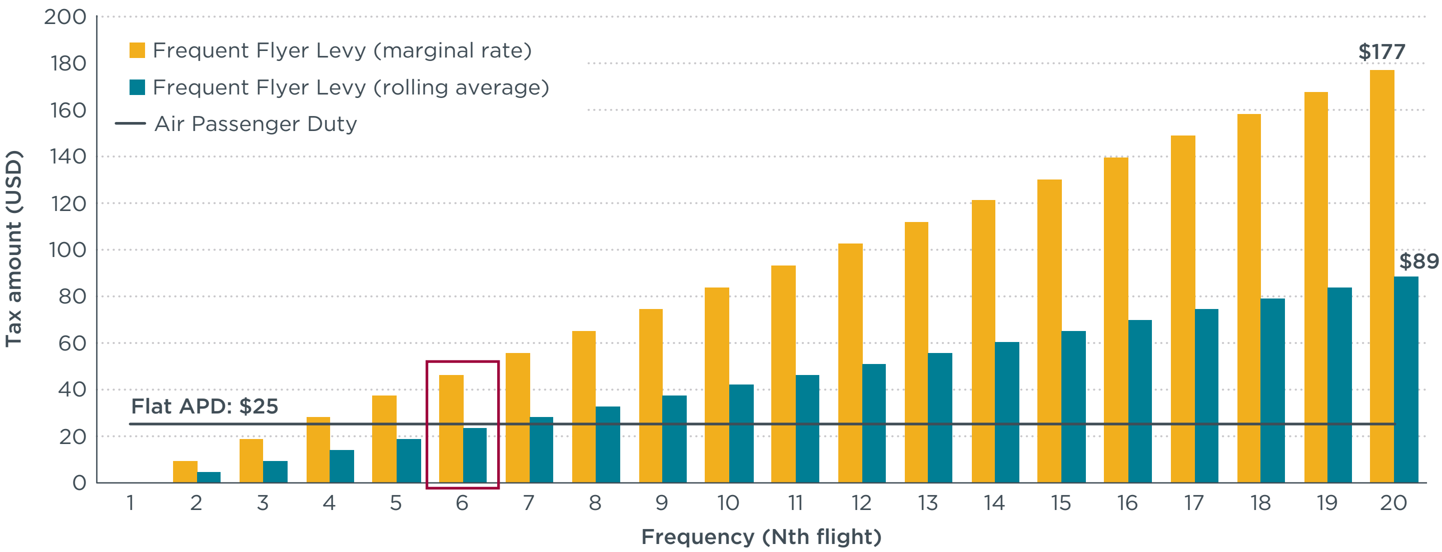

Figure 5. Modelled flat APD schedule and escalating FFL schedule to generate $121 billion revenue in a year

The majority (>67%) of a global FFL would be paid by a small portion (16%) of the global population (Table 1). Specifically, while frequent flyers[5] make up about 2% of world population, they would pay 81% of the total FFL revenue, compared to 41%

5 There is no widely recognized definition of "frequent flyer." While we use "six flights a year" as the threshold, many other groups consider everyone who fly more than once a year as "frequent flyers," hence the naming of "frequent flyer levy" and the free first flight.

under an APD. Similar concentration of revenue generation is seen by income quintile and country development status. About half (51%) of the levy revenue will come from residents of high-income countries with an APD in place, compared to 67% under an FFL. The concentration is even greater by income—with the 20% wealthiest individuals paying 98% of an FFL and 81% of an APD—because flights in middle income countries are even more skewed to residents with higher incomes than in high-income countries. The detailed distributions of revenue source are presented in the tables and graphs below.

Table 1. Summary of distribution of population, flights, and levy revenue source

Population groupings	Percentage of global population	Share of global flights	Contribution to levy revenue	
			APD	FFL
Frequent flyer (>6 flights)	2%	41%	41%	81%
High income countries	16%	51%	51%	67%
Top global income quintile	20%	81%	81%	98%

The levy schedule used in this analysis is illustrative of the concept of FFL, rather than a specific recommendation for policymaking. A sensitivity analysis was conducted for an FFL schedule under which the first flight of the year is also taxed (Table C1). The distributional impacts of the alternative schedule follow the same patterns as described above (Table C2).

DISTRIBUTION OF LEVY BY FREQUENCY

If a global APD were implemented, almost a quarter (23%) of the revenue would be collected from people who fly only once a year, while zero revenue would come from people who fly once under an FFL (designed with one free flight). Figure 6 shows that FFL shifts the levy cost burden from infrequent flyers to frequent flyers; the two levy schemes collect similar amounts of revenue from people who fly six or seven times a year. People who fly less than that threshold would pay less under an FFL. Since the APD amount for all flights is the same, the distribution of APD revenue is the same as the distribution of actual enplanements, which declines as flying frequency goes up. FFL, on the other hand, collects about the same amount of revenue from each frequent flyer group, even though the number of people who fly 20 times or more is much lower than those who fly eight times.

