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RECOMMENDED CITATION: Black, Simon, Ian Parry, Sunalika Singh, and Nate Vernon-Lin. 2024. “Destination Net Zero: The Urgent Need for a Global Carbon Tax on Aviation and Shipping.” IMF Staff Climate Note 2024/003, International Monetary Fund, Washington, DC.

ISBN:	979-8-40029-024-4 (Paper) 979-8-40029-036-7 (ePub) 979-8-40029-034-3 (PDF)
JEL Classification Numbers:	Q31; Q35; Q38; Q48; H23; Q54; Q58
Keywords:	Aviation, maritime, net zero, climate mitigation, carbon pricing, feebates, instrument choice, design issues, administration, International Civil Aviation Organization, International Maritime Organization.
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* This note was prepared under the guidance of Dora Benedek. The authors are grateful to Ruud de Mooij, Michael Keen, Tatiana Falcão and numerous IMF staff for very helpful comments.

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October 2024

Summary

The need to decarbonize international transportation has long been overlooked. Aviation (mostly passenger flights) and shipping account for a rapidly growing share of global carbon dioxide emissions. A global carbon tax on fuels used in the sectors can contribute to climate mitigation in two ways. First, it would incentivize efficiency and technological development, accelerating decarbonization of the sectors. Second, it could raise up to $200 billion a year in revenues by 2035, potentially tripling current global climate finance. There are major political hurdles, notably reaching consensus on revenue allocation, price levels, and managing impacts, which are substantive for aviation but less so for shipping. An emissions trading system is another possibility but has greater capacity requirements. Other options are “fee and rebates” or tradeable performance standards which have lower price impacts but raise fewer or zero revenues, respectively. This note assesses these policies, using a new model to quantify their impacts on fuel use, emissions, revenues, and costs, and suggests how to steer international aviation and shipping in the right direction.

Introduction

There is a strong, dual rationale for global carbon pricing in international aviation and shipping. Carbon pricing tends to be applied to carbon dioxide (CO_2) emissions or fuels at the national level but can also be imposed on global sectors like international aviation (mostly passenger flights) and shipping (also known as maritime).[1] This would have two main benefits. First, all energy-consuming sectors need to be decarbonized by midcentury to achieve the Paris Agreement’s temperature goals (limiting warming to 1.5°C to 2°C above preindustrial levels), including hard-to-abate sectors such as international aviation and maritime. Carbon pricing can provide the necessary price signal to cost-effectively promote development and deployment of low-carbon technologies while incentivizing increases in efficiency. Second, pricing consistent with net zero[2] goals could raise substantial revenues—for example, a carbon price rising to $170 per tonne in 2035 would raise about $200 billion a year.[3] The revenues could be used to scale up international climate finance (currently about $100 billion a year) or other purposes.

The case for global carbon pricing is bolstered by additional environmental, administrative, and fiscal considerations. These considerations include the following:

[1] Shipping and maritime are used interchangeably in this Note, though maritime also includes domestic activities like port operations and aquaculture.

[2] “Net zero” refers to gross emissions being equal to removals of CO_2 and other greenhouse gases from the atmosphere. Removals can be facilitated by the aviation and maritime industry through purchases of offsets based on negative emissions technologies such as direct air capture or (more controversially) on projects or policies that avoid emissions relative to a theoretical baseline. However, direct abatement is preferable since removals are costly and will be required for achieving globally net negative emissions in the second half of the century.

[3] All monetary figures in this note are expressed in year 2023 US$.

- *Emissions growth*: Without mitigation actions, emissions from international transport fuels are set to expand rapidly with growth in the global economy, potentially reaching 15 to 40 percent of total global CO_2 emissions if the sectors grow at business-as-usual while countries decarbonize at rates aligned with Paris Agreement goals.
- *Global oversight*: The supervisory agencies for the industries, the International Civil Aviation Organization (ICAO) and International Maritime Organization (IMO), have set decarbonization goals for the sectors and have established the necessary data collection procedures from plane and ship operators for applying pricing systems (although actual enforcement could be delegated to national tax authorities or newly created global entities).
- *Tax base mobility*: The tax base for international transport fuels is mobile, especially for maritime, providing a strong rationale for a globally coordinated price.
- *Fiscal anomalies*: Strengthen the case for pricing, as international aviation and maritime fuels are not subject to excise and are treated favorably from a broader fiscal perspective (see following sections).

Carbon pricing can take the form of carbon taxes or emissions trading systems (ETSs). A carbon tax (sometimes called a levy) is the simplest approach for applying global carbon pricing administratively and can provide long-term price certainty. A global ETS can be a reasonable alternative and is potentially workable at an international level, as demonstrated by the recent inclusion of international aviation and maritime in the EU ETS, though this would require more administrative and firm compliance capacity.

There are, however, political hurdles facing explicit carbon pricing systems—feebates are one alternative. It may be difficult to agree on a price (for a carbon tax) or emissions level (for an ETS) among the 193 and 175 member states of the ICAO and IMO, respectively. Some negotiators considering a carbon tax or ETS may want revenue to be allocated to climate finance (after compensation for affected states such as small island, tourist-reliant countries), whereas others may prefer to allocate revenues for research and development (R&D) or be remitted to national treasuries for their general budgets. Feebates, which apply a sliding scale of fees/rebates on (plane or ship) operators with emissions rates above/below a certain threshold level (“pivot point”), are an alternative. Feebates could help accelerate the adoption of zero-emission fuels, can be designed to raise some revenues, have smaller impacts on prices, and hence less need for compensating vulnerable states.

This note discusses the rationale, design issues, and impacts of carbon pricing for international transportation fuels. It builds on earlier IMF work[4] by considering a broader range of policy options and developing more sophisticated modeling of the sectors using the most recent assessments of zero-emission fuel technologies. The next section provides more background on the sectors. A discussion of the rationale for international carbon pricing systems follows and different policy options are compared, along with key design issues. The following section quantifies the impact of pricing systems on emissions, revenue, production costs, economic costs, zero-emission fuel use, and distributional impacts, globally and across countries. The concluding section offers brief remarks on moving the policy forward.

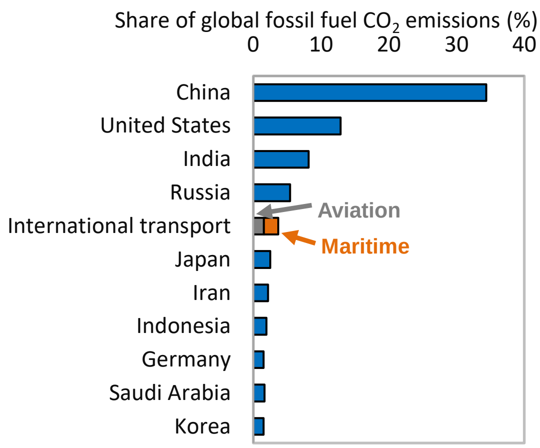
[4] IMF (2011); Keen, Parry, and Strand (2013); Parry, Heine, Kizzier, and Smith (2022).

Background

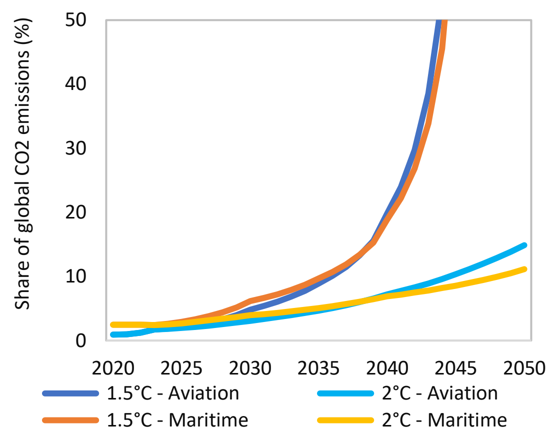
CO_2 emissions from international aviation and maritime were 610 and 850 million tonnes (Mt) in 2023, or about 1.5 and 2 percent of global fossil fuel CO_2 emissions, respectively. Combined, these sectors contributed more CO_2 emissions than all but four countries (Figure 1, panel 1). Without mitigation measures, aviation and maritime emissions are likely to increase rapidly with expansion of the global economy (see Figure 1, panel 2). Indeed, if countries follow a 2°C scenario but international transport grows at business as usual, it will account for over 15 percent of global CO_2 emissions by 2030 and 25 percent by 2050. Worse, under a 1.5°C scenario, international transport could account for up to 40 percent of global CO_2 emissions by 2030, rising rapidly thereafter (as countries' net emissions theoretically go negative). The discussion here focuses on CO_2 emissions from fuel combustion—see Annex 1 for a discussion of contrails and other non-CO_2, climate-affecting emissions.

Figure 1. CO_2 Emissions from International Transport and Shares in Global CO_2 Emissions

1. Comparing Shares with Large Emitters, 2023



2. Projected Shares Assuming Global Decarbonization, 2020–50



Source: IMF staff calculations. Note: Domestic aviation and maritime, which account for 44 percent and 21 percent of total (domestic and international) aviation and maritime emissions respectively are excluded from the figure. Emissions exclude land-use change and forestry. Emissions trajectories for 1.5°C and 2°C scenarios in panel 2 are based IPCC scenarios and amended to account for higher-than-expected emissions in 2019–23 (see Black and others 2024).

The ICAO and IMO are the specialist UN agencies responsible for setting targets and strategies to decarbonize the sectors (Table 1). Emissions from the sectors are generated largely in international airspace and waters which are beyond the purview of the United Nations Framework Convention on Climate Change and hence not covered by the Paris Agreement. The ICAO and IMO have pledged to achieve "net zero" emissions by midcentury or thereabouts, and the IMO has set intermediate targets for emissions and zero-emission fuels. The main mitigation policies implemented to date include the Carbon Offsetting and Reduction Scheme for International Aviation (CORSIA), under which most operators will soon be required to purchase international offsets for any emissions exceeding 85 percent of 2019 levels out to 2035. For maritime, policies include energy

Table 1. Targets and Policies for International Transport

		Aviation	Maritime
Targets	Emissions: long term	Aspirational goal of net zero CO_2 emissions by 2050	Zero CO_2 emissions "close" to 2050
	Emissions: intermediate	None	Reduce CO_2 20–30% by 2030 and 70–80% by 2040, relative to 2008
	Zero-emission fuels	None	5–10% of energy used by 2030
Policies	Implemented	Operators required to buy international offsets for emissions exceeding 85% of 2019 levels out to 2035	New ship fuel efficiency and existing ship carbon intensity standards
	Under consideration	None	Emissions pricing schemes

Sources: ICAO (2022); and IMO (2023).
Note: For aviation, international offsets can count toward reducing net emissions but not for maritime.

efficiency standards for all ships and carbon intensity standards (per capacity ton-mile) for the most emitting ships, although emission pricing systems are also under consideration.

The international aviation and maritime sectors differ in some notable ways. The main differences are listed as follows:

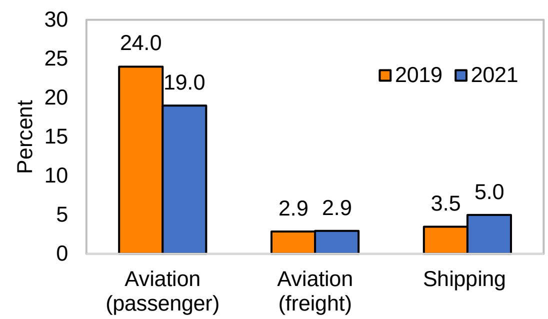
- *Fuel intensity*: On average fuel input costs contribute about 20 percent to airline passenger ticket prices but only 3 to 5 percent to the price of landed imports from ships and planes (Figure 2, panel 1)—higher fuel prices from carbon pricing can therefore significantly affect the price of, and reduce demand for, international air travel but not for shipped products or aviation freight.[5]

- *Product type*: International air travel is largely a consumer good with leisure travel accounting for about 70 percent of trips, whereas maritime is mostly an intermediate input with cargo accounting for 95 percent of emissions (Figure 2, panel 2). Within maritime, there are significant differences across container, dry bulk (for example, steel, iron ore, coal, grain), and tankers in terms of emissions intensities and projected baseline growth rates (see the following sections).

- *Tax base mobility*: Extreme tax base mobility limits the scope for differentiated pricing of maritime emissions across countries—high-volume ships can undertake long voyages on a single bunkering of fuel, enabling them to refuel at ports that have lower fuel prices, without significantly adding to operational costs. For aviation, the mobility of the tax base is moderated by significant costs of diverting planes to other airports for refueling and carrying more fuel than otherwise optimal, implying some scope for differential pricing across countries (for example, pricing might be phased in more rapidly for advanced economies).

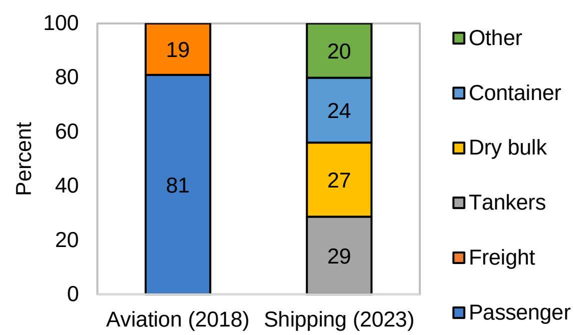
Figure 2. Emissions Sources and Fuel Shares

1. Share of Fuel Cost in Product Prices



Sources: IATA (2024); and UNCTAD (2024).

2. Emissions by Activity Type



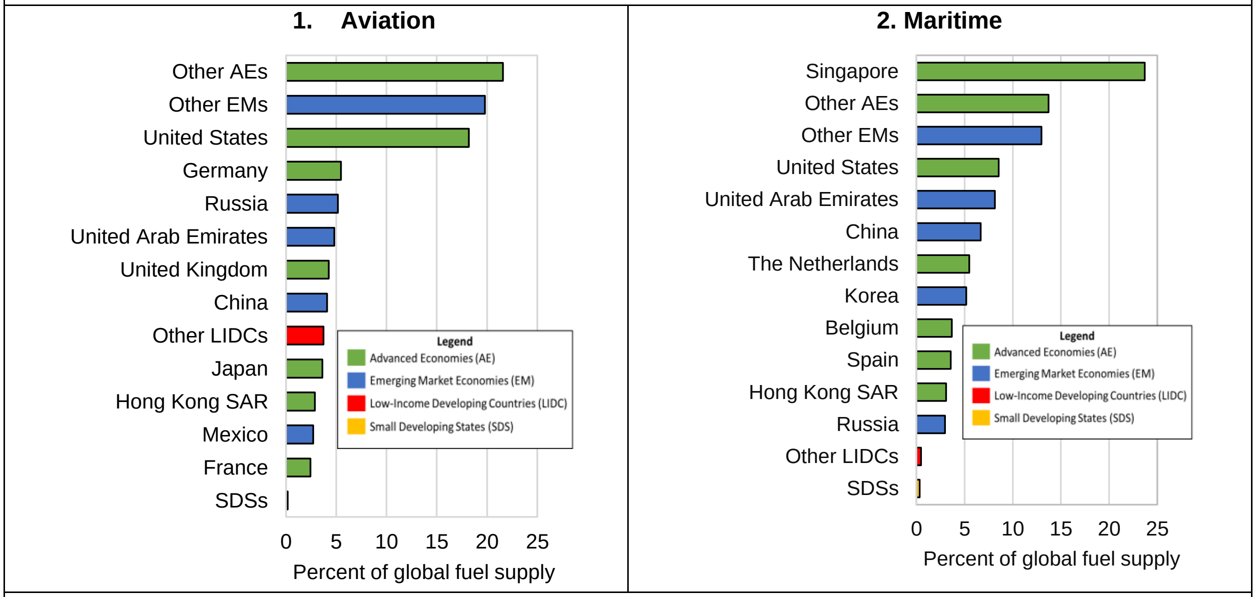
Sources: Graver and others (2019); and UNCTAD (2023).
Note: Graver and others (2019) provide estimates on emissions from total (domestic and international) aviation, and it is assumed these proportions hold true for emissions from international aviation as well. Within passenger aviation, business travel makes up 10 to 15 percent of tickets. For shipping, others includes vehicles and roll-on/roll-off ships, passenger ships, offshore ships, and service and miscellaneous ships.

Effective mitigation regimes necessitate the participation of developing economies. Overall, developing (mostly emerging market) economies account for 45 and 35 percent of global aviation and maritime supply of final fuel use, respectively. Within developing economies, however, small developing states (see Annex 7 for the country classifications), which are the most vulnerable to international fuel charges, account for only about 0.15 and 0.35 percent of international aviation and maritime bunker fuels, respectively. Some smaller economies with hub ports, including Belgium, The Netherlands, Singapore,

[5] Shipping costs account for about 10 percent of landed import prices and fuel costs are about 50 percent of shipping costs, depending on international oil prices.

and the United Arab Emirates, supply large amounts of maritime fuel, but (aside from the United Arab Emirates) this is less applicable to aviation (see Figure 3).

Figure 3. International Fuel Disbursements by Top Suppliers (2021)



Source: IEA (2024).
Note: Other AE = other advanced economies; Other EM = other emerging market economies; Other LIDC = other low-income developing countries; SAR = special administrative region; SDS = small developing states. Data labels in the figure use International Organization for Standardization (ISO) country codes.

The international aviation and maritime sectors are undertaxed from both an environmental and broader fiscal perspective:[6]

- *Fuel/carbon taxation*: International transportation fuels are not subject to excises or (except by the EU) carbon pricing. For aviation, the 1944 Chicago Convention and the subsequent ICAO resolutions prohibit taxation of fuel already on board an aircraft by the state where the aircraft lands, which is a widespread country practice, as codified in many bilateral air service agreements that provide similar exemptions. For maritime, it reflects longstanding practice and the extreme mobility of the tax base.

- *Consumption taxation*: As aviation services are mainly a consumer product, in principle they should be subject to taxes applying to most other consumer goods. International airline operators however charge no tax on sales but receive a full refund, zero-rating, or value-added tax exemptions on their inputs. With digitalization, applying value-added tax (which, for example, could require ticket sellers to remit to the consumer's government) is becoming more feasible but agreement on the allocation of receipts would be needed among the flight origin, transit, and destination countries—departure or other domestic ticket taxes are another possibility (see below and Annex 6 on ticket taxes).[7]

- *Business taxation*: International maritime is excluded from the application of the global minimum and domestic corporate taxes. Instead, it is subject to a unique tonnage tax regime amounting to only about 10 percent of the normal corporate income taxes charged on profits in other industries.[8]

There are a variety of short- and long-term mitigation opportunities for both sectors (see Table 2):

[6] Keen, Parry, and Strand (2013).
[7] Aviation tickets are also subject to user charges for services, such as security, that on net do not raise revenues for the government (Keen and Strand 2007). On applying value-added tax to digital transactions, see Brondolo (2021).
[8] Elschner (2013); Keen, Parry, and Strand (2013).

- *Shorter term*: Opportunities include, for example, improvements in engine efficiency and use of lighter construction materials in new builds as well as better maintenance and operational efficiency (for example, slower steaming to conserve fuel) for ships and reducing travel demand for aviation.
- *Longer term*: Zero-emission fuels, known as sustainable aviation fuels (SAFs) for planes, are ultimately needed for both sectors. For ships, a possibility is hydrogen-based fuels (hydrogen itself, ammonia, or methanol), ideally from "green" hydrogen (produced with zero emissions from renewable-powered electrolysis) or, less sustainably "blue" (from natural gas with carbon capture and storage). However, advances are needed to lower production costs and improve the safety of onboard storage and propulsion technologies, given that their energy content per unit of weight is only half to a third of that for fossil fuels—infrastructure is also needed to transport and disburse the fuel. Hydrogen-based fuels are even further from market for aviation, given the greater sensitivity of aviation costs to fuel costs and significant changes to aircraft design needed to accommodate hydrogen. With current engines, biofuels blends can reach up to 50 and 20 percent for aviation and maritime, respectively. The maximum biofuel share is expected to grow to 100 percent for new planes, as all major aircraft manufacturers have committed to producing such aircraft by 2030. For land-based biofuels, emissions incurred during the production process must be limited (see Annex 1).[9] Electrification has some potential for shorter trips in both sectors but less so for longer trips because of the limited range and weight of batteries.

Table 2. Classification of Potential Behavioral Responses for Reducing CO_2 Emissions

		Sector	
Mitigation Responses		**Aviation**	**Maritime**
Reduced demand (for travel or shipped goods)		Some scope	Limited scope
Short-term fuel intensity	New plane/ship efficiency	Lighter body materials; engine efficiency; smoother surface to reduce drag	Lighter construction materials; engine/propulsion efficiency; lower carbon fuels (liquefied natural gas); wind propulsion rotor sails
	Used plane/ship efficiency	Faster fleet turnover	Faster fleet turnover; better maintenance; retrofitting of engines, propellers, hulls
	Operational efficiency	Limited scope	Optimizing routes/speeds/scheduling
	Vehicle fleet composition and load factors	Optimizing occupancy	Shifting to larger (more fuel-efficient) ships; optimizing occupancy
Long-term sustainable fuels	Hydrogen/ammonia	Long term: due to lower energy density, several times volume of fuel needed than for current fuel	More promising, but needs larger storage and propulsion capacity than bunker fuels because of lower energy density, pipeline/port distribution infrastructure
	Biofuels	Promising but biomass competes for land use with agriculture/forestry	Likely transitional as limitations on blending
	Electrification	Limited potential, to trips < 1,500 km	Very limited potential, to short (for example, ferry) trips

Sources: Glenk and Reichelstein (2019); McCollum and others (2009); IMO (2009, 2011); and World Bank (2012).

The ICAO and IMO have established the data collection systems required to implement pricing policies. Since 2019, qualifying airlines in the ICAO member countries are required to monitor and

[9] Biofuels refer to liquid fuels produced with biomass, waste, or other feedstock. Biofuel production would, however, require substantial diversion of land away from forestry or agriculture—ideally biofuel use would be certified as coming from emissions-neutral farming practices, waste products (for example, cooking oils and agricultural residues), and captured CO_2 and gases with capture technology powered by zero-emissions electricity. There is some uncertainty and variation around the lifecycle emissions of different biofuel production techniques but they can be substantial; for example, the ICAO assumes that the most common production methods (from biomass and waste) result in about one-third of the lifecycle emissions of jet fuel (ICAO 2022b).

annually report their emissions (as verified by accredited third parties) to their national government. Also, in 2019, the IMO introduced a data collection system for fuel consumption, tons of cargo capacity, and miles travelled from individual shipping voyages for ships of at least 5,000 gross tonnage—these ships account for about half of the operational fleet of 50,000 vessels, but almost 90 percent of its CO_2 emissions.[10] Capacity and trip distance are also recorded for large planes/ships by satellite.

CORSIA (currently voluntary) will become mandatory for about 90 percent of international flights in 2027 but has limitations. Under the scheme (see Annex 2), flight operators are required to purchase international offsets for any company-level emissions above 85 percent of 2019 levels (although flights to and from small island and vulnerable states are exempt). Offset projects include mainly renewable energy deployment, clean cooking technologies, methane capture, and forestry projects.

Key limitations to CORSIA are as follows:

- *Net emissions targets*: These are not aligned with long-term global net zero emissions. For example, under a pathway that reduces emissions by the same absolute amount each year beginning in 2019 and reaching zero emissions in 2050, aviation emissions in 2035 would be capped at about 50 percent (rather than 85 percent) of 2019 emissions, or 350 billion tons.
- *Offsets and additionality*: Offsetting can reduce mitigation costs by reallocating emissions reductions from sectors with high abatement costs (like aviation and maritime) to sectors with lower abatement costs. However, if carbon credits are not additional, allowing for their use *increases* global emissions compared to a situation where abatement is the only option. This will apply if (1) offset projects would have gone ahead without the offset payment (for example, a renewables project that is warranted on commercial grounds) or (2) the offset-selling country also counts the project toward meeting its own mitigation commitments. In principle, both problems would be addressed if (1) global emissions pledges aligned with the Paris Agreement's temperature goals, (2) the offset-selling country's mitigation pledge is binding, and (3) the offset-selling country already has in place validated policies that will achieve the pledge. However, climate targets are not aligned globally with the Paris Agreement's temperature goals,[11] and only a limited number of countries may satisfy requirements (2) and (3).
- *Uncertainty*: Future emissions offset prices are highly uncertain, which could deter investments in zero-emission fuels that have high upfront costs and long-range emissions reductions.
- *Revenue*: CORSIA does not generate revenue since the offsets are purchased directly by airlines from third-party sellers and there is no tax on these transfers.

The IMO has focused mostly on energy efficiency to date, although a carbon levy is being discussed. The Energy Efficiency Design Index progressively tightens energy-efficiency standards for new ships every five years; the Energy Efficiency Existing Ship Index requires existing ships to meet a one-time minimum energy efficiency standard; and the Carbon Intensity Indicator requires emissions intensity (per unit of kilometer and unit of ship capacity) improvements for low-performing ships.[12] However, these standards may have limited effectiveness as they lack incentives to reduce energy or CO_2 intensity beyond the standard, have complex adjustments depending on ship type, and do not incentivize increased load factors. Importantly, they are not cost-effective because, unlike carbon pricing, they lack an automatic mechanism for equating the incremental costs of CO_2 reductions across ship

[10] IMO (2016).

[11] According to Black, Parry, and Zhunussova (2023) national targets cut emissions by only about 12 percent by 2030 compared with 2019 levels, whereas cuts of 25 percent to 50 percent are needed to be on track to limiting global warming to 2°C and 1.5°C, respectively.

[12] See https://www.imo.org/en/MediaCentre/PressBriefings/pages/CII-and-EEXI-entry-into-force.aspx. Ship operators must also have a plan for improving their operational efficiency, although improvements are not mandatory.

classes and manufacturers. Various emissions-pricing proposals have been submitted for debate at IMO meetings but there are no firm plans for implementation at present.[13]

Mitigation Instrument Choice and Design for International Transport Fuels

There are various policy options to decarbonize international transport. This section discusses carbon taxes, ETSs, feebates, and tradable performance standards (TPSs). Table 3 provides a summary comparison of the instruments, along with offsets and energy efficiency standards.

Table 3. Attributes of Alternative Global Mitigation Instruments

Instrument/Metric		Carbon Tax	ETS	Feebates	TPS	Offsets (against benchmark emissions)	Energy Efficiency for New Planes/Ships
Effectiveness	Demand response	Carbon taxes passed forward in higher flight/import prices	Carbon taxes passed forward in higher flight/import prices	Minimal price impact	Minimal price impact	Minimal price impact	Minimal price impact
	Short-term fuel intensity	Promotes all responses	Promotes all responses	Promotes all responses	Promotes all responses	No incentive to exceed standard	No incentive for exceeding standard or operational/existing ship efficiency
	Long-term sustainable fuels	Effective with robust price	Effective with robust price	Effective with robust price	Effective with robust price	No incentive to adopt ZEVs	No incentive to adopt ZEVs
	Reductions are additional	All within industry	All within industry	All within industry	All within industry	May not be additional	All within industry
Certainty over price signal to spur zero-emissions fuels		Robust and certain price path can be specified	Price floors/ceilings can help with price certainty	Robust and certain price path can be specified	Price floors/ceilings can help with price certainty	Future offset prices uncertain	No price signal (with no credit trading)
Revenue		Automatically collected	If allowances auctioned	Zero (unless pivot point less than industry emission rate)	Zero	Zero	Zero
Administrative practicality (at ICAO/IMO)		Monitoring needs established	Same as tax but monitoring also needed for trading markets	Monitoring needs established	Same as feebate but monitoring also needed for trading markets	Monitoring needed for validity of offsets	Monitoring needs established
Political difficulty: country burdens from higher transport costs		Carbon charges reflected in costs/burdens	Carbon charges reflected in costs/burdens	Modest	Modest	Modest	Modest

Source: Authors.
Note: Green indicates an advantage of an instrument, red a disadvantage, and orange neither an advantage nor a disadvantage. ETS = emissions trading system; ICAO = International Civil Aviation Organization; IMO = International Maritime Organization; TPS = tradable performance standard; ZEVs = zero-emission vehicles.

A Global Carbon Tax on Fuels Used in International Aviation and Maritime

Carbon taxes cost-effectively promote the full range of mitigation responses, but a robust price signal is critical. A carbon tax would apply charges to the carbon content of fuel use, based on jet or bunker fuel use times their respective emissions factors. The tax rate is fixed, leaving the quantity of emissions to be determined by market forces such as demand for air travel and shipped products and the costs of mitigation technologies. As the carbon tax increases prices for aviation and maritime fuels the cost increase is mostly passed through into flight ticket prices and shipped products, incentivizing reductions in demand alongside other behavioral responses, as shown in Table 2.[14] Pricing is cost-effective because it provides the same reward—the carbon tax—for cutting emissions by an extra tonne

[13] See www.imo.org/en/MediaCentre/PressBriefings/pages/IMO-agrees-possible-outline-for-net-zero-framework.aspx.
[14] IMF (2011) calculations suggest at least 95 percent of international aviation and maritime fuel charges would be passed through into higher fuel prices rather than passed back into lower operator profits.

of CO_2. To be effective, the carbon tax should be sufficiently high to promote zero-emission fuels. As technological advances bring zero-emission fuels closer to market, the carbon tax should rise to close the cost gaps between them and oil-based fuels—a credible future tax trajectory would help mobilize these, and efficiency, investments given their high upfront costs and long-term emissions reductions.

Carbon taxes could mobilize a large and sustainable revenue source which could be used for a combination of purposes. The relatively low price responsiveness of international transport emissions makes them attractive from a revenue-raising perspective. Revenue use might include the following:

- *International climate finance*: Using revenue from international aviation and maritime charges for climate finance (with disbursement, for example, through climate investment funds) has some appeal, particularly since it is difficult to allocate the tax base to national governments since fuels are mostly combusted in international air space or waters. The target amount of climate finance ($100 billion a year) was met in 2023, with about 35, 45, and 20 percent from bilateral, multilateral, and privately leveraged sources respectively.[15] Although a more ambitious target is under negotiation, it will be challenging to reach, given the pervasive budgetary pressures across countries. Potential revenues from international transportation, up to $200 billion a year, could make a huge contribution to global climate finance. See Figure 11 below for a quantification of climate finance flows after compensating vulnerable and lower income nations for mitigation policy impacts on tourism and cargo.
- *R&D and investment*: Even with a robust carbon price, operators or other entrepreneurs may underinvest in developing zero-emission fuels if they cannot capture all the spillover benefits to other operators who might copy new technologies or use knowledge embodied in them to further their own R&D efforts. Carbon tax revenues could provide a source of funding to promote R&D through, for example, grants for basic research or prizes for commercially viable technologies. Infrastructure investment needs for clean fuel suppliers are substantial[16]—for advanced economies this investment could be privately mobilized through carbon pricing, although grants and concessional loans may be needed to catalyze investment in developing economies facing higher international interest rates.
- *Domestic revenue needs*: Countries could retain revenues collected from charges on fuel disbursements within their borders for domestic needs.

However, there is likely to be strong disagreement over revenue use, which may hold up progress on carbon taxation at the needed scale. For example, developing economies may oppose using revenues for climate finance (as this is meant to come from advanced economies). Countries with large aviation/maritime production or operation industries may push for keeping revenue within the sectors.[17] Meanwhile, countries with high ratios of international transportation fuels to GDP (for example, with hub airports and ports) may push for revenues staying with national governments.

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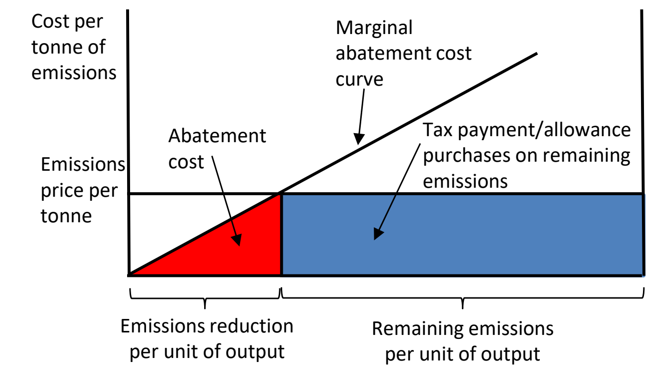
[15] OECD (2024).
[16] For example, UMAS-ETC (2020).
[17] However, there seems to be little economic basis for compensation payments to the industries themselves given their special tax preferences and given that, as noted above, carbon charges would be largely passed forward by the industries through higher tickets and goods prices.

Revenue-raising policies may also require compensation systems. Unit production costs for the aviation and maritime sectors (cost per passenger- or ton-mile) under explicit carbon pricing increase for two reasons (see Figure 4): (1) abatement costs, that is, the integral under the marginal abatement cost curve for cutting emissions per unit of output; and (2) charges on unabated emissions, that is, the product of the emissions price and the remaining emissions per unit of output. The latter is much larger than the former (at least initially when emissions reductions are more moderate). Higher production costs are ultimately borne by countries in the form of higher costs for flights and shipped imports—to the extent they burden vulnerable countries there may be a need for compensation systems. Annex 3 discusses possible compensation mechanisms, Annex 7 provides country-level impacts, and Figure 9-Figure 11 below summarizes impacts for each income group and large countries.

Figure 4. Components of Increase in Unit Production Costs under Explicit Carbon Pricing



Source: Authors.
Note: In practice, marginal abatement cost curves are likely to be convex rather than linear.

A global carbon tax should be administratively feasible, although some key elements would need to be decided. The important elements are discussed as follows:

- *Basic design choices*: The choices such as tax trajectories and revenue allocation could be agreed at international fora, such as the ICAO, IMO, United Nations Framework Convention on Climate Change, and Group of Twenty (G20).
- *Data collection and transfer*: Fuel use and emissions data now collected by the ICAO and IMO could be digitally transferred to tax collection entities.
- *Tax collection*: Taxes could be collected directly from plane or ship operators by national tax administrations,[18] analogous to enforcement of the EU ETS, CORSIA, and air ticket solidarity levy. Alternatively, new funds or tax collection consultants could be established and overseen by ICAO and IMO following the model of the International Oil Pollution Compensation Funds (although the collection agency would require key tools of tax administration such as audit capacity, the powers to fine, and dispute procedures) (see Table 4 for details on various systems). Either way, tax administration should be manageable given that large planes and ships are continuously tracked by satellite, operators could remit the carbon tax digitally on an individual-route or annual basis and, from a global perspective, the number of tax collection points (for example, 25,000 ships initially) is modest.

[18] Alternatively, taxes could be collected at the national level from aviation and shipping fuel suppliers at the refinery gate or at the point of distribution to planes and ships in airports and ports (this possibility is not discussed further here given the focus of ICAO and IMO on fuel use and emissions at the operator level). Even if revenues are used for international purposes, national governments may require some compensation if they are responsible for administration (for example, national agencies keep 10 percent of revenue collections under the European Union's common external tariff).

- *Enforcement*: If all major airport or port states were party to the scheme, it could be comprehensively enforced through the denial of airport or port access to any operator unable to provide invoices verifying upfront payment of the tax.[19]

Table 4. Precedents for a Global Carbon Tax: Administrative Responsibilities

Scheme	How the Scheme Works	Administering Entity
International Oil Pollution Compensation (IOPC) funds	Collects funds from oil-receiving entities in ports and disburses them as compensation for oil spill damages.	Specialized fund under supervision of IMO.
Aviation in the EU ETS	Airlines operating flights within the European Economic Area (EEA), Switzerland, and UK are required to monitor, verify, and report their emissions and to surrender ETS allowances accordingly. Free allowance allocations for airlines will phase out by 2027.	National authorities verify operators who have allowances for their emissions.
Maritime in the EU ETS	Ship operators are required to monitor, verify, report and acquire allowances for 50 percent of emissions from voyages starting or ending outside the EU and 100 percent for trips within EU ports. Free allowances (initially 60 percent of 2024 emissions) will phase out by 2027.	
Air ticket solidarity levy (ASL)	Imposes charges of $1/$10/$40 for economy/business/first-class tickets respectively to outbound international flights—proceeds finance health improvements in low-income countries. Participants include Cameroon, Chile, Congo, France, Madagascar, Mali, Mauritius, Niger, Norway, and Korea.	Airlines collect tax on ticket purchases and remit to the government of a country that has implemented it, who, in turn, allocate to international initiatives.
CORSIA	CORSIA requires airlines to offset emissions growth above 2019 levels, with mandatory participation from 2027, and phases implementation through voluntary and mandatory stages for international flights.	International Civil Aviation Organization (ICAO) administers and oversees, including monitoring, reporting, verification, and compliance.
Global minimum corporate income tax	The global minimum corporate tax ensures multinationals pay at least 15% tax, preventing profit shifting to low-tax jurisdictions. The initiative is part of the OECD/G20 Base Erosion and Profit Shifting (BEPS) project.	Individual countries administer and enforce the tax within their own jurisdictions, with profits taxed in the country where they are generated.

Sources: European Commission (2024), IOPC Funds (2023), Unitaid (2013)
Note: CORSIA = Carbon Offsetting and Reduction Scheme for International Aviation; EU = European Union; ETS = emissions trading scheme; ICAO = International Civil Aviation Organization; IMO = International Maritime Organization.

Carbon taxes, nonetheless, face severe set-up challenges. These include:

- *Legal*: For aviation, bilateral agreements providing for reciprocal fuel tax exemptions may need to be amended to allow carbon taxes on fuel use, and perhaps the Chicago Convention may need to be amended as well (which would require approval by two-thirds of the ICAO members).

- *Revenue disbursement*: If some revenues are used for climate finance, they would need to be remitted to the Green Climate Fund and/or other international agencies for allocation to country governments for mitigation/adaptation projects and receiving agencies would need capacity to absorb the funds, though there is already a great deal of expertise to be leveraged in these agencies.[20]

- *Compensation schemes*: Although there are workable options for compensation schemes for both aviation and maritime (Annex 3), agreeing to them complicates negotiations over establishing carbon tax regimes.

- *Political*: The biggest obstacles to carbon taxation include resistance from member states from higher transport costs and reaching agreement among countries on implementing the tax, setting the tax rate trajectory, and use of revenues.

[19] This would be the case even if some states where planes and ships are registered were not party to the scheme. For example, the United Nations Convention on the Law of the Sea allows port states to take actions against ships violating international rules, and many environmental and safety measures are enforced in this way (GloMEEP and IMarEST 2018). When a state becomes a party to an IMO convention, it agrees to make the convention part of its national law and to enforce it.

[20] See Dominioni and Englert (2022); Englert and others (2023).

Emissions Trading Systems (ETSs)

ETSs promote similar behavioral responses to carbon taxes, although uncertainty over emissions prices may forestall some investment. Under an ETS, plane and ship operators would need to acquire allowances for the CO_2 emissions from each trip. The administering authorities fix the cap on total allowances, which can be scaled down over time in line with environmental goals. Allowance prices are determined in trading markets and will vary with market forces. However, certainty over future prices, rather than annual emissions levels, seems more relevant for the aviation and maritime sectors, given the need for operators to compare the costs of zero-emissions and oil-based fuels over lifetimes of 30 years or so. Price stability under a global ETS might be promoted through the following:

1. *Price floors*: These limit the quantity of allowances when prices fall to a minimum level and could be implemented, for example, through minimum bid prices in allowance auctions—ideally, the price floor would ramp up predictably over time. Price floors can also improve the compatibility of ETSs with overlapping instruments.[21]
2. *Price ceilings*: These put extra allowances into the system when prices reach a maximum level.

ETSs could raise similar revenues as equivalently scaled carbon taxes and cause similar increases in production costs for aviation and maritime. Allowances can be auctioned to raise revenue as in other ETSs (for example, California, EU, Korea, New Zealand) although sectors subject to intense international competition are usually granted (at least temporarily) some free allowance allocations. The case for free allowances for firms is less compelling for global (rather than country or regional) systems where higher production costs are generally passed forward in higher prices for all plane and ship operators rather than passed back in lower profits for these industries. Even with free allowance allocations, unit production cost increases for plane and ship operators would be essentially the same. Free allocations act like lump-sum transfers to operators and create windfall profits at the margin since generating emissions is costly to them because emitting forgoes revenue they could have earned from selling their free allowances. Free allowances might be granted to certain countries to encourage their participation in a global ETS, although similar incentives could also be provided under a carbon tax by remitting revenues to them.[22]

A global ETS would be more complex administratively than a carbon tax, although the EU ETS provides some precedent for an internationally administered ETS. Extra administration for an ETS includes establishing and monitoring trading markets in addition to private costs to operators of ships and planes participating in trading markets. For example, for maritime, establishing the capacity to buy, sell, and hedge emission allowances could significantly increase overheads for small companies using only a few ships.[23] In principle, as international aviation and maritime become covered by a global pricing system they should become exempt from the EU ETS. However, coverage by both systems may be appropriate for an interim period, if prices in the EU system (currently about $70 per ton) substantially exceed those in the global system, with rebating in the regional system for allowance purchases in the global system to avoid double charging.

Feebates and Tradable Performance Standards (TPSs)

Alternatively, fee and rebate systems (“feebates”) are an implicit carbon-pricing option. Feebates impose charges on operators equal to the product of the following factors: (1) a CO_2 price; (2) the

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[21] Under carbon taxes, overlapping instruments such as energy efficiency standards reduce emissions without affecting the carbon price. Under an explicit emissions trading system (ETS) overlapping instruments do not affect emissions (which are set by the cap) but instead reduce allowance prices unless there is a binding floor price.

[22] For further comparison of carbon taxes and ETSs, and experiences with ETSs, see Parry and others (2022) and MacDonald and Parry (2024).