Figure 6. Percentage of total levy revenue ($121 billion) by number of flights taken in a year, APD versus FFL

DISTRIBUTION OF LEVY BY COUNTRY

In terms of the total levy revenue generated by countries, an FFL would shift about 17% ($20 billion) in cost to high-income countries relative to a flat APD design (Table 2). The increase of cost for high-income countries, from 51% under an APD revenue to 67% under an FFL, reflects the fact that residents in high-income countries on average fly more than residents of other countries. The share of FFL revenues also better aligns with each country group's contribution to historical aviation CO_2 emissions. Since high income countries emitted about 70% of aviation CO_2 since 1980, it makes sense for them to finance a similar share of decarbonization costs. Of all other country groupings, low-income countries will benefit from an FFL the most, paying 72% less compared to APD. Both upper-middle and lower-middle countries will pay about 30% less.

Table 2. Amount of total levy revenue generated, by country income bracket

Country classification	Historical aviation emissions (1980-2019)*		FFL		APD		Difference (FFL-APD)	
	CO_2 emissions (Gt)	Percentage	Total levy (billion $)	Percentage	Total levy (billion $)	Percentage	Total levy (billion $)	Percentage
High income	18.0	70%	81	67%	61	51%	20	32%
Upper middle income	5.84	23%	30	25%	43	35%	-13	-30%
Lower middle income	1.49	6%	10	8%	16	13%	-6	-38%
Low income	0.18	1%	0.1	0%	0.5	0%	-0.4	-72%
Sum	25.4	100%	121	100%	121	100%	0	0%

* Source: EIA, n.d.

Figure 7 shows that countries most impacted by FFL relative to APD include Norway (+100%), Iceland (+87%), Luxembourg (+87%), New Zealand (+74%), and Cyprus (+71%). Many low- or lower-middle income countries, in the meantime, would pay very little under a global FFL. These countries include Bangladesh, Cote d'Ivoire, North Korea, Yemen, Benin, Burundi, Democratic Republic of the Congo, Tajikistan, Mali, Chad, South Sudan, Somalia, Uganda, Lesotho, Niger, Togo, and Liberia. A large majority of Africa, Asia, and South America pay less under a global FFL compared to an APD. Meanwhile, countries in North America, the EU, and Oceania pay more under an FFL due to their larger share of frequent flyers. Details of per capita APD and FFL for each country can be found in Appendix D.

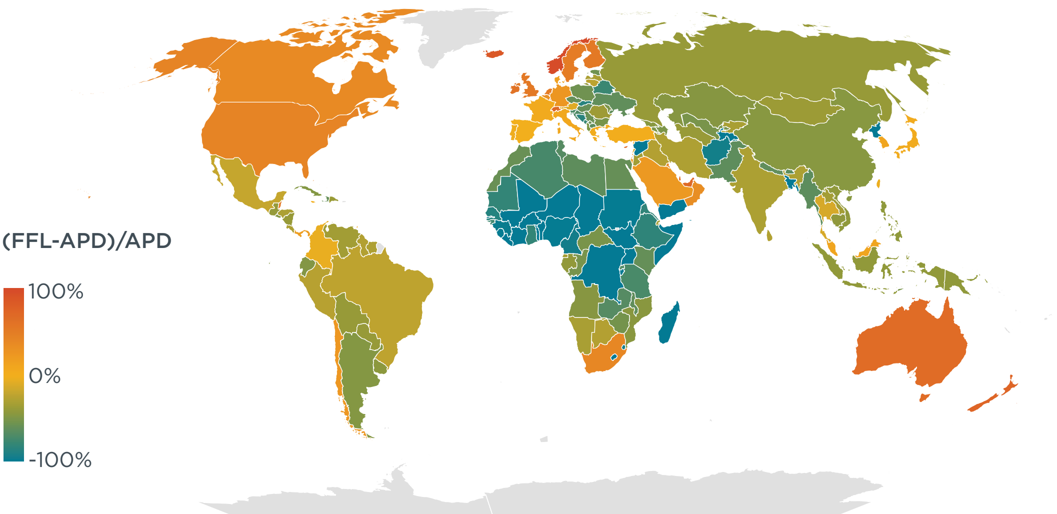

Figure 7. Percentage difference in total APD collected and total FFL collected for each country

DISTRIBUTION OF LEVY BY INCOME

The cost of a flat APD or graduated FFL would be paid mostly by higher income brackets (Table 3). Under an APD design, the top 10% of income would contribute 63% of the total revenue, while the bottom 50% contributes about 0.5% combined. When an FFL is implemented, as much as 90% of the total revenue would come from the top 10% bracket, and the bottom 70% combined pay only about 0.1% of the total levy. This distribution pattern holds true at the individual country level, but the concentration is less extreme.

Table 3. Distribution of levy revenue by global income brackets, APD vs. FFL

Income percentile	Per capita income (USD)	Average annual flights	Share of APD revenue*	Share of FFL revenue*
1st –9th	0-189	0	0.0%	0.0%
10th–19th	190-559	0	0.0%	0.0%
20th–29th	560-849	0	0.0%	0.0%
30th–39th	850-1,229	0	0.1%	0.0%
40th–49th	1,230-1,969	0.03	0.4%	0.0%
50th–59th	1,970-3,149	0.07	1.2%	0.0%
60th–69th	3,150-5,099	0.33	5%	0.1%
70th–79th	5,100-9,199	0.77	12%	2%
80th–89th	9,200-22,999	1.3	19%	9%
90th–94th	23,000-37,099	2.8	63%	90%
95th–99th	>37,100	4.5		

*Sum of the cell values in the column may exceed 1 due to rounding.

The estimated average flying frequency in 2019 ranges from no flight for the lowest 40% income bracket to on average 4.5 flights for the highest 5% income bracket (Table 3). For the 40th to 59th percentiles, average flying frequencies are all lower than 0.1, which indicates that almost no one flies. The 60th to 79th percentile averaged less than one flight per capita, suggesting that a small subset of the population flew.

It is safe to assume that when most people travel by air, they will take a round trip rather than a single one-way flight, so two flights constitute one trip by one person. For the top 10% global income percentile, the average flying frequency exceeds 2, meaning theoretically everyone could have taken one roundtrip in 2019. The average values, however, mask the fact that there can be lower-income people who fly often and higher-income people who do not fly. This summary sheds light only on the general differences in flying frequency among different income groups.

DEMAND RESPONSE

Besides distribution of revenue sources, the two tax schemes will also induce different distributions of demand responses (Figure 8). The flat APD would have reduced enplanements by about 7% in 2019, whether it is a person's first or 20th flight. Meanwhile, the demand response to FFL is differentiated. The demand for a person's first flight in the year would not be affected; demand for the second, third, and fourth flight would fall by less than 10%. The magnitude of demand reduction then increases to about 23% for the tenth flight, about 34% for the 15th, and as high as 44% for the twentieth. The overall demand reduction is also around 7%, as the levy total is the same as the APD, and a constant price elasticity is assumed. Due to the limitation of data granularity, the results shown below are more representative of short- and medium-haul economy-class tickets.