[23] Indeed, there could be risks of allowance market manipulation given concentration in the maritime sector—eight companies account for about 60 percent of shipping capacity (UNCTAD 2023).

difference between their CO_2 emission rate per unit of output (passenger- or ton-mile) and an exogenous "pivot point" emission rate (at which there is no tax or rebate); and (3) their output. For aviation and maritime, output could be passenger or plane miles[24] and ton-miles of freight, respectively. This means that under a feebate approach, whether operators pay taxes or receive subsidies depends on whether their emission rates are above or below the relevant pivot point. In maritime, where emission rates differ significantly for bulk, tanker, and container shipping (7, 9.5, and 12.5 grams of CO_2 per ton-mile, respectively), it may make sense to have separate pivot points for different segments to improve acceptability for shippers.[25] The feebate price can be aligned with emissions goals for the sector while the pivot point can be aligned with revenue objectives—at the extremes, if the pivot point is the industry average emission rate no revenues are raised, whereas if the pivot point is zero the feebate is equivalent to a tax. Procedures for administering feebate systems at the ICAO and IMO would be the same as those for carbon taxes—the main difference is that the formula for assessing fees/rebates is more complex as it depends on a measure of output, as well as on CO_2 emissions, for each plane or shipping trip.[26]

Feebates provide some of the incentives of explicit carbon pricing: they promote reductions in emission rates but may have limited demand effects. Indeed, a revenue-neutral feebate would not impose a new charge on remaining emissions for the average operator, so average production cost increases—and hence price impacts for flights and landed imports—would be much smaller than under explicit carbon pricing at lower levels of decarbonization (the blue rectangle in Figure 4 does not apply but as emissions reductions increase, abatement costs (red triangle) dominate any tax payment (blue rectangle)). The limited demand response is a significant drawback in terms of cost-effective mitigation for aviation (see Figure 7) but feebates might be designed to have more impact on ticket prices through setting a lower pivot point. Alternatively, feebates could be complemented at the national level by ticket taxes or at the international level through broadening and scaling up the air ticket solidarity levy (see Annex 6 for analysis for a feebate, ticket tax combination).

TPSs are similar to feebates but fix quantities rather than prices. Under a TPS, the administering authority specifies a progressively tightening emission rate standard—operators exceeding the standard in a given year must purchase credits for their excess emissions while operators with emission rates below the standard can sell credits (again standards may differ by ship category).[27] The TPS promotes the same behavioral responses as a feebate, has equivalent impacts on production costs, and could be administered by the ICAO or IMO with similar capacity requirements (aside from the need to monitor credit trading), but it is not designed to raise revenue. The need for price stability measures may be less pressing for TPSs than ETSs—unlike in an ETS, shifts in demand for flights and imports do not affect credit prices in a TPS. Nonetheless, price floors and ceilings in a TPS could still take the form of giving firms subsidies (in lieu of selling credits) or paying out-of-compliance fees (in lieu of purchasing credits).

For aviation specifically, transitioning from offsetting to explicit or implicit carbon pricing would be straightforward, at least from an administrative perspective. Transitioning to a TPS or feebate would require (1) expressing the current benchmark as an emission rate (that is, dividing allowed industry

[24] In principle, applying the feebate to emissions per passenger-mile for planes or per ton-mile of freight is more efficient than applying it to capacity mile (for planes) or capacity ton-mile (for ships) in that it promotes optimization of load factors—but in practice this only moderately affects fuel consumption since there is limited scope to improve loads.

[25] In principle, a single pivot point is more efficient as it promotes shifting among shipping categories with different emissions intensities but in practice the scope for these responses is very limited (because they carry very different products).

[26] Feebates applied only to fuels or new plane/ship builds are less effective. The former would apply a sliding scale of fees/rebates to fuels with emission rates above/below a pivot point rate, scaled by fuel consumption. This is (moderately) less effective than a feebate applying to emission rates per unit of output as the former does not promote reductions in energy efficiency. And applying a feebate to new plane/vessel builds would not promote efficiency improvements for existing vehicles or changes in operational efficiency.

[27] The credit purchases or sales are the difference between the operators' emission rate and the standard times of their output.

emissions by total passenger/plane miles) and (2) that operators with emission rates above this standard purchase credits not from international offsets but rather from airline operators with emission rates below the standard (under a TPS), or pay fees (under a feebate). The standard could then be tightened over time. Under an ETS or carbon tax, the ICAO would be monitoring operators' absolute emissions (rather than emission rate), specifying limits on industry emissions or tax rates, and phasing out the use of offsets.

Quantitative Analysis

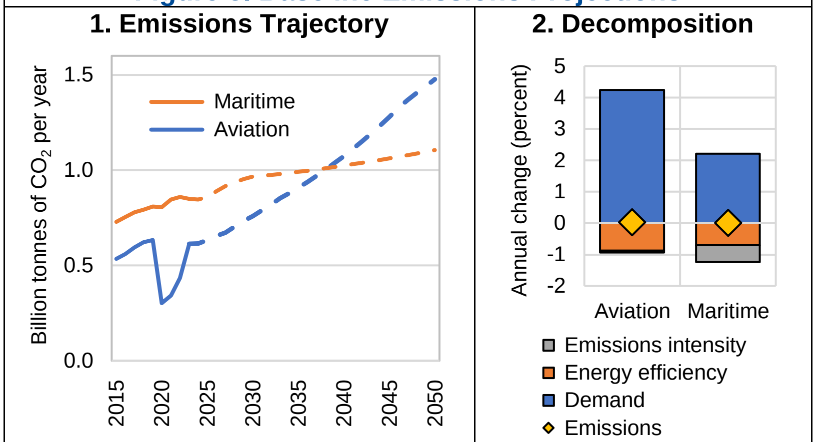
***Methodology*: Dynamic, partial equilibrium models of the international aviation and maritime sectors are used for quantitative analysis.** The models capture changes in global demand for transport from growing income and changing end user prices, improvements in energy- and emissions-intensity from mitigation policies and exogenous technical improvements, and projected costs of zero-emission fuels (as a result of innovation, economies of scale, and feedstock availability). Lifetimes for planes and ships are taken to be 30 and 25 years, respectively, and only combustion emissions are modeled (see Annex 1 on other emissions). The maritime sector is disaggregated into bulk/tanker and container shipping and aviation between passenger and cargo (accounting for differing emissions-intensities and income/price responsiveness for the different segments). Baseline emissions projections and behavioral responses to mitigation policies align with other industry models and empirical studies.[28] See Annex 4 for details on the models and their parameterization as well as the sensitivity of key results to different assumptions. The modeling exercise extends recent literature[29] by analyzing more policy scenarios and their impacts on emissions, revenue, and country-level distributional impact.

***Zero-emission fuels*: Assumptions related to zero-emission fuels play a critical role in estimating long-term emissions impacts of carbon pricing.** For aviation, SAF blending shares are modeled based on the price gap between a mix of biomass- and CO_2-based fuels, with planes purchased prior to 2030 limited to a maximum of 50 percent blending, and hydrogen and electrification are excluded from explicit calculations given their limited expected deployment through 2050 (ICAO 2022). Most SAF is sourced from biomass and waste, which face an upward sloping (but gradually flattening) supply curve because of limited, sustainably sourced feedstock availability and currently cost about $40 per gigajoule (GJ). A carbon price of $285 per ton is needed to achieve 50 percent SAF use in 2040 and about $400 per ton achieves price parity with jet fuel in 2050. For maritime, the share of ships capable of using both fossil and zero-emission fuels increases with strengthening mitigation policies and declining zero-emission fuel prices (as do the share of dual-firing heavy fuel oil and liquefied natural gas (LNG) powered ships, rather than strictly heavy fuel oil–powered ships). Depending on the vessel engine type, ships can reduce their emissions intensity through a combination of biofuel blending up to 20 percent and, for dual-firing LNG and zero-emission ships, respectively, using a share (or all) LNG or zero-emission fuel. The price of zero-emission fuel is expected to decline from around $70 per GJ in 2022 to $25 per GJ in 2050 (the average of projected green ammonia and methanol prices), resulting in price parity under a carbon price of $400 and $200 per ton in 2030 and 2050, respectively. Figures 4.1 and 4.3 in Annex 4 provide price projections for each fuel. Owing to the uncertainty around future prices of zero-emissions fuels, results are also provided for low and high price assumptions (see Annex Figure 4.4 for details).

[28] For example, ICAO (2022); IEA (2023); ICCT (2022).
[29] ICCT (2024); ICAO (2022).

***Baseline emissions projections*: With no new, or tightening of existing, mitigation measures, CO_2 emissions from international aviation and maritime are projected to increase by 85 and 20 percent between 2023 and 2040, respectively (Figure 5).**[30] The large increase in aviation emissions (in the absence of CORSIA)[31] is driven by demand growth of about 4 percent per year as a result of annual GDP growth of slightly over 3 percent and a high responsiveness of demand to income—income responsiveness is much lower for maritime products.[32] Energy efficiency improves in both sectors as a result of the gradual replacement of less efficient older planes and ships, while emissions intensity of fuel declines as the share of LNG grows in maritime. Zero-emissions fuel shares remain at about 5 percent through 2050 given that costs are 2.5–3 times those for oil-based fuels. If zero-emission fuel prices fall faster than expected, baseline emissions are about 15 percent lower, while slower price declines do not materially affect emissions because of limited zero-emission fuel in the base case (see Annex 4 for sensitivity analysis assumptions and additional analysis).

Figure 5. Baseline Emissions Projections



Source: IMF staff calculations.
Note: Data after 2023 are projections. The data only includes CO_2 emissions from fuel combustion. Aviation projections exclude the effects of Carbon Offsetting and Reduction Scheme for International Aviation. The decomposition shows annual changes in emissions. See Annex 4 for detailed fuel price assumptions.

***Policy scenarios*: Two policies are modeled for both aviation and maritime.** These include (1) a carbon tax (CT) by itself and (2) a carbon tax combined with a revenue-neutral feebate (CT + FB), with the policy stringency split evenly across instruments (this combination is equivalent to a feebate alone with an appropriately scaled pivot point). The feebate provides a sliding scale of subsidies (taxes) for planes/ships, respectively, with emission-intensities below (above) the previous year's average, promoting both energy efficiency improvements and lower carbon intensity of fuels.[33] Two policy stringencies are modeled:

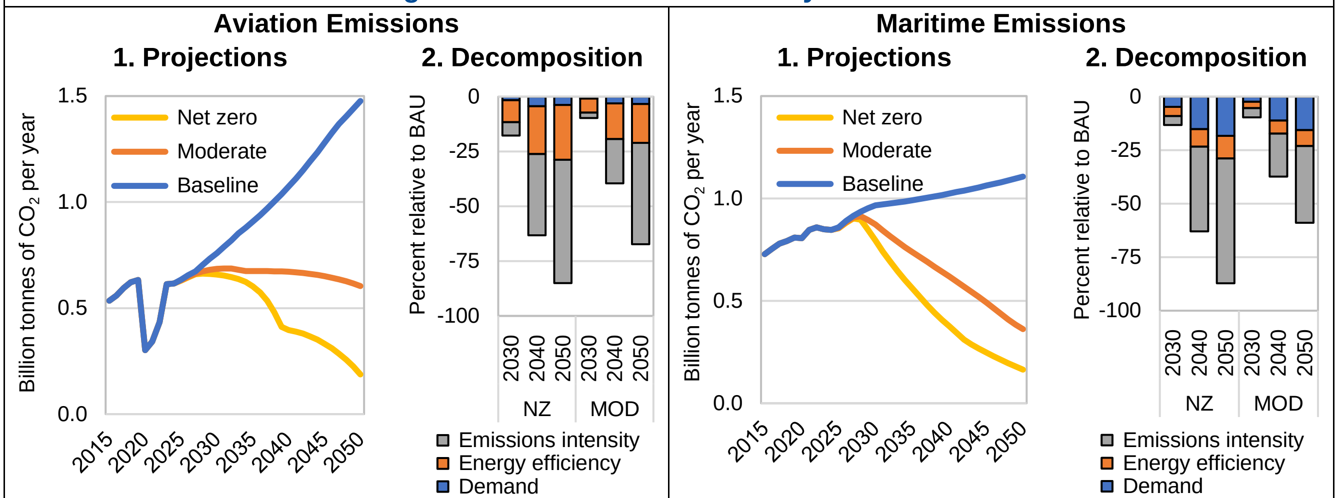
1. *Net zero pathway*: The explicit (or implicit) carbon price increases linearly from $20 per tonne in 2028 to $170 in 2035 to $500 per tonne by 2050, which puts aviation and maritime emissions reductions in line with the International Energy Agency's least cost pathway to achieve net zero (IEA 2023).
2. *Moderate pathway*: Carbon prices rise from $10 per tonne in 2028 to $250 per tonne by 2050.

[30] The model used in this note projects 2050 emissions of 250 and 29 percent above 2022 levels for international aviation and maritime, respectively. In the case of international aviation, this compares with 266 percent with no operational improvements and 152 percent with above trend but identified energy-efficiency improvements in ICAO (2022), total aviation emissions growth of 100 percent under stated policies in IEA (2023), and 117 percent in Smith and others (2016). For maritime, emissions grow 28 percent for stated policies in IEA (2023), 27 percent with no new measures, decline about 19 percent with no pricing measures in Longva and others (2024). A middle scenario of about 20 percent growth is in IMO (2020).
[31] The impacts of Carbon Offsetting and Reduction Scheme for International Aviation on within-sector aviation emissions are highly uncertain because of uncertainties over future emissions offset prices—a price trajectory equal to that assumed in the United Kingdom's analysis (UK 2022) would reduce baseline emissions by about 10 percent in 2040. Similarly, the future stringency of the IMO's energy and carbon-intensity standards are unknown—energy efficiency in the baseline projection meets the IMO targets (40 percent below 2008 levels) two years late in 2032 rather than 2030.
[32] Income elasticities (the percent increase in demand per 1 percent increase in income) are 1.5 for passenger flights (a luxury good), and 1, 0.8, and 0.5 percent for aviation freight, container shipping, and bulk/tanker shipping, respectively (Annex 4).
[33] While a fuel standard is not modeled, results are similar to those of the feebate by midcentury but with a substantial difference for maritime over the next decade since the fuel standard does not leverage energy efficiency improvements.

Results

***Emissions:* Aviation and maritime emissions peak around 2030 and decline steadily thereafter under the net zero pathways while falling only gradually under moderate policies.** See Figure 6, which shows emissions paths for only the carbon tax scenarios since both the carbon tax and carbon tax/feebate policies achieve similar emissions reductions. Under the least cost pathway to net zero, aviation and maritime emissions are significant in 2050 given their relatively high abatement costs. The near-term price responsiveness of both aviation and maritime emissions is less than that for CO_2 emissions from domestic fossil fuel use.[34]

Figure 6. Emissions under Policy Scenarios



Source: IMF staff calculations.
Notes. NZ = Net zero pathway, MOD = Moderate pathway. Only the carbon tax is shown since long-term emissions under the tax and combination policies do not vary significantly for a given stringency. See Annex 4 for detailed assumptions fuel price assumptions. Decompositions reflect the base case price assumptions.

Aviation: The net zero pathway reduces emissions 13 and 63 percent below baseline levels in 2030 and 2040, respectively. 50 percent SAF blending is achieved around 2040, at which time the emissions decline slows given limited SAF blending capabilities for older planes. Deeper decarbonization is achieved by the midcentury as the policy stringency increases, SAF supply constraints lessen allowing for SAF to achieve cost-parity with jet fuel, and a greater share of planes are 100 percent SAF capable. Energy efficiency improvements play a minor role compared with demand reductions (20 percent in 2040) and increased biofuel use (50 percent in 2040). Emissions fall slowly, under the moderate carbon tax when the policy is strong enough to promote SAF demand closer to the mid-2030s. Low and high assumptions for SAF prices result in 20 to 50 percent lower and higher emissions relative to the base case scenario, respectively.

Maritime: In this case, the net zero pathway reduces emissions 18 percent and 63 percent below baseline levels in 2030 and 2040, respectively. Fuel emissions-intensity improvements cause the bulk of emissions reductions (60 percent), followed by energy efficiency (35 percent), in 2040. Emissions continue to trend toward zero by midcentury from continuing reductions in green ammonia and methanol production costs and strengthening policies to the point that cost-parity is achieved between fossil and zero-emissions fuels, as well as the steady penetration of zero-emissions fuel capable ships with retirement of heavy fuel oil only ships.[35] Moderately stringent policies achieve neither cost-parity nor an immediate shift to zero-

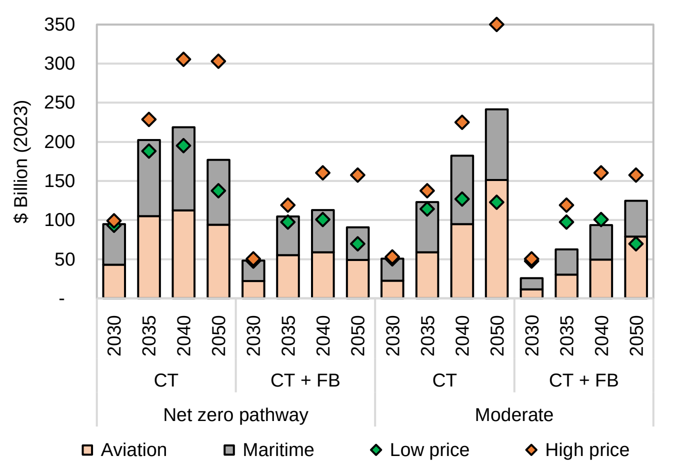
[34] Comparing with Black, Parry, and Zhunussova (2024), Figure 1.
[35] Under the net zero pathway, zero-emissions fuels for maritime are estimated to require up to 500, 2,600, and 4,350 TWh of green electricity in 2030, 2040, and 2050, respectively, under current electrolyzer efficiencies and assuming that all ammonia is green

emissions fuel ship purchases, resulting in emissions of about 120 percent higher than the net zero policies by midcentury. For a given policy, emissions are 50 percent higher or about 30 percent lower with high and low green hydrogen and methanol prices, respectively.

***Policy certainty and decarbonization*: Large and predictable price signals are needed to get emissions on track with decarbonization goals.** Planes and ships are long-lasting assets, and hence purchasers' decisions consider the expected policy impacts over the assets' lifetime. Model calculations assume that the energy efficiency of ship and plane designs and zero-emissions capabilities of new ships incorporate future increases in policy stringency (for example, a purchase in 2030 would consider the carbon price path from 2030 to retirement). Less confidence in the carbon price trajectory may make investors to discount expected future carbon prices, resulting in less investment in abatement technologies. For example, if calculations assumed that ship purchasers made decisions solely from policies at the time of purchase (that is, a scenario without credible future carbon pricing), the share of zero-emissions capable ships is 20 percent (compared with 40 percent with policy certainty), the energy efficiency of ships is 10 percent worse, and emissions are 520 million tons (compared to 380) in 2040 under the net zero carbon price scenario. Policy certainty is also important for aviation since the lifetime energy efficiency of a plane is determined primarily at the time of purchase whereas ships have a significant margin to improve energy efficiency through maintenance adjustments and speed reductions. Investment in zero-emission fuels would also be impacted, likely resulting in slower declines in production costs and, thus, more costly abatement (for example, the high price scenarios in Figure 6). The volatility of ETS and offset prices could have similar impacts but are not explicitly modeled because of uncertainties around the extent of price volatility and associated changes in behavioral responses.

***Revenue*: By 2035, policies are raising large amounts of revenue at $65 billion to $200 billion.** The net-zero-aligned carbon tax raises revenue of $100 billion by 2031, peaking at $230 billion in 2040 after which revenue losses from tax base erosion (mainly from switching to zero-emission fuels) dominate revenue gains from higher tax rates. The carbon tax/feebate combination raises slightly above half the revenue of carbon-tax-only policy. Moderate policy stringencies raise about half the revenue of net-zero-aligned policies in the short-term, but then generate the most revenue by midcentury as emissions reductions (especially in aviation) lag those of more stringent policies since SAF prices still exceed those of jet fuel (by about 40 percent in 2050). About half of revenue comes from each sector in 2030 but then the share from aviation grows as aviation emissions exceed those of maritime. Revenue over the next decade is somewhat resilient to lower zero-emission fuel prices since emissions reductions from zero-emissions fuel use primarily occur closer to 2040. Revenue continues to increase through midcentury to about $300 billion if zero-emission fuel prices decline more slowly than expected (see Figure 7).

Figure 7. Revenue Projections under Policy Scenarios



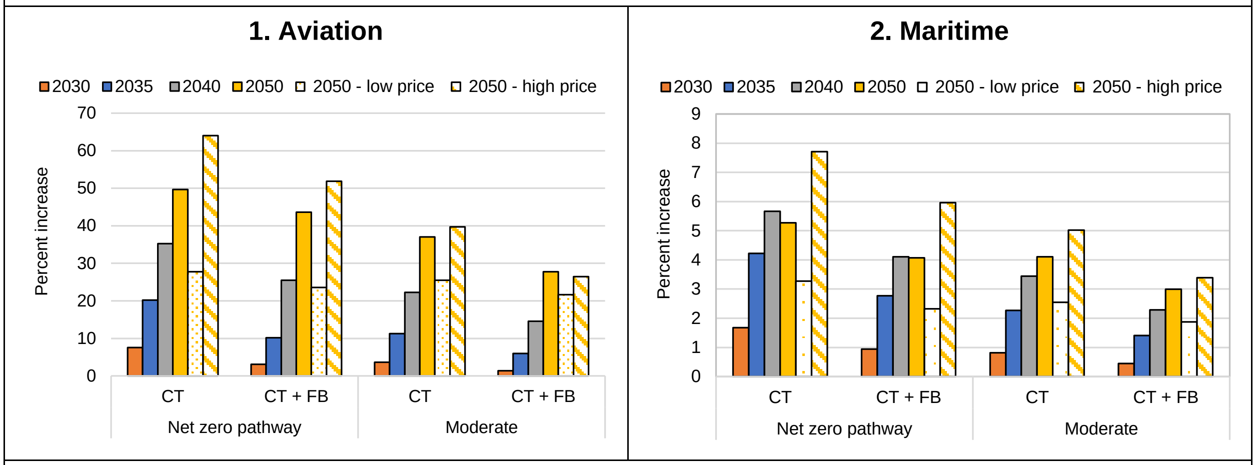
Source: IMF staff calculations.

Note: CT = carbon tax; FB = feebate.

rather than a mix of green and blue (that is, natural gas with carbon capture). This compares to the current global electricity use of 27,500 TWh, highlighting the need to scale up renewable power generation and synthetic e-fuel supply.

***Price impacts*: The cost of flying increases substantially whereas shipped product prices increase less than 6 percent (Figure 8).** Price increases are driven by higher fuel costs and switching to costlier lower emission fuels; the share of fuel costs in end user prices; energy efficiency improvements; investment in zero-emission fuel bunkering, storage, and plane/ship infrastructure; and the pass through of costs to end users. Aviation's larger price increases are caused primarily by the higher share of fuel in end user costs (about five times higher than for maritime) and, to a lesser extent, a bigger policy-induced fuel cost increase since switching to less-emission-intensive fuel is more costly and energy efficiency improvements are somewhat limited. Pass-through is assumed to be near complete at 95 percent for maritime and 100 percent for aviation based on empirical studies. Net zero aligned policies lead to maritime price increases peaking slightly after 2040 under base case assumptions, at which point zero-emissions fuels become cheaper than fossil fuel alternatives and the share of zero-emissions ships grows. The carbon tax-feebate combination leads to about half of the price increase in the near-term but prices begin to converge as abatement costs grow (red triangle in Figure 4). End user price increases are minimally affected by lower and higher price assumptions for zero-emissions fuels through the next decade because of limited zero-emissions fuel use but then diverge to be about 40–50 higher (lower) for the high (low) price assumptions by midcentury.

Figure 8. Price Impacts under Policy Scenarios



Source: IMF staff calculations.
Note: CT = carbon tax; FB = feebate.

***Distributional impacts.* The country-level economic impact of higher costs for internationally transported goods and flying depends on several factors**, including the level of trade openness, transport costs as a share of end user prices, reliance on tourism, and demand and supply elasticities for traded goods and tourism. Here, economic costs are estimated as the policy-induced loss in surplus, before any revenue use, from (1) reductions in consumption and production of shipped products and tourism and (2) the higher consumer costs paid and lower producer prices received for remaining consumption/production of shipped products and tourism. The analysis provides an illustration of potential trends, magnitudes, and drivers but should be interpreted with caution given uncertainties and data constraints—for example, the extent to which reduced flying for leisure is borne by travelers (through higher tourism prices) or destinations (through lower prices for tourism providers) is highly uncertain (see Annex 5 for methodological details and sensitivity analysis).

In addition, some relatively small but still important impacts are not captured. These include the loss for oil exporters from reduced oil demand and prices and benefits to (future) zero-emission fuel producers;[36] the benefits of smaller global temperature increases and less local air pollution, noise, and distortions caused by the current under-taxation of aviation and maritime; producer surplus losses to aircraft and maritime providers; and differential impacts across airlines and shipping companies based on their emissions-rates, cost of capital, and other factors impacting their ability to decarbonize. Further studies of such impacts could enrich distributional analysis but are not likely to materially change results given their magnitudes relative to global trade and tourism, both of which are captured here.

Impacts vary substantially across countries, indicating that any economic compensation for needs to consider some country-specific factors. The impacts are generally less than one percent of GDP in low income and emerging markets but larger for small developing states and some other less developed economies, offering a potential rationale for compensation (or weighting decarbonization policies toward feebates in the near-term) and reinforce the need to phase in policies to allow household and firms to adjust. Country-level impacts are listed in Annex 7.

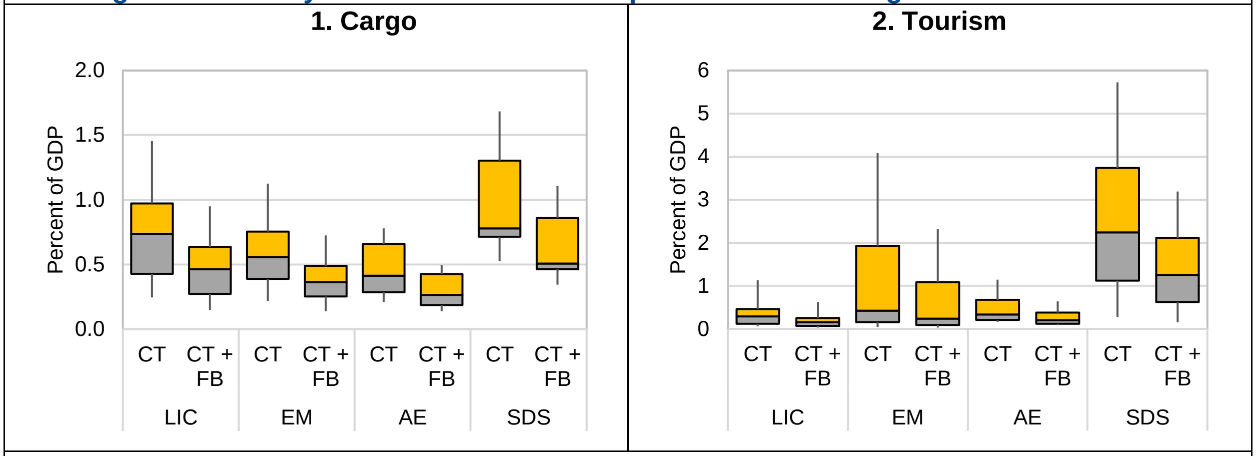
Shipped products: For cargo (both from air and sea), small and developing states are affected the most because of their higher transport costs and greater reliance on air and sea transport (10 and 40 percent above that of the average country, respectively), with impacts varying from 0.5 to 1.7 percent of GDP in 2035 under the net-zero-aligned carbon tax. Low-income countries and emerging markets are affected moderately since their above-average transport costs are offset by less reliance on traded goods. Advanced economies are the least affected because their low transportation costs (40 percent below average) more than make up for higher trade openness. The feebate and carbon tax combination results in slightly above half of the impact of the carbon tax in isolation in 2035, but the burdens across policies converge over time as emissions reductions increase since the cost of abatement (rather than tax payments on remaining emissions) makes up a larger portion of the decarbonization policies' costs.

Tourism: The largest impacts relate to tourism since there is a relatively large reduction in flying for leisure (for which price elasticities are estimated to be two to three times higher than for business) and tourism makes up a large share of GDP in some countries (for example, 21 countries have tourism-to-GDP shares greater than 20 percent). If it is assumed that tourism burdens are split evenly between tourist destinations and travelers, small and developing states face economic costs of 0.5 to 6 percent of GDP due to their higher tourism reliance (19 percent of GDP compared with 7 percent on average), whereas impacts are smallest for low-income and advanced countries where tourism to GDP is 3 percent on average.[37] The top quartile of emerging markets also faces substantial costs (2+ percent of GDP), respectively, owing to significant amounts of both tourism supply and demand. Again, impacts from the carbon tax, feebate combination are about half those of the carbon tax only in 2035.

[36] International aviation and maritime make up about 4 and 5 million barrels of oil per day (mbpd), respectively, compared with total oil consumption of 102 mbpd in 2023. Under business as usual, oil demand grows to 6 mbpd each in 2040, while consumption falls to about 2.5 mbpd each with a net zero align scenario. The impact on individual producers would depend on the global oil price impacts and, where the producing country is along the supply curve, with low-cost producers primarily affected through lower prices rather than reduced production.

[37] Results likely overestimate impacts for tourism suppliers with some level of uniqueness, as this would lead to more inelastic tourism demand and larger burdens for tourists, or underestimate impacts if there is switching toward domestic tourism in large countries (for example, China, India, United States) if, for example, domestic aviation decarbonization policies are relatively weak.

Figure 9. Country-Level Distributional Impact of Net Zero Aligned Policies in 2035

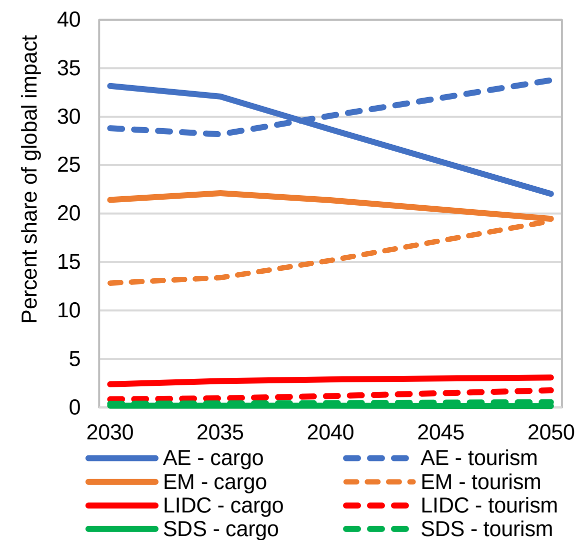


Source: IMF staff calculations.

Notes: The chart shows the 10th (end of the bottom line), 25th (bottom of grey box), median (intersection of grey and yellow box), 75th (top of yellow box), and 90th percentile (end of the top line) for countries within a given country group. AE = advanced economy; CT = carbon tax; EM = emerging market; FB = feebate; LIC = low-income country; SDS = small developing state. Cargo costs include impacts on both aviation and maritime trade.

Most of the negative economic impacts accrue to advanced economies (Figure 10) and, most likely, the wealthy within countries. When converting impacts to US dollars, about sixty percent of the economic impacts accrue to advanced economies followed by 35 percent in emerging markets and less than 5 percent in low income and small developing states through 2035.[38] Over time, the burden shifts slightly to emerging markets due to relatively fast economic growth but advanced economies still account for more than half through midcentury. Tourism and business air travel account for an increasing share of the impact as the global tourism industry grows with the global economy, rising from 45 to 60 percent share of the impact from 2030 to 2050. As tourism's share rises, the policy is likely to become more progressive within countries since higher income households disproportionally spend on tourism, especially in low- and middle-income countries. For example, the top two deciles account for over 90 percent of air travel in India, China, Brazil, and Indonesia (ICCT 2022).

Figure 10. Aggregate Distributional Impact by Country Group



Source: IMF staff calculations.

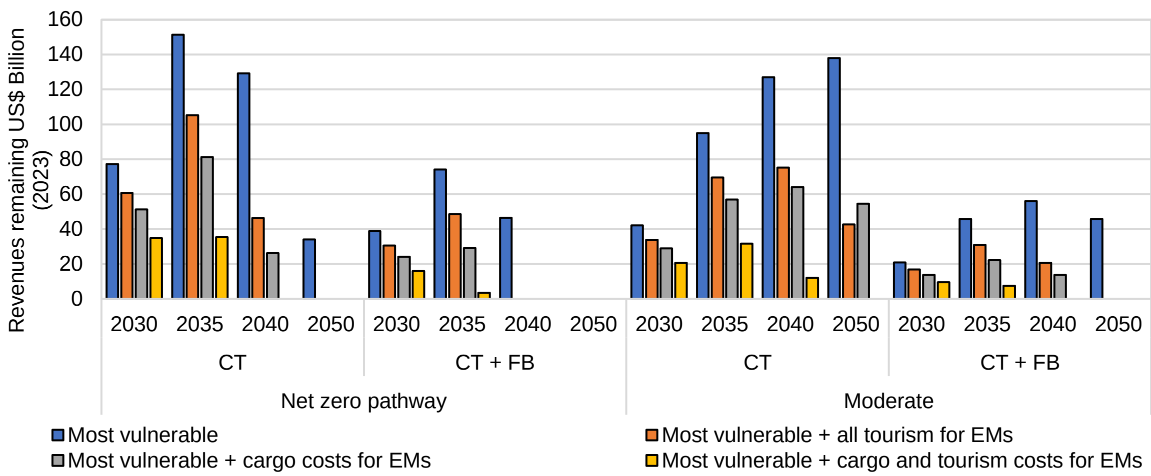
Note: AE = advanced economy; CT = carbon tax; EM = emerging market; FB = feebate; LIC = low-income country; SDS = small developing state. Cargo costs include impacts on both aviation and maritime trade. The chart shows distributional impact for the net zero aligned carbon tax but patterns are similar across scenarios.

Even after compensating less developed countries for economic costs, there would be substantial revenue left over out to around 2040, though this varies by scenario. Figure 11 shows the amount of revenue collected by mitigation policies that is remaining after various sets of countries are fully compensated for the economic impacts shown in Figure 9. For this illustrative analysis, the most vulnerable countries are defined as low-income countries,

[38] The analysis here likely understates impacts on advanced economies as income groupings for 2024 are used but some low income and emerging markets will move to advanced economy status over time.

small developing states, and tourism-dependent emerging markets.[39] Under the net-zero-aligned carbon-pricing scenario, aggregate economic impacts on the most vulnerable countries are $15 billion in 2030, increasing to $70 billion in 2040, leaving annual revenue of over $100 billion from 2032 to 2045 after full compensation. If emerging markets are also compensated for cargo costs, remaining revenue falls to $50 and $80 billion in 2030 and 2035, respectively, and further declines to about $35 billion in 2030 and 2035 when adding compensation for emerging markets' tourism impacts. The feebate/carbon price scenario imposes smaller burdens but leaves substantially less revenue remaining. For example, in 2035, there is about $30 billion in revenue after compensation, less than half that available from carbon pricing only (since the feebate does not generate revenues). Toward midcentury, revenues remaining declines as the sectors decarbonize economic costs from higher transport costs rise (primarily caused by more expensive zero-emission fuels). Compensation exceeds revenue under most policies by the early 2040s. The moderate carbon tax results in less remaining revenue after compensating the most vulnerable and cargo costs in emerging markets over the next decade, plateauing at around $50 billion in 2035.[40]

Figure 11. Revenue Remaining after Compensation for Economic Impacts



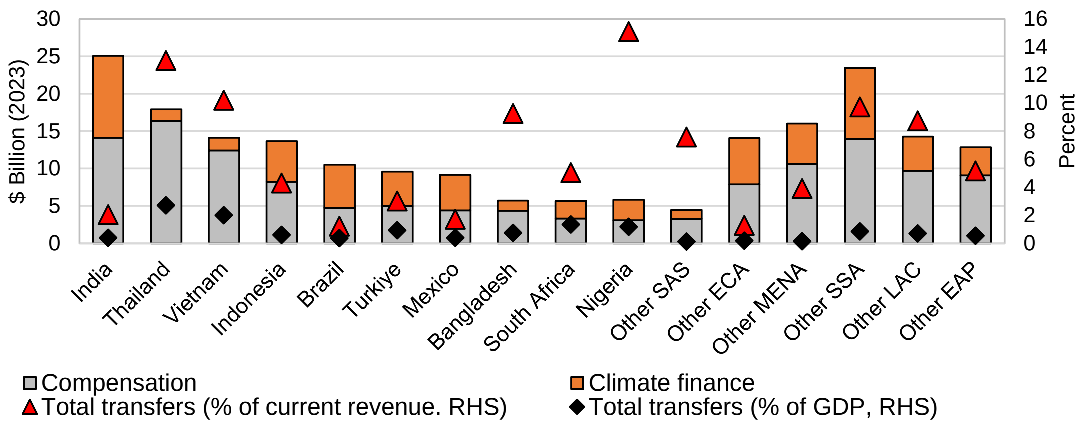
Source: IMF staff calculations.
Notes: Most vulnerable is defined as low income countries, small developing states and tourism reliant emerging markets, with tourism reliance measured as a tourism to GDP shares of greater than 10 percent. CT = carbon tax; FB = feebate; SDS = small developing state. Cargo costs include impacts on both aviation and maritime trade. The chart shows cases where compensation exceeds revenue as zero.

These policies could substantially increase concessionary climate finance to developing countries, potentially dwarfing even current total official development assistance. Under an illustrative scenario, the most vulnerable countries (that is, small developing states, low-income countries, and tourism-reliant emerging markets) are compensated for all costs while other emerging markets are compensated for cargo costs. The remaining revenue is then allocated based on regional climate finance flows (reported by CPI 2023), apportioned based on GDP within a given region. The biggest transfers in dollar terms go to the largest emerging market economies—for example, $25 billion for India, $18 billion

[39] Emerging markets exclude those in the World Bank's high-income classification.
[40] Results would likely not be significantly affected if a portion of revenues were allocated to sector research and development (R&D) where there is a strong economic rationale for government support. While R&D needs are uncertain, ICAO (2022) estimates that public R&D support for aviation decarbonization needs are roughly $100 billion through 2050 (or $4 billion a year on average but there may be some rationale for front-loading support). There are no known studies on the public R&D support needed to achieve net zero maritime emissions. While total investment needs are potentially higher for aviation—for example, $1.4 to $2 trillion for maritime (Krantz and others 2020) versus $5 trillion for aviation (WEF 2023)—the extent of public support would depend on the size of positive externalities (for example, learning by doing and knowledge spillovers). Domestic policies, such as the SAF tax credits under the US Inflation Reduction Act, provide R&D support and reduce the need for international support.

for Thailand, and between $10 to $15 billion for Brazil, Indonesia, and Vietnam each. When expressed as a share of current government revenue, transfers reach 9 percent for Sub-Saharan Africa and Latin American and Caribbean countries (reflecting lower current revenue to GDP ratio and a larger share of countries receiving compensation). Transfers would exceed current Official Development Assistance for 51 countries. See Annex 7 for country-level information transfer levels under different mitigation policies.

Figure 12. Illustrative Allocation of Revenue for Net Zero Aligned Carbon Tax in 2035



Source: IMF staff calculations.
Notes: Total transfers = compensation plus climate finance. SAS = South Asia; ECA = Europe & Central Asia; MENA = Middle East & North Africa; LAC = Latin America & Caribbean; SSA = Sub-Saharan Africa; EAP = East Asia & Pacific.

Conclusion

There is an urgent need for global action to kick-start the sectors' decarbonization. The time has come for a global tax in international aviation and shipping. Carbon pricing instruments, such as those examined in this note, can accelerate decarbonization (via technological development of for example zero-emission fuels and efficiency improvements) while raising substantial revenues. A carbon tax is the most desirable instrument overall—it is simpler than an emissions trading regime and provides more certainty over future prices, which is important for mobilizing investment in zero-emission fuels. Revenues raised could be up to $200 billion by 2035, which could make a substantial contribution to climate finance for developing economies. This could be a game changer in the international climate negotiations, potentially unlocking further mitigation ambition in developing countries and narrowing the huge global mitigation ambition gap (Black and others 2024). Alternatively, a feebate also provides price certainty and may face less political opposition but raises fewer revenues.

Various obstacles have, however, held up progress on pricing emissions from aviation and shipping. Besides legal uncertainties (for aviation) and extreme mobility of the tax base (for shipping), there is a lack of experience and administrative capacity at the ICAO and IMO for overseeing a global tax or similar regime. That said, systems could now be administratively feasible with recent innovations in digitalized payments, fuel-reporting requirements, satellite tracking of planes/ships, and airport/port access conditional on upfront payments, as well as tax collection by national authorities or new specialized funds supervised by the ICAO and IMO. The more fundamental obstacles include opposition by several countries to the establishment of the robust price signals needed to level the playing field for zero-emission fuels, alongside disagreements on carbon price trajectories and use of potential revenues.

Moving forward, dialogue across multiple forums could establish a broad coalition of support for carbon pricing. Regular meetings of the ICAO and IMO provide a platform for extensive consultations among member states and industry stakeholders. Stock-taking of, and dialogue at the United Nations

Framework Convention on Climate Change meetings could emphasize the potentially catalyzing role from allocating revenues from international transport fuel charges. Such charges could also be incorporated into ongoing discussions at a future UN convention on international tax cooperation[41] and meetings of the G20. Coalition building requires an awareness about the lack of alternative effective policy options for achieving decarbonization goals (aside from outright bans on conventional planes and ships), the need for robust price signals, the role of compensation systems for vulnerable countries, and the trade-offs between explicit pricing and feebate-type approaches. Compromise over revenue allocations may also be needed, with revenues split across multiple objectives. However, only a coalition of the willing can steer the world toward finally decarbonizing international aviation and shipping.

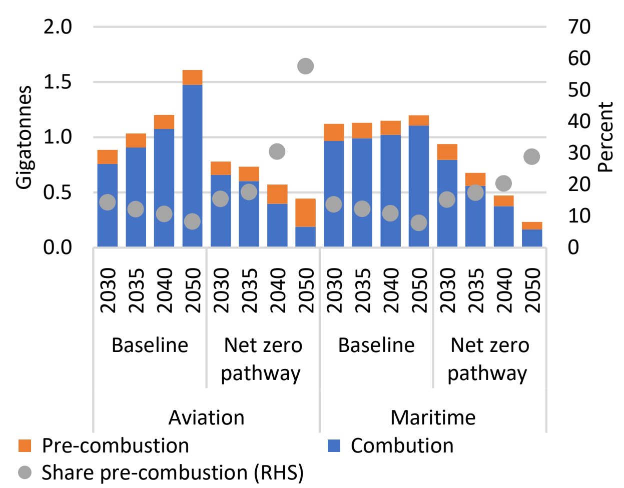
[41] See IMF (2024) on broader areas of tax cooperation.

Annex 1. Non-CO_2 and Life Cycle Emissions

Emissions are incurred in the production of biofuels, other zero-emission fuels, and fossil fuels. These pre-combustion emissions (that is, well-to-tank emissions) can vary significantly across fuel sources, meaning that the impact on lifecycle emissions of switching from fossil fuels to different zero-emissions fuels is not straightforward. For aviation, contrails and other non-CO_2 emissions can have a significant warming impact and, according to initial estimates, may be much lower with sustainable aviation fuels (SAF). This annex provides a brief quantification of lifecycle emissions and short-lived warming impacts of aviation fuels.