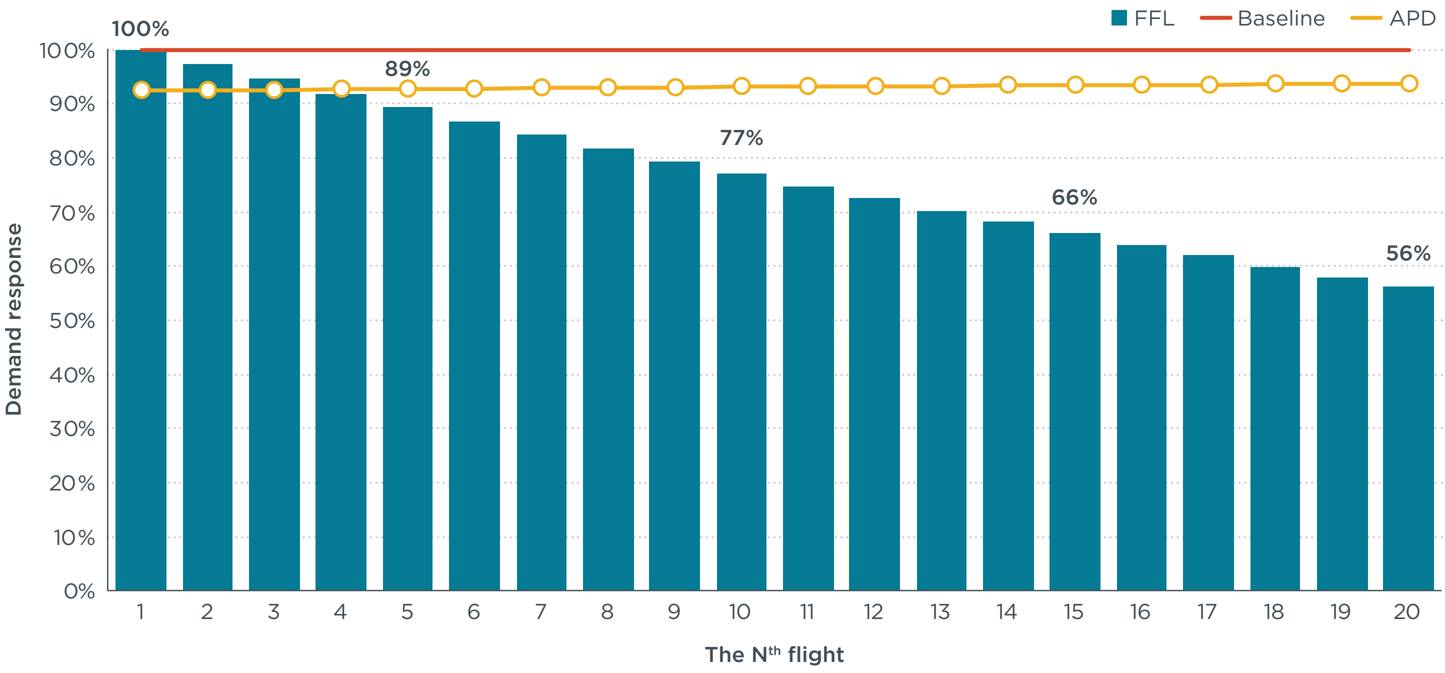

Figure 8. Demand response to APD and FFL by flying frequency

Table 4 below shows the effect of FFL on air travel demand for each income bracket. We model virtually no change in demand from the bottom 70% of the population at their current travel frequency. For the top 5% income bracket, even though their demand is less elastic to price, the increased charge of FFL can theoretically reduce demand by 12%. APD, on the other hand, will trigger a higher level of demand reduction from the lowest income brackets, as the average tax is the same, but the price elasticity is higher.

Table 4. Demand response to FFL by income brackets

Income percentile	Average Levy (USD)		Price elasticity of air travel by income bracket*	Percentage demand change	
	FFL	APD		FFL	APD
1st –9th	0	25	-0.89	0%	-11%
10th–19th	0		-0.84	0%	-11%
20th–29th	0		-0.80	0%	-10%
30th–39th	0		-0.77	0%	-10%
40th–49th	0		-0.73	0%	-9%
50th–59th	0		-0.69	0%	-9%
60th–69th	1		-0.66	0%	-8%
70th–79th	3		-0.63	-1%	-8%
80th–89th	12		-0.60	-4%	-7%
90th–94th	23		-0.57	-7%	-7%
95th–99th	46		-0.51	-12%	-6%
Overall	25		-	-7%	-7%

*Global average price elasticity of -0.6 is used for the 80th-89th percentile and scaled for other income brackets to reflect the decrease in demand elasticity as income increases.

CONCLUSIONS

A small subset of the global population takes a disproportionate share of flights each year. Most evidently, the richest 20% of the world takes about 80% of all flights. And residents of high-income countries, making up about 16% of the world, take half of all flights. The rest of the world, however, fly only occasionally or do not fly at all. Among the flying population, frequent flyers, who are only 2% of the world population, take 40% of the flights.

Despite this uneven distribution of flying activities, all countries now face the urgent need to reduce aviation emissions, which require large investments to bring down the cost of zero-emission planes and clean fuels. While governments can shoulder some of this cost burden with existing resources, additional tax revenues that help internalize the climate cost of flying are likely needed. In this study, we investigated per-flight taxation, especially an FFL, as an equitable way to generate revenues for deploying low-carbon technologies.

We conclude that an FFL would focus costs on high-income countries, individuals, and frequent flyers who can more easily afford the environmental levies. A flat $25 duty on each flight can help generate the $121 billion a year needed for aviation decarbonization through midcentury. An FFL starting at $9 for a person's second flight in a year and escalating to $177 for the twentieth flight can do the same.

Compared to a flat APD, a global FFL distributes its costs more fairly for several reasons. First, as the name suggests, FFL would draw a bigger share of total revenue from frequent flyers and completely exempt people who fly once a year. Second, high-income countries would pay 30% more revenue under an FFL, shifting costs away from low-income and lower middle-income countries. This could support the principle of "common but differentiated responsibilities" advocated by countries with low historical emissions at UN climate meetings. This differentiation will also be front and center when ICAO member states delineate their efforts to achieve the long-term climate goal (ICAO, 2022b). Lastly, from the income bracket point of view, while a flat APD would concentrate a majority (81%) of the cost burden on the world's richest quintile, an FFL further would alleviate the pressure on the less well-off and generate 90% of revenue from the richest 10%.

When designed to generate the same amount of total revenue, APD and FFL will result in very similar levels of demand reduction: around a 7% decrease in enplanements. FFL would provide negligible demand impact for the bottom 70% income brackets, where a large majority of the people do not fly or fly only once a year. The population with the top 5% of income would reduce flying the most. And regardless of income brackets, people's first flight in a year will not be impacted, while frequent flyers may need to think twice before taking their twentieth flight of the year. People constantly flying premium class may not be sensitive to even the highest charge of $177; in order to gather environmental levies from the extremely wealthy, including those who fly in private jets, additional policy instruments will be needed.