The share of pre-combustion emissions relative to combustion emissions is expected to increase as aviation and maritime decarbonize, highlighting the importance of strong sustainability criteria and standardized emissions reporting for zero-emissions fuels. For aviation, biomass and waste-based biofuels are assumed to make up the majority of SAF through midcentury and to have pre-combustion emissions of 21 to 30 kg per gigajoule (GJ), on average, compared with 13 to 17 kg per GJ for CO_2-based biofuels and 6 to 16 kg per GJ for jet fuel (ICAO 2022). Maritime zero-emission fuels generally have smaller non-combustion emissions because of reliance on ammonia and methanol produced using low-carbon electricity (3 kg per GJ) or with carbon capture and storage (18 kg per GJ) (MMMCZCS 2024). It should be noted that pre-combustion emissions estimates, including for fossil fuels, are highly uncertain and likely vary substantially by fuel source.

Annex Figure 1.1. Lifecycle Emissions



Source: IMF staff calculations.
Note: Contrails and other non-CO_2 emissions are not included in the chart.

Contrails, which form as particles emitted by jet fuel freezes, and nitrogen oxides (NO_x) are important sources of global warming from aviation. The magnitude of the associated warming impact is uncertain, although estimates from a recent study show that contrails and NO_x triple the short-term warming impact of jet fuel and, at a minimum, increase the warming effects by two-thirds (Lee and others 2021). It is expected, but not conclusively studied, that SAF would reduce contrails significantly—Voigt and others (2021) estimate that switching from jet fuel to SAF reduces contrails by 50 to 70 percent. Additional changes can reduce contrails and NO_x, including the use of jet fuel with less aromatic and sulfur contamination, and rerouting flights to weather conditions, times, and locations that produce fewer contrails. Policies to incentivize changes to exploit these opportunities could include higher taxes on flights more likely to produce contrails (for example, those in the early evening and night) and taxes or requirements to lower aromatic content of fuel within safe ranges.

Increasing demand for biomass and waste-based-biofuels and synthetic zero-emission fuels (for example, CO_2-based biofuels and green hydrogen-based fuels methanol and ammonia) put pressure on land and electricity demand, respectively (Annex Figure 1.2).

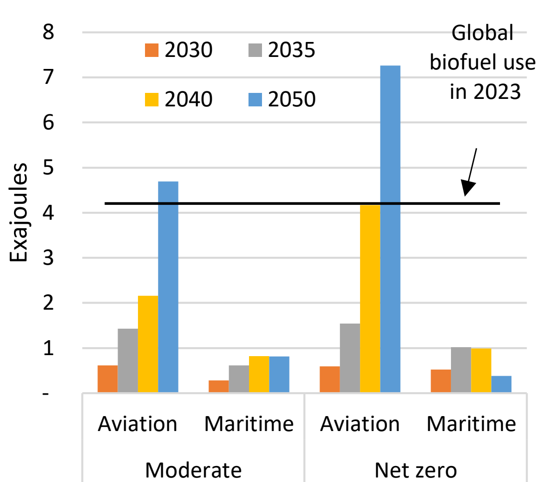
Biofuels are currently produced only using biomass and waste-based feedstocks at commercial scale and it is expected that these sources will dominate through midcentury—for example, ICAO (2022) estimates that two-thirds of biofuels for aviation are produced from biomass and waste and the remainder using captured CO_2 as a feedstock unless there is a breakthrough in CO_2-based biofuel technologies. Under the net zero scenario modeled here, biomass and waste-based biofuel demand for aviation and maritime increases from current levels of effectively zero (600 million liters in 2023 or 0.02 exajoules [EJ] for aviation in 2023) to 1.1 EJ by 2030 and then significantly increases to 2.6, 5.2, and 7.6 EJ in 2035, 2040, and 2050, respectively. The majority of projected biofuel use is for aviation, given the relatively low-cost potential of other zero-emissions fuels in maritime. This compares with existing biofuel production, which is used primarily for road transport, or 4.3 EJ (IEA 2024).

Producing biofuels from carbon and green hydrogen requires large amounts of electricity to capture CO_2 from the air (inclusive of direct air capture and capture from fossil fuel combustion) and extract hydrogen from water (green hydrogen produced with electrolysis). Water-based electrolysis and direct air capture are assumed to require 1.7 and 2.0 units of electricity per unit of fuel, declining by about 5 percent through 2050 (in line with ICAO 2022). For the calculations here, it is assumed that all hydrogen is produced using green electricity; but, in practice, hydrogen production will rely on a mix of green electricity and natural gas with carbon capture (that is, blue hydrogen). Production of hydrogen and CO_2-based maritime fuels is projected to require over 1,000 terawatt hours (TWh) of (green) electricity by the early 2030s, while aviation demand is negligible. Electricity demand for hydrogen and CO_2-based zero-emissions is expected to increase to about 3,000 and 6,000 TWh by 2040 and 2050, respectively. To put these figures in perspective, current global electricity production is about 25,000 TWh.

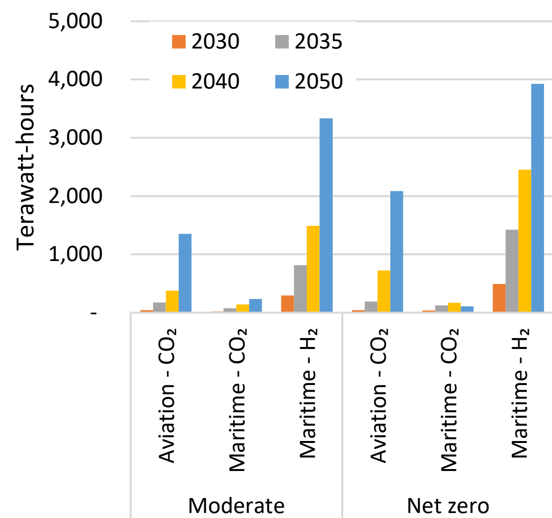
The large land and electricity demands, as a result of the increasing demand for biomass-based biofuels and CO_2 and hydrogen fuels, will need to be managed in order to ensure efficient and effective decarbonization. Ideally, this would be done through extending carbon-pricing systems to incorporate lifecycle emissions, potentially with revenue collected on pre-combustion emissions allocated to the fuel producing country since pre-combustion emissions are accounted for at the domestic level under the framework of the United Nations Framework Convention on Climate Change. An improved and standardized measurement of pre-combustion emissions, including for oil and natural gas, would be needed to operationalize such a policy.

Annex Figure 1.2. Biofuel and Other Zero-Emissions Fuel Use

1. Biomass and Waste-Based Biofuel Use



2. Electricity Demand and Green-Hydrogen–Based Fuels



Source: IMF staff calculations.

Annex 2. A Closer Look at the Carbon Offsetting and Reduction Scheme for International Aviation

The Carbon Offsetting and Reduction Scheme for International Aviation (CORSIA) obliges most airlines to monitor and report their emissions (since 2019) and (since 2021) to purchase carbon credits in other sectors to compensate for any growth in CO_2 emissions above 2019 levels.[42]

The ICAO allows for the use of offsets from various voluntary carbon market programs (such as the Clean Development Mechanism, American Carbon Registry, Verified Carbon Standard). The system is being implemented in three phases: the pilot phase, 2021–23; the first phase, 2024–26; and the second phase, 2027–35 (split into three-year compliance cycles).[43]

Participation is voluntary for the pilot and first phases. As of January 2024, 125 countries are participating including those with large international aviation markets such as Australia, the United Kingdom, and the United States (non-participants include Brazil, China, India, and Russia). Beginning in 2027, however, CORSIA will be mandatory for more than 90 percent of international flights, except for those to and from countries with low aviation activity or classified as "Least Developed," "Small Island Developing," or "Landlocked Developing." Compliance obligations apply to flights between CORSIA-participating countries.

Between 2021 and 2029, sectoral crediting obligations are being divided among participating airplane operators based solely on the sector's global average growth factor of emissions each year. Beginning in 2030, crediting obligations will be determined based on the average growth factor in emissions not only of the sector but also of individual operators. Every three years starting in 2025, operators will have to acquire and retire the number of emissions units that match their offsetting obligation for the relevant compliance period.

Originally, the baseline for determining the annual CO_2 emissions cap for the entire 2021–35 period was to be based on the average of international aviation's 2019 and 2020 emissions. After the COVID-19 pandemic (which lowered 2020 emissions by more than 50 percent), the ICAO announced that benchmark emissions would be based on (1) 2019 emissions for the pilot phase and (2) 85 percent of 2019 emissions from 2024 onward.

[42] This applies to direct ("scope 1") emissions only.
[43] See ICAO (2013) and www.icao.int/environmental-protection/CORSIA/Pages/default.aspx.

Annex 3. Schemes for Compensating Vulnerable Countries

Aviation

Although a portion of the burden of explicit carbon pricing for aviation is likely to fall on travelers from higher-income countries and relatively well-off domestic travelers, impacts on low-income countries and tourism destinations are nonetheless a concern, suggesting a need for compensation mechanisms. These mechanisms might include the following measures:

- Low-income countries retain revenues from charges on fuel disbursements within their borders for international flights, which would amount to about half of the total fuel consumed for a flight to and from another country.
- Rebate the ICAO-collected revenues to low-income countries based, for example, on inward passenger kilometers traveled to that country as a share of global passenger kilometers traveled.

Both mechanisms cause some distortions—for example, under the first, developing economies may have an additional incentive to establish themselves as hubs (to expand their revenue base), while under the second they have an incentive to encourage more passengers—but these seem manageable. The first scheme is simpler, less demanding in its information requirements, and it seems likely to deliver adequate compensation in many cases.[44]

Maritime

Similarly, for maritime, the concern has focused on low-income countries and (remote) small island developing states, where imports and shipping costs are disproportionately high relative to GDP (the rationale for compensating middle- and high-income developing economies is questionable, given the relatively small impact of carbon pricing on import prices). There are several options for compensation, although no single mechanism may be entirely satisfactory. Some of the measures for compensation are as follows:

- Reimbursing vulnerable countries for charges on their maritime fuel sales would be reasonable in most cases; but there are exceptions—countries with hub ports (where ships frequently refuel prior to offloading cargo in other countries) would be overcompensated while small islands where ships offload cargo without refueling others would be undercompensated.
- Basing compensation on countries' shares of global import values is another possibility.[45] Import value tends to be negatively corrected with CO_2 however (for example, light electronic equipment has a low ratio of CO_2 to import value). This approach may disadvantage poor countries importing low value products.
- Compensation could also be based on cross-country distributional impact studies by external experts.

Some form of acceptable compensation system should be feasible, however, especially given the modest impact of carbon pricing on landed import prices.[46]

[44] See Keen, Parry, and Strand (2013), Section 3.2.
[45] See, for example, Stochniol (2011).
[46] This is still the case even though import price increases could be approximately twice as high for low-income countries and small island developing states because maritime transport costs as a share of landed import prices are about double those for other countries (UNCTAD 2017).

Annex 4. Modeling Approach

A similar approach is used to forecast maritime and aviation demand and emissions under baseline and policy scenarios. At a high level, this approach explicitly models the capital stock, split between fossil fuel–based and zero-emissions ships and planes. As capital is retired and demand grows, new ships and planes are added to the capital stock based on the relative total cost of fossil fuel versus zero-emissions options for ships and manufacturers announcements for planes. The fuel and emissions intensity of fossil fuel–based ships and planes changes with exogenous technological improvement and fuel costs, which vary according to international prices and mitigation policies. The specific assumptions for aviation and maritime are described in the following sections.

Aviation

Separate calculations are performed for passenger and cargo planes given their different economics, particularly their variation in fuel costs as a share of total costs. Historical data comes from various sources, including emissions (IEA 2023), commercial passenger and freight activity (IATA 2024; ICAO 2024), and fuel prices (IATA 2023; EIA 2024).[47]

Capital Stock

All current planes are assumed to allow for up to 50 percent blending with biofuels (EASA 2022) and no planes allowing for 100 percent SAF are assumed to come into the market before 2030.[48] From 2030 to 2035, the share of new planes capable of using all SAF progressively increases to 100 percent as per the given plans by major aircraft manufacturers (ICCT 2024). The total quantity of new planes is equal to those retired in the previous year and additional demand determined using an income elasticity of 1.5 (IATA 2008, and in line with growth from ICAO 2022).

Fuel Prices

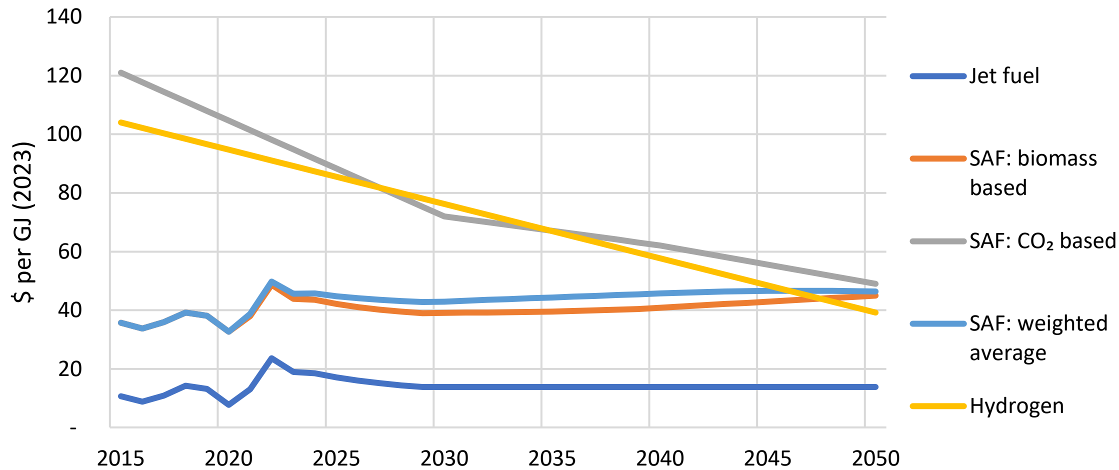
The prices of SAF and jet fuel are projected forward using the estimates from ICAO 2022 (for example, Figures 6.2 and 6.4 of ICAO 2022) and the April 2024 IMF World Economic Outlook (WEO), respectively (Annex Figure 4.1). Jet fuel prices are assumed to change in tandem with future crude oil prices, falling slightly below current levels through 2027 and then remaining stable in constant real terms. A weighted average across biomass-based, CO_2-based SAF, and hydrogen is assumed for zero-emissions fuel. Biomass-based SAF currently costs $20–$30 per gigajoule (GJ) more than jet fuel, with the difference slowly declining over time through learning by doing. The biomass-based SAF supply curve is upward sloping because of reliance on land and strict sustainability requirements, but is expected to flatten over time as technology improves.[49] CO_2-based SAF declines from about $100 per GJ to just below $50 per GJ by 2050 and hydrogen falls from $95 per GJ to $39 per GJ by 2050, but also faces an upward price pressure as supply expands because of land and clean energy constraints. In addition, $3 and $13 per GJ are added to SAF and hydrogen prices to account for the additional spending needed for related infrastructure in airports (estimated by ICAO 2022 to be $125 billion). The share of biomass-based SAF, CO_2-based SAF, and hydrogen is calibrated to follow ICAO assumptions, with each respectively making up 65, 31, and 4 percent of fuel under a net-zero-aligned trajectory in 2050.

[47] Annual data on the portion of emissions from international passenger and cargo aviation, respectively, is not available; so, the share of revenue from cargo versus passenger revenue (which is similar to Graver, Zhang, and Rutherford [2019]) is used.

[48] Additional research is needed to assess whether it is safe to achieve blending ratios of above 50 percent using current technology and the expectation is that new planes, with technological modifications, are needed to achieve 100 percent blending (EASA 2022). Aircraft manufacturers target 100-percent SAF-compatible airplanes by 2030.

[49] This is incorporated into the model as a change in biomass cost of $0.06 per gigajoule (GJ) increase for every billion GJ of biomass-based SAF consumed over the preceding three years but declining to $0.035 by 2050 (in line with ICAO 2022, M5, Figure 6.2).

Annex Figure 4.1. Prices of Aviation Fuels over Time



Source: IMF staff calculations using data from ICAO 2022 and IMF WEO 2024.
Note: SAF = sustainable aviation fuels. GJ = gigajoule

Emissions Intensity of Aviation

The fuel intensity of aviation changes using a fuel price elasticity of −0.2 (Keen, Parry, and Strand 2013), with 20 percent of the behavioral response coming from changes to the maintenance and operations of existing aircraft versus the purchase of more efficient new aircraft (in line with ICAO 2022). Additional emissions reductions come from biofuel blending with fossil fuels, assuming a relationship between carbon prices and biofuel blends aligned with the ICCT (2022) ($300 per ton of CO_2 is needed to achieve 50 percent SAF use in 2050 under base case assumptions). The energy efficiency of new planes is 15 percent better than that of the average existing plane and all planes have an annual exogenous energy efficiency improvement of 0.5 percent—the latter is needed to replicate historical energy efficiency changes. The emissions intensity of jet fuel and SAF, including both well-to-tank and tank-to-wake, are from the ICAO (ICAO 2022).

Activity per Plane

Aviation activity per plane (that is, revenue passenger and cargo ton kilometers) assumes a price elasticity of ticket prices of −0.6 for passenger travel (ICAO 2022; ICCT 2022) and −1 for cargo, with fuel costs making up 25 percent of ticket prices for passengers and 3 percent of shipped product value for cargo, under the baseline fuel price assumptions. Pass-through of taxes to end user prices is assumed to be complete (Keen, Parry, and Strand 2013; Wozny 2024) and in line with the data showing tight profit margins for airlines.

Maritime

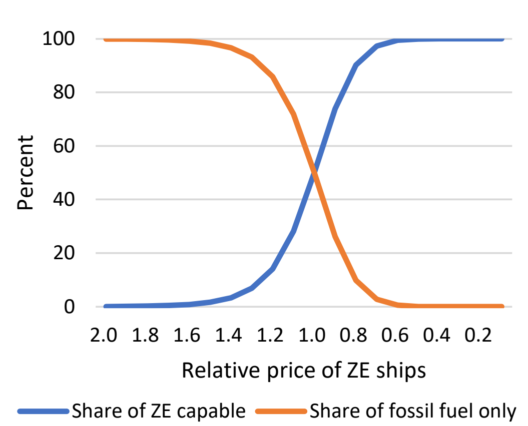
Separate calculations are performed for bulk (both wet and dry) and container shipping given their different economics, particularly variation in income elasticities and fuel costs as a share of total costs. Historical data on fuel use and prices, emissions intensities, emissions, and shipping activity come from UNCTAD (2023).

Capital Stock

All the available ships are assumed to be fossil fuel–based with about 6,000 and 45,000 being container and bulk in 2023, respectively (UNCTAD 2023). The present orderbook contains 64 percent, 22 percent, and 14 percent heavy-fuel-oil (HFO)-only, dual-powered liquefied natural gas (LNG) and HFO, and HFO and zero-emission ships and lead times are 3 to 4 years (BRS 2024).[50] Once the existing orderbook is fulfilled in 2027, the portion of new ships capable of using HFO-only, HFO and LNG, and HFO and zero-emissions fuels is determined based on the TCO for a representative vessel of each type (for example, fossil fuel–powered container) using the assumptions in Annex Table 4.1.

The relationship between the relative prices of the representative vessel is parameterized based on the orderbook, reflecting that a portion of ships are zero-emissions and LNG capable despite a higher relative cost (Annex Figure 4.2 for zero-emissions capable versus HFO ships). The total quantity of new ships is equal to the number retired in the previous year with additional demand determined using an income elasticity of 0.5 and 0.8 for bulk and container products, respectively.[51] The distance traveled per ship is adjusted based on changes in shipped goods demand using shipped good's price elasticity of −1and a share of fuel costs in shipped goods value of 4 percent for tankers/bulk and 6 percent for containers under current price levels.

Annex Figure 4.2. Price Sensitivity of Purchase Decisions



Source: IMF staff calculations.
Note: ZE = zero emissions.