We conclude that a frequency-based aviation tax with revenue recycling for technology development could be an equitable way to fund aviation decarbonization. A differentiated, progressive climate tax is greatly needed for a sector with uneven participation from around the world.

We hope to refine the study through two future workstreams. One is to quantify the emission impacts of FFL after further segmenting the flying activities by distance and seating class. Carbon intensities of flights vary greatly based on these two factors. Since frequent flyers are more likely to travel long-haul and in premium class, an emissions-based FFL may further concentrate the decarbonization costs on those who fly and emit the most. The segmentation, however, would require more granular data on global flying behavior.

The other workstream is to investigate the implementation logistics of a potential FFL; there are a few major challenges. National governments or an international body need to maintain a real-time, accurate database of the number of flights individuals have taken in a year. This would likely require airlines to collect travel document numbers at the point of ticket sales; airlines would also charge the appropriate amount of levy based on information retrieved from the database (Fellow Travellers, 2014). However, travelers may use different travel documents for different flights, which complicates the accounting. And with the large amounts of personal data, the database would need to adhere to high privacy protection standards. Tiered levy schedules, rather than escalating by each single flight, might help simplify the process and reduce the sensitivity of personal data collected. Distinction between business and leisure trips would be necessary to avoid charging high levies for the few personal trips on top of many business trips, or vice versa.

Moreover, ensuring that all governance bodies reinvest the collected revenue into low-carbon aviation technologies will be important. The revenues can be managed by individual countries or pooled internationally to accelerate specific decarbonization efforts. If pooled internationally, the decarbonization funds can be prioritized for states that make the least contributions to climate change, but bear the greatest impacts of it (e.g., small island developing states). Differentiated distribution of collected revenue can be an alternative or complementary policy tool to an FFL.

While we continue to investigate the effects and logistics of FFL, it will be helpful to understand the equity implications of other policies that promote low-carbon aviation. The philosophy that FFL embodies—funding climate mitigation in a fair way—should be considered and incorporated into the overall strategy of aviation decarbonization.

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APPENDIX A: TOURISM ADJUSTMENT

To better reflect asymmetric tourism between richer and poorer countries, we adjusted the attribution of air passengers to individual countries by applying GDP (logged) and tourism adjustment factors onto departure airport-based 2019 operations data. Table A1 shows the change in passenger attribution for the top 30 aviation countries (by 2019 RPK).

As an example, more passengers on UK-Portugal routes are attributed to UK than to Portugal. In 2019, UK's GDP was about $2.8 trillion, while Portugal's GDP was about $240 billion. The logged GDP weight of UK is therefore higher than that of Portugal. Meanwhile, UK has a large outgoing tourist flow; its outbound vs. inbound tourism ratio was 2.28 in 2019. Portugal, on the other hand, is a tourism-dependent country and had a tourism ratio of 0.18. UK therefore holds a much higher tourism weight than Portugal. The larger the multiple of the GDP weight and the tourism weight is, the more passengers are assigned to a country, in this case the UK.

Higher-income countries such as the UK, Germany, Switzerland, Netherlands, and South Korea with more outgoing than incoming tourism activities "gain" passengers. Countries with large tourist inflow, such as Portugal, Spain, Turkey, Thailand, and Singapore, have fewer passengers attributed to them under this approach. The adjustment corrects some of the biases of attributing passengers based on departure airports, but the adjusted passenger counts may still differ from the actual counts.

Our estimate of total air passengers with UK residency is within 0.5% of that recorded by the UK government (UK, 2021; UK ONS, 2022). We summed the 2019 total visits abroad by UK residents (assuming each visit consists of two flights) and the 2019 total domestic scheduled passenger throughput. The total was 225 million, while our estimate is 224 million.

Table A1. Passengers attributed to top 30 aviation markets after adjustment

Country	Total passengers (million)	Adjusted total passengers (million)	Difference
United Kingdom	154	224	+46%
Germany	134	180	+35%
Switzerland	27	35	+29%
Netherlands	41	51	+24%
Republic of Korea	77	93	+21%
Russian Federation	102	117	+15%
Saudi Arabia	49	54	+12%
Argentina	23	25	+8%
France	104	111	+7%
Canada	87	93	+7%
Brazil	110	117	+6%
Australia	86	91	+6%
India	181	190	+5%
Philippines	48	49	+2%
China	708	720	+2%
Mexico	79	79	0%
United States	958	957	0%
Indonesia	122	122	0%
South Africa	25	24	-4%
Malaysia	57	54	-5%
Japan	164	154	-6%
Italy	101	95	-6%
Viet Nam	60	56	-8%
Qatar	20	18	-10%
United Arab Emirates	60	54	-11%
Singapore	35	29	-18%
Thailand	84	61	-27%
Turkey	97	66	-32%
Spain	139	75	-46%
Portugal	30	14	-53%

APPENDIX B: MODEL VALIDATION

BY INCOME

The estimated distribution of flying activity by income bracket was validated against data from the Mastercard report (Choong & Wong, 2017). We chose the Mastercard survey as validation data because it covers the greatest number of countries and provides more standardized results than the other consumer surveys. The Mastercard survey, however, collected data only about international outbound travel, so it should be considered as a proxy only for the overall propensity to fly, as the tendency of domestic versus international travel may vary among countries.