Annex Table 4.1. Total Cost of Ownership Parameters for Vessels

	HFO-Only	LNG with HFO	Zero-Emissions with HFO
Ship purchase price	$80 million per ship (UMAS 2023)	20 percent higher than HFO (UNCTAD 2023)	
Lifetime	25 years (in line with the NavigaTE model, MMMCZCS 2023)		
Discount rate	6.7 percent (Damodaran 2024)		
Fuel economy	12.5 percent less than that of the average, existing ship (UNCTAD 2023)		
Fuel costs[2]	Annex Figure 4.3 (EIA for historical HFO, IMF WEO 2024 for projections and both historical and projected LNG prices)		Annex Figure 4.3 (MMMCZCS 2024)

Source: UMAS (2023), UNCTAD (2023), MMMCZCS (2023, 2024), Damodaran (2024), EIA (2024), IMF WEO (2024)
Notes: The fuel economy improvement of new ships implies fuel economy of the in-use shipping fleet increases at 0.5 percent per year which is consistent with Smith and others (2016). Vessel purchase decisions consider the average, expected post tax fuel price over the next 25 years. HFO = heavy fuel oil; LNG = liquefied natural gas; WEO = IMF World Economic Outlook

Fuel Prices

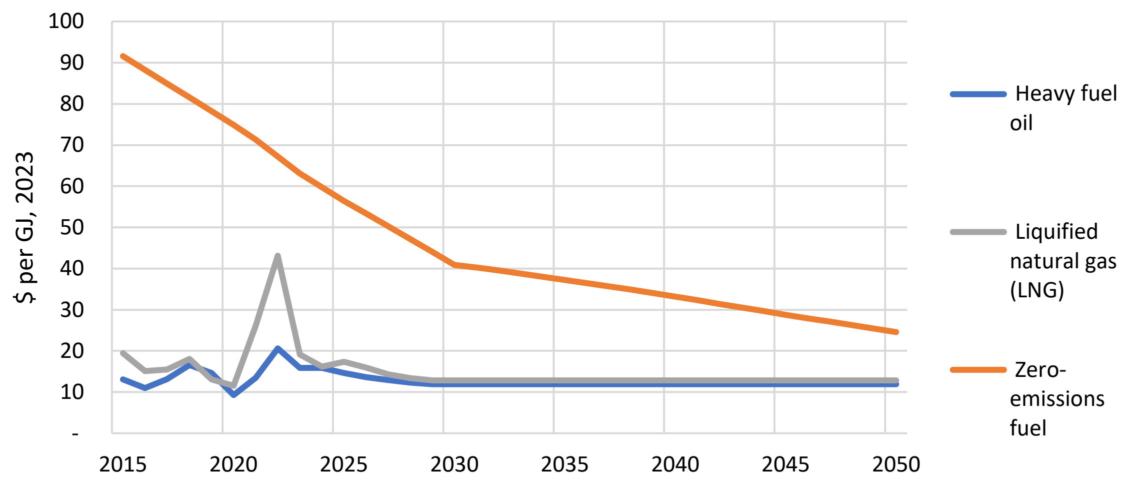
Maritime fuel price projections are from the IMF WEO for fossil fuels and the Mærsk McKinney Møller Center (MMMCZCS 2024) for zero-emission fuels. HFO prices are assumed to move in tandem with crude oil; the LNG price is the average of the Japanese and European natural gas prices reported by the WEO, with an additional $6 per ton added to account for liquefaction costs in the United States and Europe and since LNG prices need to be above those of HFO to rationalize the share of HFO-only ships

[50] Six percent of ships will be dual fuel capable once the current orderbook is fulfilled (currently 3 percent), with most allowing fueling of liquefied natural gas (LNG) and a minimal amount allowing for dual fueling using methanol, ammonia, batteries, or wind (BRS 2024).

[51] This below-unitary income elasticity for container shipping reflects the larger budget shares of services and higher quality products among higher income households. Estimated income elasticities for crude oil (a major component of bulk shipping) are around 0.5 to 1.0 (for example, Gately and Huntington 2001; Xiong and Wu 2009; Huntington, Barrios, and Arora 2017), although the lower bound in this range seems to more accurately account for future efforts to curb fossil fuel use. Global GDP follows the IMF WEO's assumptions (a 16 expansion between 2023 and 2029 (IMF WEO April 2024) and to grow at 3 percent a year thereafter).

in the current orderbook. The zero-emission fuel price assumes the average of green ammonia in Europe, Asia, and the US reported in MMMCZCS (2024), with an additional $2 per GJ included to account for $150 billion investments in bunkering infrastructure and CO_2 transport (WEF 2023), which it is assumed are not included in zero-emissions fuel price projections. Of the price changes from policies, 95 percent is assumed to be passed through to end user prices (Keen, Parry, and Strand 2013).

Annex Figure 4.3. Prices of Shipping Fuels over Time



Source: IMF staff calculations using data from MMMCZCS 2024 and April 2024 IMF World Economic Outlook database.

Emissions Intensity of Shipping

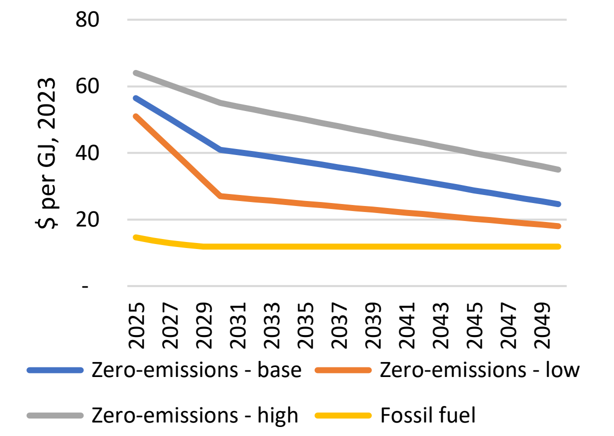
The fuel intensity of shipping changes using a fuel price elasticity of −0.45 (based on McCollum, Gould, and Greene 2009; Smith and others 2016), with 75 percent of the behavioral response attributed to changes made to existing ships (for example, reduced speeds and better maintenance) and 25 percent to factors determined at the time of purchase (for example, engine and ship design), in line with IMO 2020, Table 78. Additional emissions reductions come from (1) biofuel blending with fossil fuels, assuming a relationship between carbon prices and biofuel blends aligned with the International Energy Agency (a $1 per ton of CO_2 results in 0.08 percent biofuel blending); (2) LNG use for dual-powered LNG–HFO ships, assuming the share of LNG increases from 0 to 100 percent as the relative price of LNG increases from −3 to 3 per GJ; and (3) zero-emissions fuels for dual powered zero-emissions capable ships, assuming a zero-emissions share of 0 under zero-emissions current prices and linearly increasing to 100 percent as post-tax prices reach parity. The emissions intensity for each fuel, including both well-to-tank and tank-to-wake, are from the Mærsk fuel cost calculator (MMMCZCS 2024).

Sensitivity Analysis

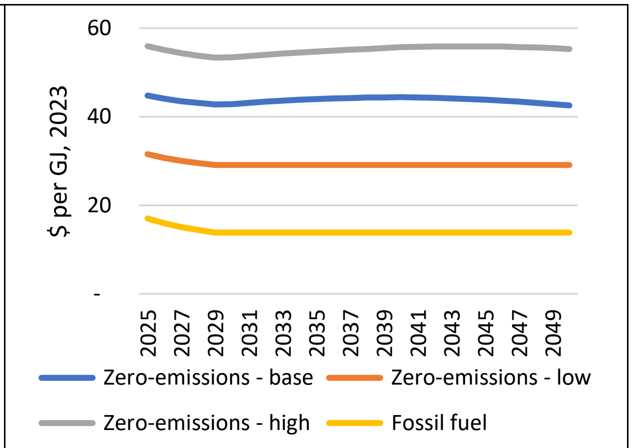
There is significant uncertainty over the future price trajectory of zero-emissions fuels. The analysis here presents emissions, revenue, and price increases under a high and low price scenario. For maritime, the prices are the low and high price scenarios in UMAS 2023 and, for aviation, the high and low prices are 25 above and below, respectively, and the low case has no supply constraint. See Annex Figure 4.4 for prices, showing that zero-emissions fuels do not achieve price parity with fossil fuel alternatives even under lower price assumptions.

Annex Figure 4.4. Fuel Price Sensitivity Analysis Assumptions

1. Maritime	2. Aviation



Source: UMAS 2023 for zero-emissions fuel.



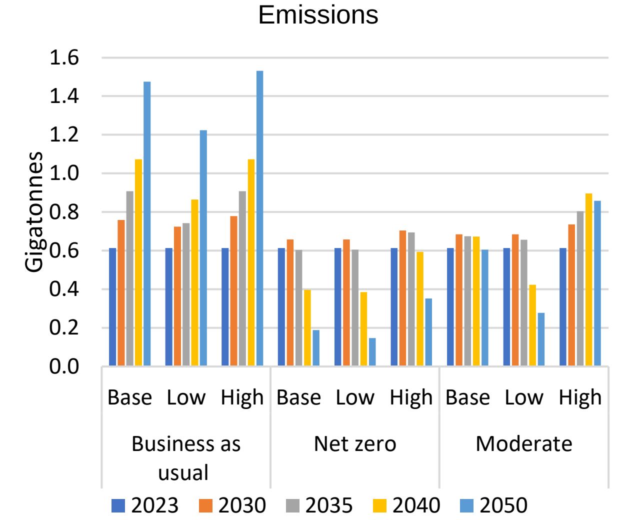
Sources: ICAO 2022; and IMF staff calculations.

Business as usual emissions increase under all price scenarios because of a lack of significant zero-emissions fuel diffusion but there are material differences. In aviation, emissions are 40 percent lower in 2050 with low SAF prices but only 4 percent higher under high SAF prices since there is little SAF use in the baseline. Differences are slightly smaller for maritime since there is still little zero-emissions fuel use under all price scenarios. When comparing similar policies across different price scenarios, midcentury emissions are 50 to 80 percent higher with high zero-emissions fuel prices (the larger differences are in aviation) and emissions are 20 percent lower with the low price scenario.

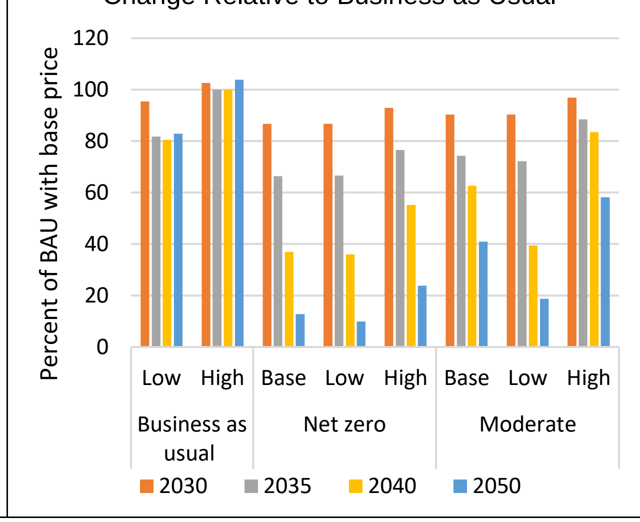
Annex Figure 4.5. Emissions Sensitivity Analysis

1. Aviation

Emissions



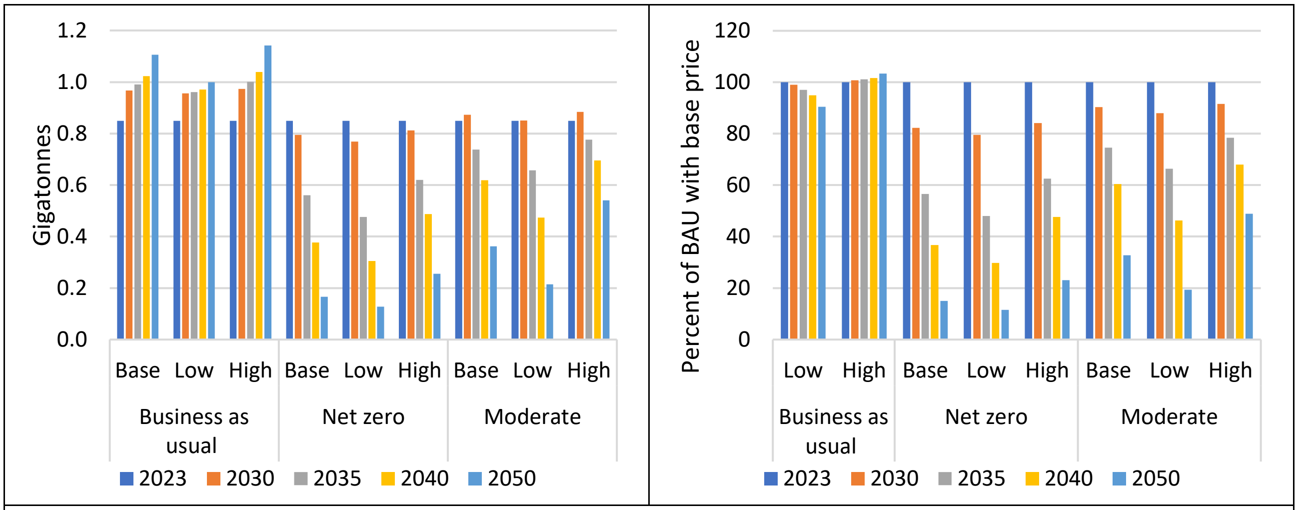
Change Relative to Business as Usual



2. Maritime

Emissions

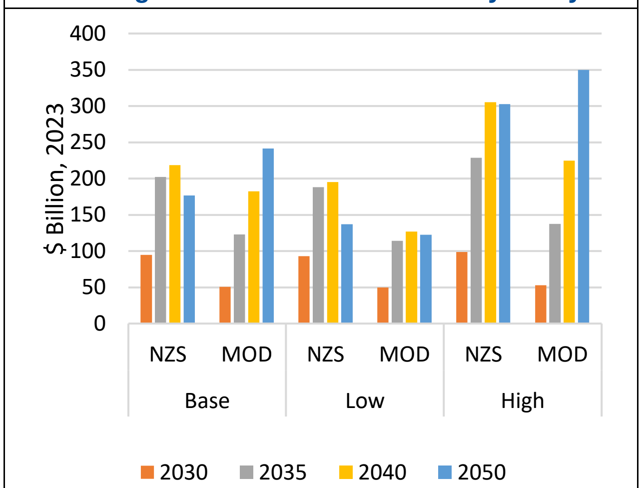
Change Relative to Business as Usual



Source: IMF staff calculations.

Revenue follows predictable trends across the price scenarios with much higher revenue if zero-emissions fuels are more costly since the tax base (that is, emissions) is larger. If prices are high, revenue is about $300 billion in 2040 with net zero aligned carbon prices and peaks only around midcentury (compared to peaking in the early 2040s for low and base case prices), although there is not much difference across price scenarios until after 2035. For the moderate carbon price and low zero-emissions fuel combination, revenue is much lower through midcentury than for the base and high prices since emissions decline significantly compared with scenarios with higher low emissions fuel costs.

Annex Figure 4.6. Revenue Sensitivity Analysis



Source: IMF staff calculations.

Note: NZS = Net zero pathway, MOD = Moderate pathway.

Annex 5. Distributional Analysis

For traded products, the country-level impact is determined by the change in prices of imports and exports, trade openness, and price elasticities of imports and exports (following Keen, Parry, and Strand 2013). Higher import prices brought about by a tax result in higher consumer prices, with a consumer burden before any revenue transfer equal to a combination of (1) a loss from foregone consumption of goods and (2) higher prices of remaining consumption. Higher export prices induced by a tax, result in lower exports and, thus, reduced domestic producer surplus.

Equations (1-2) and describes these relationships, where *v* and *m* refer to exports and imports, respectively; $\boldsymbol{t_m}$ and t_x refers to the increase in product costs induced by the policy in proportion to import and export prices; V_m and V_x refer to import and export values as a share of GDP; n_x^{ROW} and $\boldsymbol{n_m}^{\mathrm{ROW}}$ are the elasticities of export supply and import demand, respectively, from the rest of the world; and n_m^A and n_x^A are the absolute value of elasticity of demand and supply for imported and exported goods, respectively. Data on imports and exports of goods as a share of GDP come from the April 2024 IMF World Economic Outlook (2019 shares are used because of COVID-19 impacts in future years), which are disaggregated among trade by sea, air, and road (with the latter excluded from calculations since policies do not affect road transport) using data from the United Nations Conference on Trade and Development. The share of transport costs in traded product volumes by sea and air come from the United Nations Conference on Trade and Development with fuel costs assumed to make up half of the transport costs for maritime and one-quarter for aviation; and price increases are specific to the modeled policies (Figure 9).

$$\boldsymbol{C_m = t_m V_m * \left(\frac{n_x^{\mathrm{ROW}}}{n_x^{\mathrm{ROW}} + n_m^A}\right)} \qquad (1)$$

$$\boldsymbol{C_x = t_x V_x * \left(\frac{n_m^{\mathrm{ROW}}}{n_m^{\mathrm{ROW}} + n_x^A}\right)} \qquad (2)$$

The calculation contains several assumptions. First, import and export elasticities are not country-specific. These likely vary according to the types of goods imported and availability of domestic substitutes—for example, imports of food are likely less elastic given that they are a necessity unless there are relatively low-cost possibilities to expand domestic food production—but recent country-level data is not available. Tokerick (2010) provides estimates for the early 2000s and finds short-term import elasticities of −0.8 to −0.9 for lower income countries. Second, oil is treated similarly to any other good but there will be a significant global demand and, thus, price and export levels affect under more aggressive mitigation scenarios since maritime and aviation oil demand currently makes up between 10 and 15 percent of global oil consumption. Third, there could be a small domestic producer benefit, especially for goods with higher transport costs, because of more expensive imports. Fourth, import and export shares and compositions are fixed at 2019 values; however, there could be significant changes over time, partly in response to higher transport costs and also because of changes in trade policies, comparative advantages, and more general economic development—historical data shows that faster growing countries should have two potentially offsetting trends from increased trade openness and reduced fuel costs related to trade (potentially due to economies of scale and improved transportation infrastructure). Fifth, the producer burden from a lack of full pass-through to end user prices is not considered but pass-through is expected to be nearly complete.

For tourism, a similar approach is taken (following Keen et al 2013 and shown in Equations 1-2) where the distributional impact is determined by the relative elasticities of tourism supply and demand and economy's reliance on tourism. $\boldsymbol{t_x}$ equal to the change in price of flying induced by the policy, $\boldsymbol{V_x}$ and $\boldsymbol{V_m}$ equal to the share of GDP received from tourism and spending of tourists, $\boldsymbol{n_m}^{\mathrm{ROW}}$ and n_x^{ROW} are equal to the absolute value of the rest of the world's price elasticity of demand and supply of tourism, respectively. n_m^A and $\boldsymbol{n_x^A}$ equal to the price elasticity of demand and supply of domestic tourists and tourism supply, respectively. Data on tourism related expenditure by residents and in destinations is from UN Tourism Statistics Database (UN 2024), which is split among maritime, aviation, and land travel based on shares of arrivals from UN 2024 and the average spending per tourist for cruises vs. non-cruises across available studies, with cruise visitors spending seven times less than non-cruise visitors;[52] price increases are specific to the modelled policies (Figure 8); fuel cost shares of 25 percent for aviation and 12 percent for cruises based on the average of three large cruise companies; tourism demand is adjusted based on country-level GDP growth projections, while tourism supply only considers global economic growth; and see below for supply and demand elasticities and sensitivity analysis.

The price responsiveness of international tourism demand is assumed to be −1 (IATA 2008) but with a large variance in the literature. (For example, Morlotti and others [2017] estimate elasticities of −2 and beyond and Keen, Parry, and Strand [2013] posit that a globally applied tax would increase prices across all tourism destinations and result in a relatively small demand response.) To the extent that international tourism can be substituted for domestic tourism (and domestic aviation fuel taxes do not increase in tandem with international ones), the demand elasticity would be higher. This could be especially important for large countries with ample domestic tourism options, such as the United States, India, and China. Conversely, if tourism destinations are unique, partly because of the natural characteristics that cannot be replicated elsewhere, demand would be less elastic.

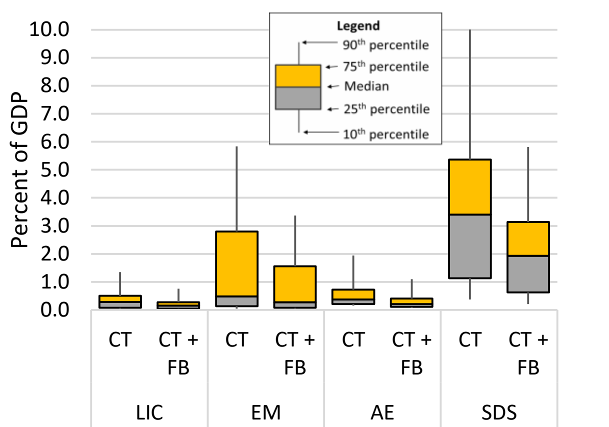
For tourism supply, there is little to no empirical research on the topic. The value of −1 is assumed, meaning that the tourism supply decreases over time (relative to a business-as-usual scenario) in tandem with increases in flying prices and the burden is shared between demand and supply.

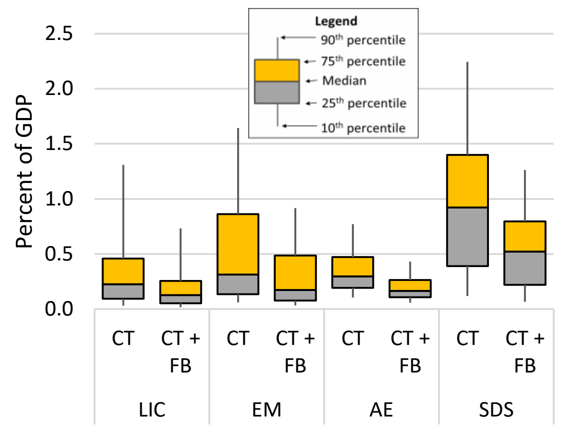
Sensitivity Analysis

Annex Figure 5.1 shows the aggregate impact on tourists and tourism supply for different assumptions related to the elasticity of tourism supply. Three scenarios are explored: (1) full burden on tourist destinations wherein the supply of tourism services is inelastic (for example, accommodations are already built on all available locations and the economy has no opportunities to diversify if tourism prices decline); (2) an equal share between destinations and tourists, as assumed in the main text so the chart is not repeated here; and (3) all burden falling on tourists (for example, tourists are not price sensitive and destinations can easily diversify to other economic sectors). The distributional impact may be country-specific with more unique locations shifting higher costs to tourists and vice versa.