In Figure B1, each dot represents the cumulative share of population and cumulative share of flights taken in a year, from lowest to highest income brackets (left to right). The orange line represents the surveyed distribution; each country has three income bands, and the income thresholds vary between developed and emerging markets. The blue line shows our modeled results, with one data point for each decile plus the top 1%.

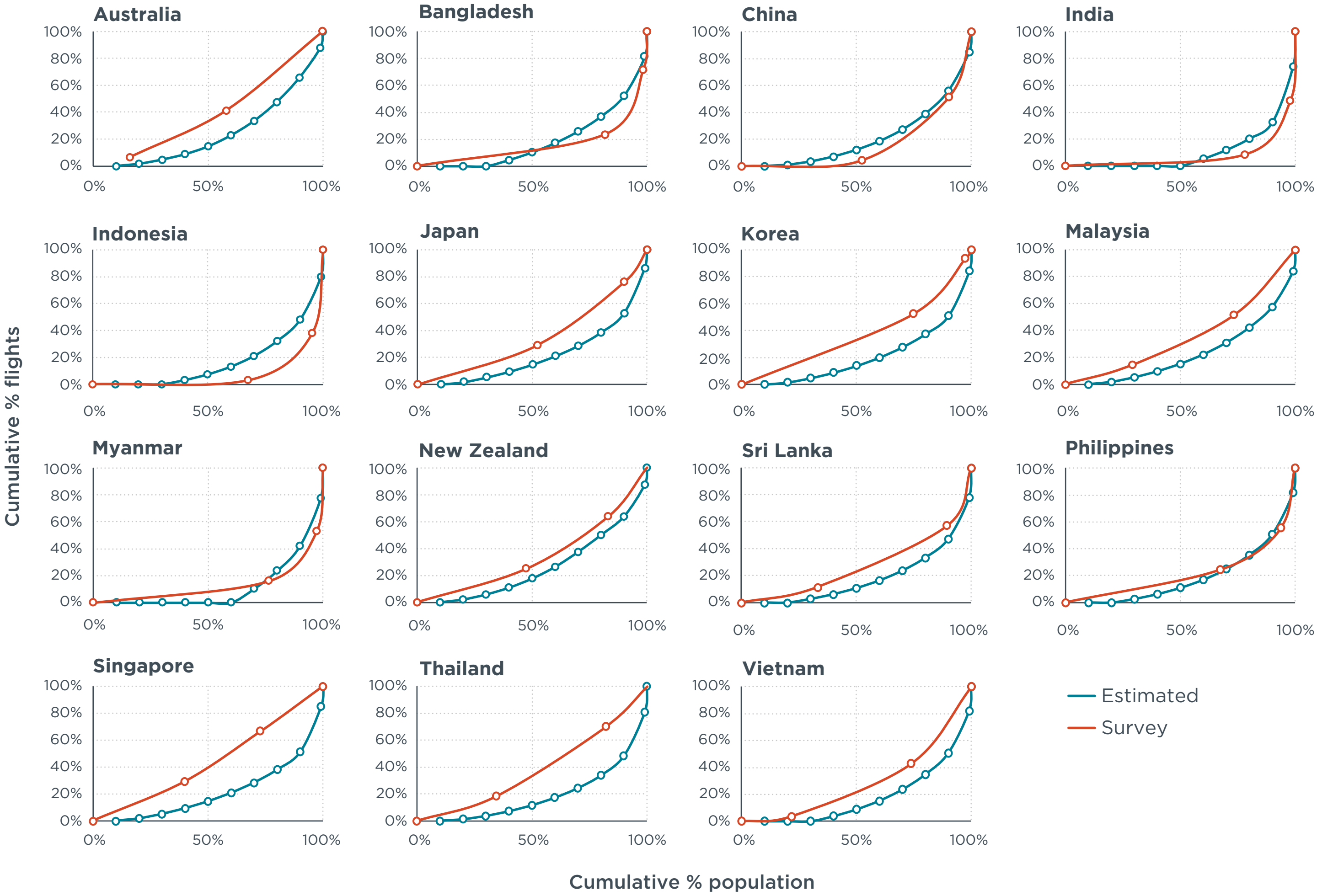

Figure B1. Cumulative share of population and flights by income brackets within select Asia-Pacific countries, estimated versus surveyed.