[52] Responsible Travel Consulting, LLC, 2022, Tourism Economics 2020

Annex Figure 5.1. Distributional Impact of Tourism-Related Impacts





Source: IMF staff calculations.

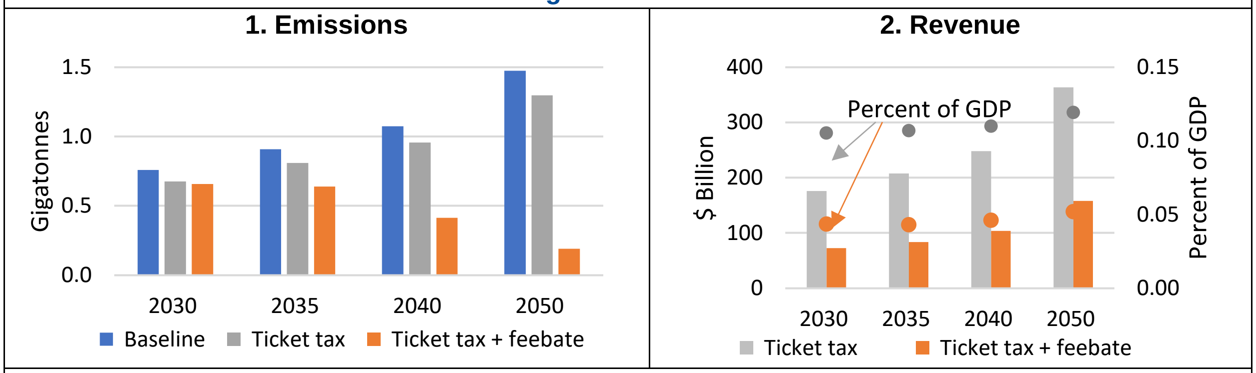
Notes: The chart shows the 10th (end of the bottom line), 25th (bottom of grey box), median (intersection of grey and yellow box), 75th (top of yellow box), and 90th percentile (end of the top line) for countries within a given country group. AE = advanced economy; CT = carbon tax; EM = emerging market; FB = feebate; LIC = low-income country, SDS = small developing state. NZS = Net zero pathway, MOD = Moderate pathway.

Annex 6. Ticket Taxes as an Interim Solution

Ticket taxes are easy to administer and can promote emissions reductions through demand responses, while raising revenue. To quantify the impact of ticket taxes, a ticket tax of 25 percent and a lower ticket tax of 10 percent combined with a feebate increasing from $20 to $500 per ton from 2028 to 2050 is modeled (Figure 6.1). The ticket tax is applied only to passenger flights.

Ticket taxes generate a significant and resilient revenue stream but have limited impacts on emissions. It is estimated that a 25-percent ticket tax would raise nearly $200 billion in revenue in 2030, progressively increasing to $450 billion in 2050 as aviation activity expands. Emissions decline by slightly over 10 percent (lower than the price elasticity applied to the price increase since the tax applies only to passenger aviation). The lower ticket tax raises 40 percent of the revenue of the higher ticket tax, proportionally to the difference in tax levels, but large-scale emissions reductions are driven by the feebate.

Annex Figure 6.1. Ticket Taxes



Source: IMF staff calculations.

Results indicate that the ticket tax when expressed as a percentage of ticket value requires complementary policies that incentivize emissions reductions, such as a feebate, or an alternative design. The ticket tax could also be adjusted to better mimic a carbon tax—for example, the tax could be expressed as a specific amount that varies based on the distance travelled (which is highly correlated with emissions), the airlines average annual lifecycle emissions per unit of fuel (since the fuel used for a specific flight is not known at the time of purchase), and the engine's NO_x emissions factor (see Hoen and others 2018 for more information). An inherent weakness of a ticket tax is that it does not provide an additional incentive for airlines to maximize occupancy, but this could be remedied by applying the tax at the plane/flight level.

Annex 7. Country-Level Classifications and Impacts of Mitigation Policies

The table below show country-level impacts of the various mitigation policies in 2030 and 2035, following the methodology discussed in the main text (for example, Figure 9) and Annex 5. Compensation is assumed to cover the full economic burden for low income countries and small developing states and the cargo costs for emerging markets. Remaining revenue is then allocated based on existing regional climate finance flows, following CPI 2023. Results here differ slightly from what is described in the main text of the paper since country-level GDP trends, rather than regional trends, are used. Results are only shown for the net zero carbon tax and carbon tax-feebate combination in 2035 but authors can provide more years and scenarios to readers upon request.

Country-Level Classifications and Impacts of Mitigation Policies

Country	SDS	Policy	Year	Compensation (USD billion)	Compensation (% of GDP)	Climate finance (USD billion)	Climate finance (% of GDP)	Compensation + climate finance (% of current ODA)	Compensation + climate finance (% of current revenue)	Compensation + climate finance (% of GDP)
Afghanistan	0	CT	2035	0.031	0.126%	0.043	0.178%	1.901%	1.129%	0.304%
Afghanistan	0	CT + FB	2035	0.017	0.070%	0.014	0.057%	0.795%	0.472%	0.127%
Albania	0	CT	2035	0.127	0.390%	0.147	0.453%	86.983%	3.096%	0.843%
Albania	0	CT + FB	2035	0.084	0.258%	0.047	0.144%	41.501%	1.477%	0.402%
Algeria	0	CT	2035	1.305	0.569%	0.586	0.256%	879.685%		0.825%
Algeria	0	CT + FB	2035	0.844	0.368%	0.187	0.081%	479.405%		0.449%
Andorra	0	CT	2035	0.000	0.000%	0.000	0.000%			0.000%
Andorra	0	CT + FB	2035	0.000	0.000%	0.000	0.000%			0.000%
Angola	0	CT	2035	0.711	0.663%	0.601	0.560%	1346.171%	5.779%	1.224%
Angola	0	CT + FB	2035	0.457	0.426%	0.191	0.178%	664.645%	2.853%	0.604%
Anguilla	0	CT	2035	0.024	3.750%	0.000	0.000%		16.464%	3.750%
Anguilla	0	CT + FB	2035	0.015	2.255%	0.000	0.000%		9.903%	2.255%
Antigua and Barbuda	1	CT	2035	0.174	7.046%	0.005	0.212%	654.223%	38.945%	7.258%
Antigua and Barbuda	1	CT + FB	2035	0.102	4.106%	0.002	0.068%	376.206%	22.395%	4.174%
Argentina	0	CT	2035	0.971	0.179%	1.148	0.212%	551.782%	1.175%	0.391%
Argentina	0	CT + FB	2035	0.625	0.115%	0.366	0.068%	257.893%	0.549%	0.183%
Armenia	0	CT	2035	0.044	0.148%	0.133	0.453%	58.881%	2.512%	0.601%
Armenia	0	CT + FB	2035	0.027	0.092%	0.042	0.144%	23.178%	0.989%	0.237%
Aruba	0	CT	2035	0.255	6.304%	0.000	0.000%		26.777%	6.304%
Aruba	0	CT + FB	2035	0.144	3.545%	0.000	0.000%		15.056%	3.545%
Australia	0	CT	2035	0.000	0.000%	0.000	0.000%		0.000%	0.000%
Australia	0	CT + FB	2035	0.000	0.000%	0.000	0.000%		0.000%	0.000%
Austria	0	CT	2035	0.000	0.000%	0.000	0.000%		0.000%	0.000%
Austria	0	CT + FB	2035	0.000	0.000%	0.000	0.000%		0.000%	0.000%
Azerbaijan	0	CT	2035	0.441	0.474%	0.421	0.453%	1828.114%	2.234%	0.926%
Azerbaijan	0	CT + FB	2035	0.280	0.300%	0.134	0.144%	877.082%	1.072%	0.444%
Bahamas, The	1	CT	2035	0.559	3.755%	0.032	0.212%		21.570%	3.967%
Bahamas, The	1	CT + FB	2035	0.329	2.212%	0.010	0.068%		12.397%	2.280%
Bahrain	0	CT	2035	0.000	0.000%	0.000	0.000%		0.000%	0.000%
Bahrain	0	CT + FB	2035	0.000	0.000%	0.000	0.000%		0.000%	0.000%
Bangladesh	0	CT	2035	4.371	0.576%	1.353	0.178%	110.240%	9.261%	0.754%
Bangladesh	0	CT + FB	2035	2.835	0.374%	0.431	0.057%	62.890%	5.283%	0.430%
Barbados	0	CT	2035	0.000	0.000%	0.000	0.000%		0.000%	0.000%
Barbados	0	CT + FB	2035	0.000	0.000%	0.000	0.000%		0.000%	0.000%
Belarus	0	CT	2035	0.814	1.086%	0.340	0.453%	7074.815%	4.021%	1.539%
Belarus	0	CT + FB	2035	0.523	0.698%	0.108	0.144%	3869.902%	2.200%	0.842%
Belgium	0	CT	2035	0.000	0.000%	0.000	0.000%		0.000%	0.000%
Belgium	0	CT + FB	2035	0.000	0.000%	0.000	0.000%		0.000%	0.000%
Belize	1	CT	2035	0.109	3.151%	0.007	0.212%	571.264%	13.597%	3.363%
Belize	1	CT + FB	2035	0.067	1.929%	0.002	0.068%	339.054%	8.070%	1.996%
Benin	0	CT	2035	0.327	1.085%	0.169	0.560%	58.820%	11.700%	1.645%
Benin	0	CT + FB	2035	0.213	0.706%	0.054	0.178%	31.620%	6.290%	0.884%
Bhutan	1	CT	2035	0.063	1.435%	0.008	0.178%	36.556%	6.640%	1.614%
Bhutan	1	CT + FB	2035	0.040	0.905%	0.002	0.057%	21.780%	3.956%	0.961%
Bolivia	0	CT	2035	0.225	0.359%	0.133	0.212%	107.005%	1.980%	0.571%
Bolivia	0	CT + FB	2035	0.146	0.233%	0.042	0.068%	56.365%	1.043%	0.301%
Bosnia and Herzegovina	0	CT	2035	0.023	0.069%	0.152	0.453%	61.777%	1.247%	0.522%
Bosnia and Herzegovina	0	CT + FB	2035	0.015	0.045%	0.048	0.144%	22.337%	0.451%	0.189%
Botswana	0	CT	2035	0.194	0.649%	0.167	0.560%	402.967%	4.321%	1.210%
Botswana	0	CT + FB	2035	0.126	0.421%	0.053	0.178%	199.707%	2.142%	0.599%

Country	SDS	Policy	Year	Compensation (USD billion)	Compensation (% of GDP)	Climate finance (USD billion)	Climate finance (% of GDP)	Compensation + climate finance (% of current ODA)	Compensation + climate finance (% of current revenue)	Compensation + climate finance (% of GDP)
Brazil	0	CT	2035	4.754	0.175%	5.772	0.212%	1824.228%	1.228%	0.387%
Brazil	0	CT + FB	2035	3.091	0.114%	1.837	0.068%	854.136%	0.575%	0.181%
Brunei Darussalam	0	CT	2035	0.000	0.000%	0.000	0.000%		0.000%	0.000%
Brunei Darussalam	0	CT + FB	2035	0.000	0.000%	0.000	0.000%		0.000%	0.000%
Bulgaria	0	CT	2035	0.000	0.000%	0.000	0.000%		0.000%	0.000%
Bulgaria	0	CT + FB	2035	0.000	0.000%	0.000	0.000%		0.000%	0.000%
Burkina Faso	0	CT	2035	0.233	0.780%	0.167	0.560%	28.710%	6.673%	1.340%
Burkina Faso	0	CT + FB	2035	0.142	0.474%	0.053	0.178%	13.969%	3.247%	0.652%
Burundi	0	CT	2035	0.016	0.328%	0.028	0.560%	7.665%	3.972%	0.889%
Burundi	0	CT + FB	2035	0.010	0.204%	0.009	0.178%	3.295%	1.707%	0.382%
Cabo Verde	1	CT	2035	0.155	4.034%	0.021	0.560%	213.373%	17.128%	4.595%
Cabo Verde	1	CT + FB	2035	0.089	2.320%	0.007	0.178%	116.003%	9.312%	2.498%
Cambodia	0	CT	2035	1.474	2.132%	0.166	0.241%	106.077%	8.860%	2.373%
Cambodia	0	CT + FB	2035	0.872	1.261%	0.053	0.077%	59.816%	4.996%	1.338%
Cameroon	0	CT	2035	0.438	0.639%	0.385	0.560%	69.890%	7.777%	1.199%
Cameroon	0	CT + FB	2035	0.269	0.391%	0.122	0.178%	33.197%	3.694%	0.570%
Canada	0	CT	2035	0.000	0.000%	0.000	0.000%		0.000%	0.000%
Canada	0	CT + FB	2035	0.000	0.000%	0.000	0.000%		0.000%	0.000%
Central African Republic	0	CT	2035	0.043	1.293%	0.019	0.560%	9.000%	10.106%	1.853%
Central African Republic	0	CT + FB	2035	0.024	0.733%	0.006	0.178%	4.429%	4.973%	0.912%
Chad	0	CT	2035	0.170	0.781%	0.122	0.560%	42.051%	9.463%	1.341%
Chad	0	CT + FB	2035	0.109	0.499%	0.039	0.178%	21.241%	4.780%	0.677%
Chile	0	CT	2035	0.000	0.000%	0.000	0.000%		0.000%	0.000%
Chile	0	CT + FB	2035	0.000	0.000%	0.000	0.000%		0.000%	0.000%
China	0	CT	2035	0.000	0.000%	0.000	0.000%		0.000%	0.000%
China	0	CT + FB	2035	0.000	0.000%	0.000	0.000%		0.000%	0.000%
Colombia	0	CT	2035	0.198	0.048%	0.884	0.212%	57.475%	0.883%	0.260%
Colombia	0	CT + FB	2035	0.121	0.029%	0.281	0.068%	21.393%	0.329%	0.097%
Comoros	1	CT	2035	0.033	1.898%	0.010	0.560%	31.483%	15.519%	2.459%
Comoros	1	CT + FB	2035	0.020	1.131%	0.003	0.178%	16.761%	8.262%	1.309%
Congo, Democratic Republic	0	CT	2035	0.986	0.896%	0.616	0.560%	49.295%	13.442%	1.457%
Congo, Democratic Republic	0	CT + FB	2035	0.624	0.568%	0.196	0.178%	25.244%	6.884%	0.746%
Congo, Republic of	0	CT	2035	0.280	1.458%	0.108	0.560%	54.782%	7.553%	2.019%
Congo, Republic of	0	CT + FB	2035	0.176	0.919%	0.034	0.178%	29.787%	4.107%	1.098%
Costa Rica	0	CT	2035	0.000	0.000%	0.000	0.000%	0.000%	0.000%	0.000%
Costa Rica	0	CT + FB	2035	0.000	0.000%	0.000	0.000%	0.000%	0.000%	0.000%
Croatia	0	CT	2035	0.000	0.000%	0.000	0.000%		0.000%	0.000%
Croatia	0	CT + FB	2035	0.000	0.000%	0.000	0.000%		0.000%	0.000%
Cyprus	0	CT	2035	0.000	0.000%	0.000	0.000%		0.000%	0.000%
Cyprus	0	CT + FB	2035	0.000	0.000%	0.000	0.000%		0.000%	0.000%
Czechia	0	CT	2035	0.000	0.000%	0.000	0.000%		0.000%	0.000%
Czechia	0	CT + FB	2035	0.000	0.000%	0.000	0.000%		0.000%	0.000%
Côte d'Ivoire	0	CT	2035	1.145	0.909%	0.706	0.560%	93.764%	9.770%	1.469%
Côte d'Ivoire	0	CT + FB	2035	0.746	0.592%	0.225	0.178%	49.148%	5.121%	0.770%
Denmark	0	CT	2035	0.000	0.000%	0.000	0.000%		0.000%	0.000%
Denmark	0	CT + FB	2035	0.000	0.000%	0.000	0.000%		0.000%	0.000%
Djibouti	1	CT	2035	0.218	3.503%	0.016	0.256%	395.530%	16.005%	3.759%
Djibouti	1	CT + FB	2035	0.137	2.200%	0.005	0.081%	240.031%	9.713%	2.281%
Dominica	1	CT	2035	0.031	3.634%	0.002	0.212%	55.815%	10.637%	3.846%
Dominica	1	CT + FB	2035	0.018	2.127%	0.001	0.068%	31.850%	6.070%	2.195%
Dominican Republic	0	CT	2035	0.864	0.479%	0.383	0.212%	339.667%	4.799%	0.691%
Dominican Republic	0	CT + FB	2035	0.566	0.314%	0.122	0.068%	187.386%	2.648%	0.381%
Ecuador	0	CT	2035	0.511	0.426%	0.255	0.212%	203.565%	1.894%	0.638%
Ecuador	0	CT + FB	2035	0.336	0.279%	0.081	0.068%	110.741%	1.031%	0.347%
Egypt	0	CT	2035	1.780	0.267%	1.703	0.256%	59.863%	2.708%	0.523%
Egypt	0	CT + FB	2035	1.149	0.172%	0.542	0.081%	29.061%	1.315%	0.254%
El Salvador	0	CT	2035	0.238	0.616%	0.082	0.212%	45.111%	3.430%	0.828%
El Salvador	0	CT + FB	2035	0.152	0.394%	0.026	0.068%	25.165%	1.914%	0.462%
Equatorial Guinea	0	CT	2035	0.125	0.935%	0.075	0.560%	1784.065%	8.030%	1.495%
Equatorial Guinea	0	CT + FB	2035	0.081	0.606%	0.024	0.178%	935.894%	4.213%	0.785%
Eritrea	0	CT	2035	0.023	0.884%	0.014	0.560%	67.500%	4.253%	1.445%
Eritrea	0	CT + FB	2035	0.014	0.565%	0.005	0.178%	34.744%	2.189%	0.744%
Estonia	0	CT	2035	0.000	0.000%	0.000	0.000%		0.000%	0.000%
Estonia	0	CT + FB	2035	0.000	0.000%	0.000	0.000%		0.000%	0.000%
Eswatini	1	CT	2035	0.045	0.933%	0.027	0.560%	74.519%	5.461%	1.494%
Eswatini	1	CT + FB	2035	0.030	0.613%	0.009	0.178%	39.486%	2.893%	0.792%