The estimated distribution aligns well with the surveyed data, except for Singapore and Thailand. One possible explanation is that the propensity to fly is not as strongly linked to a person's income in these two states as in other states. For Singapore, people of different income levels may have similar travel needs because of their small geographical size and easy access to the airport. Geographical factors like this, which may influence flying frequency, are not captured in our methodology. Thailand also has a more uniform distribution of flying activity, but it seems to be driven by the low frequency of flying in the high-income bracket, which averages 1.8 flights per capita annually, the lowest among all emerging markets. The low-income bracket of Thailand averages 0.6 flight per person, which is higher than other emerging markets. Therefore, compared to countries with similar incomes per capita, Thailand sees a more even distribution of flying, and that is not reflected in our income-based estimations.

BY FLIGHT FREQUENCY

We compared our estimated distribution of population by annual flying frequency to the consumer survey results in various high-income countries (Figure B2). The orange line represents survey data, usually with data points up to six flights, on the x-axis; this is because most surveys include an option of "six times or more" to capture the more frequent flyers. The blue line shows our estimated percentage of population that takes different numbers of flights in a year. Our estimated distributions span from 0 to 20 flights, but we show only the data up to ten flights here for easier comparison. The percentage of people flying more than ten times is also marginal compared to the bulk of population who do not fly or who fly infrequently, in all countries.

The surveyed and estimated curves generally line up, except for the shares of people who fly once or twice a year in certain countries. In our modeling, we assumed normal distributions around the average number of flights predicted for each income bracket, and that can lead to more even distributions of flying frequency among the infrequent flyers. For the countries where the two curves do not perfectly line up, estimated share of people who fly once or twice a year is lower than surveyed, while the share of those who fly 3 to 5 times is higher than surveyed, resulting in a similar overall share of people who fly fewer than 6 times.

Figure B2. Surveyed and estimated distribution of flying frequency in select countries

Table B1 shows the detailed breakdown of nonflyers (people who do not fly in a given year) and frequent flyers (people who fly more than 6 times a year) estimated for each country group. The percentages of nonflyers are lower than those estimated in

Gossling and Trumpe (2020), potentially because the income distribution data from World Inequality Database is for adults only. We did not try to correct the distribution for the entire populations of countries, as it is difficult to estimate children's flying frequency based on income and to estimate the average number of children by country and income bracket. Moreover, our modelling shows the same trend of decreasing shares of flyers and frequent flyers from high income countries to low income countries as estimated in the Gossling and Trumpe study. The scale of differences in percentages is also similar.

Table B1. Estimated nonflyers and frequent flyers by country income groups for 2019, with 2018 estimated share of nonflyers from the literature for comparison

Country classification	Total population, 2019 (million)	Nonflyer			Frequent flyer	
		Count, 2019 (million)	Percentage of population, 2019	Reference percentage of population, 2018*	Count, 2019 (million)	Percentage of population, 2019
High Income	1,210	614	51%	60%	121	10%
Upper Middle Income	2,679	1,848	69%	90%	46	2%
Lower Middle Income	3,058	2,695	88%	98%	16	1%
Low Income	724	710	98%	99%	0.2	0.02%
Total	7,670	5,868	76%	89%	182	2%

* Grossling and Trumpe (2020)

APPENDIX C: SENSITIVITY ANALYSIS

In the main analysis, we used an FFL schedule where the first flight of the year is free. This is based on the "A Free Ride" concept, which advocates for equal access to infrequent air travel service by all. However, from the emissions perspective, it is important to tax all flights, since the emissions from the first flight of the year is no different from emissions of the 20th flight. We therefore conducted a sensitivity analysis for an FFL schedule that starts from the first flight of the year. To generate an annual revenue of $121 billion, the levy would range from $7 for the first flight to $136 for the 20th (Table C1). The rolling average FFL would reach the level of an equivalent APD after the sixth flight.

Table C1. Frequent flying levy schedule starting with no free flight

Number of flights taken	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
Per-flight levy	7	14	20	27	34	41	48	54	61	68	75	82	89	95	102	109	116	123	129	136
Rolling average levy	7	10	14	17	20	24	27	31	34	37	41	44	48	51	54	58	61	65	68	71

An FFL with no free flight would slightly reduce the amount of revenue collected from wealthier individuals and states, compared to the levy design with one free flight (Table C2). This is most evident with frequent flyers, where 70% of the revenue would be collected from them, rather than 81%. Nevertheless, the distribution of cost burden under FFL remains more progressive than that under an APD.

Table C2. Contribution to FFL revenue under different tax schedule design

Population groupings	Percentage of global population	Contribution to APD revenue	Contribution to FFL revenue	
			One free flight	No free flight
Frequent Flyer (>6 flights)	2%	41%	81%	70%
High income countries	16%	51%	67%	63%
Top global income quintile	20%	81%	98%	94%

APPENDIX D: APD AND FFL PER CAPITA

In the main analysis, we show the map of percentage difference between total APD and total FFL for each country. Figure D1 and D2 provides the details of APD and FFL by country in the form of levy amount per capita. The color spans of both maps are set to the range of per capita FFL, since the range of per capita FFL ($0-$211) is greater than that of per capita APD ($0-$106).

The relative levels of per capita tax are similar between the two types of taxation. High per capita tax are observed in Australia, Europe, and North America (in red or orange shades). Countries in Asia, Africa, and South America (in green or blue shades) would have low per capita tax (less than $30), with many African countries paying almost $0 tax on a per capita basis. Most countries in this latter group would pay less tax per capita under FFL than under APD, as seen from the lighter shades of green and blue in the maps.

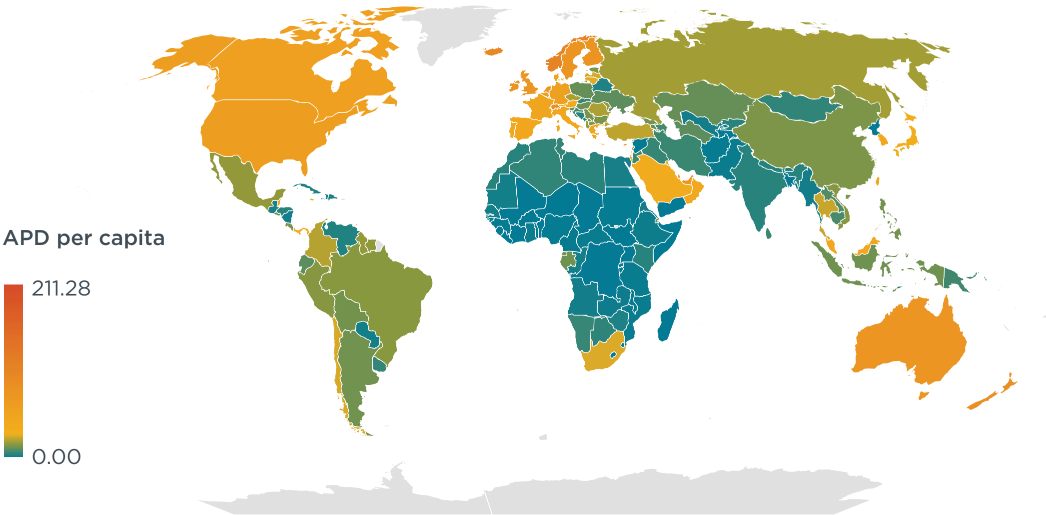

Figure D1. APD per capita by country

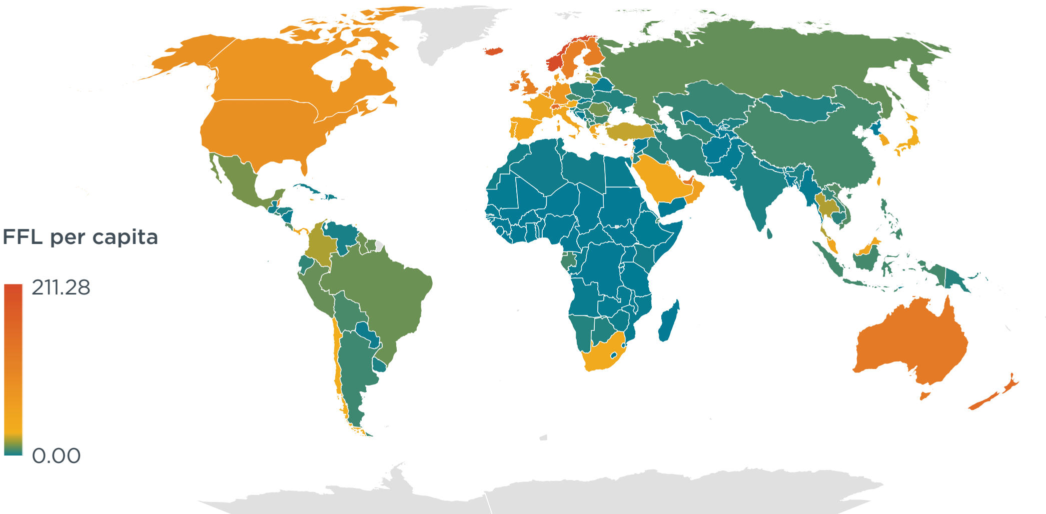

Figure D2. FFL per capita by country