Country	SDS	Policy	Year	Compensation (USD billion)	Compensation (% of GDP)	Climate finance (USD billion)	Climate finance (% of GDP)	Compensation + climate finance (% of current ODA)	Compensation + climate finance (% of current revenue)	Compensation + climate finance (% of GDP)
Ethiopia	0	CT	2035	1.210	0.605%	1.122	0.560%	47.337%	9.088%	1.165%
Ethiopia	0	CT + FB	2035	0.694	0.347%	0.357	0.178%	21.344%	4.098%	0.525%
Fiji	1	CT	2035	0.277	4.131%	0.016	0.241%	81.825%	16.490%	4.371%
Fiji	1	CT + FB	2035	0.161	2.409%	0.005	0.077%	46.530%	9.377%	2.486%
Finland	0	CT	2035	0.000	0.000%	0.000	0.000%		0.000%	0.000%
Finland	0	CT + FB	2035	0.000	0.000%	0.000	0.000%		0.000%	0.000%
France	0	CT	2035	0.000	0.000%	0.000	0.000%		0.000%	0.000%
France	0	CT + FB	2035	0.000	0.000%	0.000	0.000%		0.000%	0.000%
Gabon	0	CT	2035	0.153	0.858%	0.100	0.560%	189.670%	7.261%	1.418%
Gabon	0	CT + FB	2035	0.099	0.556%	0.032	0.178%	98.222%	3.760%	0.734%
Gambia, The	0	CT	2035	0.015	0.381%	0.022	0.560%	13.478%	4.444%	0.942%
Gambia, The	0	CT + FB	2035	0.008	0.212%	0.007	0.178%	5.591%	1.843%	0.391%
Georgia	0	CT	2035	0.187	0.490%	0.173	0.453%	95.627%	3.478%	0.943%
Georgia	0	CT + FB	2035	0.120	0.314%	0.055	0.144%	46.427%	1.689%	0.458%
Germany	0	CT	2035	0.000	0.000%	0.000	0.000%		0.000%	0.000%
Germany	0	CT + FB	2035	0.000	0.000%	0.000	0.000%		0.000%	0.000%
Ghana	0	CT	2035	0.920	0.949%	0.543	0.560%	139.950%	10.887%	1.509%
Ghana	0	CT + FB	2035	0.568	0.586%	0.173	0.178%	70.844%	5.511%	0.764%
Greece	0	CT	2035	0.000	0.000%	0.000	0.000%		0.000%	0.000%
Greece	0	CT + FB	2035	0.000	0.000%	0.000	0.000%		0.000%	0.000%
Grenada	1	CT	2035	0.100	6.043%	0.003	0.212%		23.503%	6.255%
Grenada	1	CT + FB	2035	0.057	3.443%	0.001	0.068%		13.190%	3.510%
Guatemala	0	CT	2035	0.617	0.395%	0.331	0.212%	216.455%	5.421%	0.607%
Guatemala	0	CT + FB	2035	0.397	0.254%	0.105	0.068%	114.668%	2.872%	0.322%
Guinea	0	CT	2035	0.290	1.029%	0.158	0.560%	89.674%	10.802%	1.589%
Guinea	0	CT + FB	2035	0.174	0.616%	0.050	0.178%	44.795%	5.396%	0.794%
Guinea-Bissau	0	CT	2035	0.039	1.397%	0.016	0.560%	36.427%	13.104%	1.957%
Guinea-Bissau	0	CT + FB	2035	0.023	0.829%	0.005	0.178%	18.750%	6.745%	1.007%
Guyana	1	CT	2035	0.179	1.860%	0.020	0.212%	99.985%	8.092%	2.072%
Guyana	1	CT + FB	2035	0.116	1.208%	0.006	0.068%	61.533%	4.980%	1.275%
Haiti	0	CT	2035	0.078	0.403%	0.041	0.212%	13.345%	7.677%	0.615%
Haiti	0	CT + FB	2035	0.045	0.231%	0.013	0.068%	6.474%	3.724%	0.298%
Honduras	0	CT	2035	0.667	1.415%	0.100	0.212%	97.612%	6.304%	1.627%
Honduras	0	CT + FB	2035	0.414	0.880%	0.032	0.068%	56.815%	3.669%	0.947%
Hong Kong SAR	0	CT	2035	0.000	0.000%	0.000	0.000%		0.000%	0.000%
Hong Kong SAR	0	CT + FB	2035	0.000	0.000%	0.000	0.000%		0.000%	0.000%
Hungary	0	CT	2035	0.000	0.000%	0.000	0.000%		0.000%	0.000%
Hungary	0	CT + FB	2035	0.000	0.000%	0.000	0.000%		0.000%	0.000%
Iceland	0	CT	2035	0.000	0.000%	0.000	0.000%		0.000%	0.000%
Iceland	0	CT + FB	2035	0.000	0.000%	0.000	0.000%		0.000%	0.000%
India	0	CT	2035	14.128	0.231%	10.924	0.178%	884.862%	2.051%	0.409%
India	0	CT + FB	2035	9.006	0.147%	3.477	0.057%	440.915%	1.022%	0.204%
Indonesia	0	CT	2035	8.239	0.368%	5.393	0.241%	2057.099%	4.298%	0.608%
Indonesia	0	CT + FB	2035	5.274	0.235%	1.717	0.077%	1054.935%	2.204%	0.312%
Iran	0	CT	2035	1.138	0.287%	1.014	0.256%	743.194%	5.618%	0.543%
Iran	0	CT + FB	2035	0.727	0.183%	0.323	0.081%	362.592%	2.741%	0.265%
Iraq	0	CT	2035	1.821	0.537%	0.867	0.256%	171.271%	2.204%	0.792%
Iraq	0	CT + FB	2035	1.170	0.345%	0.276	0.081%	92.121%	1.186%	0.426%
Ireland	0	CT	2035	0.000	0.000%	0.000	0.000%		0.000%	0.000%
Ireland	0	CT + FB	2035	0.000	0.000%	0.000	0.000%		0.000%	0.000%
Israel	0	CT	2035	0.000	0.000%	0.000	0.000%		0.000%	0.000%
Israel	0	CT + FB	2035	0.000	0.000%	0.000	0.000%		0.000%	0.000%
Italy	0	CT	2035	0.000	0.000%	0.000	0.000%		0.000%	0.000%
Italy	0	CT + FB	2035	0.000	0.000%	0.000	0.000%		0.000%	0.000%
Jamaica	0	CT	2035	0.654	3.393%	0.041	0.212%	730.532%	11.710%	3.605%
Jamaica	0	CT + FB	2035	0.379	1.965%	0.013	0.068%	411.878%	6.602%	2.033%
Japan	0	CT	2035	0.000	0.000%	0.000	0.000%		0.000%	0.000%
Japan	0	CT + FB	2035	0.000	0.000%	0.000	0.000%		0.000%	0.000%
Jordan	0	CT	2035	0.224	0.350%	0.164	0.256%	19.536%	2.494%	0.606%
Jordan	0	CT + FB	2035	0.140	0.219%	0.052	0.081%	9.675%	1.235%	0.300%
Kazakhstan	0	CT	2035	2.057	0.604%	1.541	0.453%	4874.262%	5.372%	1.057%
Kazakhstan	0	CT + FB	2035	1.326	0.390%	0.491	0.144%	2460.933%	2.712%	0.534%
Kenya	0	CT	2035	0.668	0.437%	0.857	0.560%	57.489%	5.866%	0.997%
Kenya	0	CT + FB	2035	0.407	0.266%	0.273	0.178%	25.641%	2.616%	0.445%
Kiribati	0	CT	2035	0.006	1.932%	0.001	0.241%	7.409%	1.602%	2.173%
Kiribati	0	CT + FB	2035	0.004	1.192%	0.000	0.077%	4.324%	0.935%	1.268%

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Korea	0	CT	2035	0.000	0.000%	0.000	0.000%		0.000%	0.000%
Korea	0	CT + FB	2035	0.000	0.000%	0.000	0.000%		0.000%	0.000%
Kosovo	0	CT	2035	0.048	0.341%	0.063	0.453%	29.173%	2.942%	0.794%
Kosovo	0	CT + FB	2035	0.031	0.221%	0.020	0.144%	13.418%	1.353%	0.365%
Kuwait	0	CT	2035	0.000	0.000%	0.000	0.000%		0.000%	0.000%
Kuwait	0	CT + FB	2035	0.000	0.000%	0.000	0.000%		0.000%	0.000%
Kyrgyz Republic	0	CT	2035	0.315	1.745%	0.082	0.453%	54.284%	6.762%	2.198%
Kyrgyz Republic	0	CT + FB	2035	0.180	0.999%	0.026	0.144%	28.239%	3.518%	1.143%
Lao P.D.R.	0	CT	2035	0.488	2.060%	0.057	0.241%	99.594%	14.939%	2.301%
Lao P.D.R.	0	CT + FB	2035	0.311	1.312%	0.018	0.077%	60.117%	9.017%	1.389%
Latvia	0	CT	2035	0.000	0.000%	0.000	0.000%		0.000%	0.000%
Latvia	0	CT + FB	2035	0.000	0.000%	0.000	0.000%		0.000%	0.000%
Lebanon	0	CT	2035	2.218	3.380%	0.168	0.256%	167.267%	17.484%	3.635%
Lebanon	0	CT + FB	2035	1.267	1.932%	0.053	0.081%	92.620%	9.681%	2.013%
Lesotho	0	CT	2035	0.001	0.022%	0.017	0.560%	11.378%	1.204%	0.582%
Lesotho	0	CT + FB	2035	0.000	0.012%	0.005	0.178%	3.722%	0.394%	0.190%
Liberia	0	CT	2035	0.001	4.031%	0.000	0.560%	0.314%	16.763%	4.591%
Liberia	0	CT + FB	2035	0.001	2.299%	0.000	0.178%	0.169%	9.045%	2.478%
Libya	0	CT	2035	0.000	0.000%	0.182	0.256%	68.778%	0.431%	0.256%
Libya	0	CT + FB	2035	0.000	0.000%	0.058	0.081%	21.893%	0.137%	0.081%
Lithuania	0	CT	2035	0.000	0.000%	0.000	0.000%		0.000%	0.000%
Lithuania	0	CT + FB	2035	0.000	0.000%	0.000	0.000%		0.000%	0.000%
Luxembourg	0	CT	2035	0.000	0.000%	0.000	0.000%		0.000%	0.000%
Luxembourg	0	CT + FB	2035	0.000	0.000%	0.000	0.000%		0.000%	0.000%
Macao SAR	0	CT	2035	0.000	0.000%	0.000	0.000%		0.000%	0.000%
Macao SAR	0	CT + FB	2035	0.000	0.000%	0.000	0.000%		0.000%	0.000%
Madagascar	0	CT	2035	0.515	2.100%	0.137	0.560%	65.218%	19.087%	2.661%
Madagascar	0	CT + FB	2035	0.315	1.286%	0.044	0.178%	35.892%	10.504%	1.464%
Malawi	0	CT	2035	0.119	0.827%	0.080	0.560%	14.797%	9.394%	1.387%
Malawi	0	CT + FB	2035	0.070	0.491%	0.026	0.178%	7.139%	4.533%	0.669%
Malaysia	0	CT	2035	2.579	0.468%	1.326	0.241%	79860.260%	3.287%	0.709%
Malaysia	0	CT + FB	2035	1.552	0.282%	0.422	0.077%	40360.635%	1.661%	0.358%
Maldives	1	CT	2035	0.861	7.508%	0.020	0.178%	740.319%	28.539%	7.686%
Maldives	1	CT + FB	2035	0.486	4.239%	0.007	0.057%	413.721%	15.949%	4.295%
Mali	0	CT	2035	0.239	0.829%	0.161	0.560%	33.404%	6.472%	1.389%
Mali	0	CT + FB	2035	0.144	0.500%	0.051	0.178%	16.315%	3.161%	0.679%
Malta	0	CT	2035	0.000	0.000%	0.000	0.000%		0.000%	0.000%
Malta	0	CT + FB	2035	0.000	0.000%	0.000	0.000%		0.000%	0.000%
Marshall Islands	1	CT	2035	0.008	2.554%	0.001	0.241%	6.157%	4.437%	2.794%
Marshall Islands	1	CT + FB	2035	0.005	1.541%	0.000	0.077%	3.565%	2.569%	1.618%
Mauritania	0	CT	2035	0.095	0.934%	0.057	0.560%	46.590%	7.456%	1.494%
Mauritania	0	CT + FB	2035	0.061	0.594%	0.018	0.178%	24.078%	3.853%	0.772%
Mauritius	1	CT	2035	0.582	2.709%	0.120	0.560%	922.044%	15.681%	3.269%
Mauritius	1	CT + FB	2035	0.339	1.577%	0.038	0.178%	494.995%	8.418%	1.755%
Mexico	0	CT	2035	4.394	0.195%	4.783	0.212%	1852.219%	1.722%	0.407%
Mexico	0	CT + FB	2035	2.840	0.126%	1.523	0.068%	880.532%	0.819%	0.193%
Micronesia	1	CT	2035	0.003	0.732%	0.001	0.241%	2.855%		0.972%
Micronesia	1	CT + FB	2035	0.002	0.471%	0.000	0.077%	1.609%		0.548%
Moldova	0	CT	2035	0.179	0.704%	0.115	0.453%	33.182%	3.791%	1.157%
Moldova	0	CT + FB	2035	0.108	0.426%	0.037	0.144%	16.344%	1.867%	0.570%
Mongolia	0	CT	2035	0.323	1.052%	0.074	0.241%	139.465%	4.062%	1.293%
Mongolia	0	CT + FB	2035	0.208	0.676%	0.024	0.077%	81.198%	2.365%	0.753%
Montenegro, Rep. of	1	CT	2035	0.124	1.355%	0.042	0.453%	161.422%	4.284%	1.808%
Montenegro, Rep. of	1	CT + FB	2035	0.074	0.808%	0.013	0.144%	85.035%	2.257%	0.952%
Montserrat	0	CT	2035	0.002	1.870%	0.000	0.000%		2.552%	1.870%
Montserrat	0	CT + FB	2035	0.001	1.063%	0.000	0.000%		1.451%	1.063%
Morocco	0	CT	2035	1.124	0.621%	0.463	0.256%	112.184%	3.681%	0.876%
Morocco	0	CT + FB	2035	0.726	0.401%	0.147	0.081%	61.716%	2.025%	0.482%
Mozambique	0	CT	2035	0.550	1.641%	0.188	0.560%	28.840%	7.351%	2.201%
Mozambique	0	CT + FB	2035	0.351	1.047%	0.060	0.178%	16.061%	4.094%	1.226%
Myanmar	0	CT	2035	0.922	0.890%	0.250	0.241%	116.804%	6.914%	1.130%
Myanmar	0	CT + FB	2035	0.592	0.571%	0.079	0.077%	66.889%	3.959%	0.647%
Namibia	0	CT	2035	0.080	0.546%	0.082	0.560%	49.683%	3.466%	1.106%
Namibia	0	CT + FB	2035	0.052	0.358%	0.026	0.178%	24.074%	1.679%	0.536%
Nauru	1	CT	2035	0.001	0.947%	0.000	0.241%	4.781%	0.798%	1.187%
Nauru	1	CT + FB	2035	0.001	0.610%	0.000	0.077%	2.764%	0.462%	0.687%

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Nepal	0	CT	2035	0.530	0.744%	0.127	0.178%	54.352%	4.127%	0.923%
Nepal	0	CT + FB	2035	0.316	0.444%	0.040	0.057%	29.487%	2.239%	0.501%
Netherlands	0	CT	2035	0.000	0.000%	0.000	0.000%		0.000%	0.000%
Netherlands	0	CT + FB	2035	0.000	0.000%	0.000	0.000%		0.000%	0.000%
New Zealand	0	CT	2035	0.000	0.000%	0.000	0.000%		0.000%	0.000%
New Zealand	0	CT + FB	2035	0.000	0.000%	0.000	0.000%		0.000%	0.000%
Nicaragua	0	CT	2035	0.272	1.080%	0.053	0.212%	28.909%	4.689%	1.293%
Nicaragua	0	CT + FB	2035	0.169	0.671%	0.017	0.068%	16.510%	2.678%	0.738%
Niger	0	CT	2035	0.116	0.436%	0.149	0.560%	12.985%	5.533%	0.997%
Niger	0	CT + FB	2035	0.068	0.255%	0.047	0.178%	5.643%	2.404%	0.433%
Nigeria	0	CT	2035	3.076	0.622%	2.773	0.560%	131.633%	15.097%	1.182%
Nigeria	0	CT + FB	2035	1.889	0.382%	0.883	0.178%	62.370%	7.153%	0.560%
North Macedonia	0	CT	2035	0.124	0.661%	0.085	0.453%	93.285%	3.784%	1.114%
North Macedonia	0	CT + FB	2035	0.080	0.428%	0.027	0.144%	47.940%	1.945%	0.573%
Norway	0	CT	2035	0.000	0.000%	0.000	0.000%		0.000%	0.000%
Norway	0	CT + FB	2035	0.000	0.000%	0.000	0.000%		0.000%	0.000%
Oman	0	CT	2035	0.000	0.000%	0.000	0.000%		0.000%	0.000%
Oman	0	CT + FB	2035	0.000	0.000%	0.000	0.000%		0.000%	0.000%
Pakistan	0	CT	2035	1.320	0.286%	0.823	0.178%	116.370%	4.121%	0.464%
Pakistan	0	CT + FB	2035	0.849	0.184%	0.262	0.057%	60.335%	2.137%	0.241%
Palau	1	CT	2035	0.016	4.936%	0.001	0.241%	30.989%	11.644%	5.176%
Palau	1	CT + FB	2035	0.009	2.819%	0.000	0.077%	17.335%	6.514%	2.896%
Panama	0	CT	2035	0.000	0.000%	0.000	0.000%	0.000%	0.000%	0.000%
Panama	0	CT + FB	2035	0.000	0.000%	0.000	0.000%	0.000%	0.000%	0.000%
Papua New Guinea	0	CT	2035	0.375	1.215%	0.074	0.241%	68.006%	8.921%	1.456%
Papua New Guinea	0	CT + FB	2035	0.243	0.788%	0.024	0.077%	40.401%	5.300%	0.865%
Paraguay	0	CT	2035	0.300	0.589%	0.108	0.212%	422.462%	4.169%	0.801%
Paraguay	0	CT + FB	2035	0.187	0.368%	0.034	0.068%	229.380%	2.263%	0.435%
Peru	0	CT	2035	1.251	0.423%	0.627	0.212%	226.394%	3.209%	0.635%
Peru	0	CT + FB	2035	0.821	0.278%	0.200	0.068%	123.072%	1.745%	0.345%
Philippines	0	CT	2035	2.346	0.319%	1.768	0.241%	255.180%	2.798%	0.560%
Philippines	0	CT + FB	2035	1.510	0.206%	0.563	0.077%	128.553%	1.410%	0.282%
Poland	0	CT	2035	0.000	0.000%	0.000	0.000%		0.000%	0.000%
Poland	0	CT + FB	2035	0.000	0.000%	0.000	0.000%		0.000%	0.000%
Portugal	0	CT	2035	0.000	0.000%	0.000	0.000%		0.000%	0.000%
Portugal	0	CT + FB	2035	0.000	0.000%	0.000	0.000%		0.000%	0.000%
Puerto Rico	0	CT	2035	0.000	0.000%	0.000	0.000%			0.000%
Puerto Rico	0	CT + FB	2035	0.000	0.000%	0.000	0.000%			0.000%
Qatar	0	CT	2035	0.000	0.000%	0.000	0.000%		0.000%	0.000%
Qatar	0	CT + FB	2035	0.000	0.000%	0.000	0.000%		0.000%	0.000%
Romania	0	CT	2035	0.000	0.000%	0.000	0.000%		0.000%	0.000%
Romania	0	CT + FB	2035	0.000	0.000%	0.000	0.000%		0.000%	0.000%
Russia	0	CT	2035	0.000	0.000%	0.000	0.000%		0.000%	0.000%
Russia	0	CT + FB	2035	0.000	0.000%	0.000	0.000%		0.000%	0.000%
Rwanda	0	CT	2035	0.152	0.759%	0.112	0.560%	24.468%	5.711%	1.320%
Rwanda	0	CT + FB	2035	0.090	0.448%	0.036	0.178%	11.620%	2.712%	0.627%
Samoa	1	CT	2035	0.037	3.203%	0.003	0.241%	31.387%	10.354%	3.444%
Samoa	1	CT + FB	2035	0.021	1.850%	0.001	0.077%	17.559%	5.793%	1.926%
San Marino	0	CT	2035	0.000	0.000%	0.000	0.000%		0.000%	0.000%
San Marino	0	CT + FB	2035	0.000	0.000%	0.000	0.000%		0.000%	0.000%
Saudi Arabia	0	CT	2035	0.000	0.000%	0.000	0.000%		0.000%	0.000%
Saudi Arabia	0	CT + FB	2035	0.000	0.000%	0.000	0.000%		0.000%	0.000%
Senegal	0	CT	2035	0.446	0.908%	0.275	0.560%	49.684%	7.219%	1.468%
Senegal	0	CT + FB	2035	0.275	0.560%	0.088	0.178%	24.973%	3.628%	0.738%
Serbia	0	CT	2035	0.262	0.236%	0.504	0.453%	150.261%	1.638%	0.689%
Serbia	0	CT + FB	2035	0.169	0.152%	0.160	0.144%	64.635%	0.705%	0.296%
Seychelles	1	CT	2035	0.233	7.177%	0.018	0.560%		21.679%	7.737%
Seychelles	1	CT + FB	2035	0.134	4.144%	0.006	0.178%		12.110%	4.322%
Sierra Leone	0	CT	2035	0.062	1.233%	0.028	0.560%	17.139%	9.880%	1.793%
Sierra Leone	0	CT + FB	2035	0.038	0.753%	0.009	0.178%	8.905%	5.134%	0.932%
Singapore	0	CT	2035	0.000	0.000%	0.000	0.000%		0.000%	0.000%
Singapore	0	CT + FB	2035	0.000	0.000%	0.000	0.000%		0.000%	0.000%
Slovak Republic	0	CT	2035	0.000	0.000%	0.000	0.000%		0.000%	0.000%
Slovak Republic	0	CT + FB	2035	0.000	0.000%	0.000	0.000%		0.000%	0.000%
Slovenia	0	CT	2035	0.000	0.000%	0.000	0.000%		0.000%	0.000%
Slovenia	0	CT + FB	2035	0.000	0.000%	0.000	0.000%		0.000%	0.000%

Country	SDS	Policy	Year	Compensation (USD billion)	Compensation (% of GDP)	Climate finance (USD billion)	Climate finance (% of GDP)	Compensation + climate finance (% of current ODA)	Compensation + climate finance (% of current revenue)	Compensation + climate finance (% of GDP)
Solomon Islands	1	CT	2035	0.051	2.371%	0.005	0.241%	22.214%	8.216%	2.612%
Solomon Islands	1	CT + FB	2035	0.031	1.460%	0.002	0.077%	13.073%	4.835%	1.537%
Somalia	0	CT	2035	0.195	0.959%	0.114	0.560%	15.963%	29.091%	1.519%
Somalia	0	CT + FB	2035	0.124	0.609%	0.036	0.178%	8.269%	15.069%	0.787%
South Africa	0	CT	2035	3.314	0.789%	2.353	0.560%	550.916%	5.046%	1.350%
South Africa	0	CT + FB	2035	2.148	0.512%	0.749	0.178%	281.645%	2.580%	0.690%
South Sudan	0	CT	2035	0.259	2.965%	0.049	0.560%	14.832%	9.667%	3.526%
South Sudan	0	CT + FB	2035	0.160	1.827%	0.016	0.178%	8.439%	5.500%	2.006%
Spain	0	CT	2035	0.000	0.000%	0.000	0.000%		0.000%	0.000%
Spain	0	CT + FB	2035	0.000	0.000%	0.000	0.000%		0.000%	0.000%
Sri Lanka	0	CT	2035	0.456	0.397%	0.205	0.178%	5974.673%	4.819%	0.575%
Sri Lanka	0	CT + FB	2035	0.293	0.255%	0.065	0.057%	3242.336%	2.615%	0.312%
St. Kitts and Nevis	1	CT	2035	0.053	3.858%	0.003	0.212%		11.423%	4.070%
St. Kitts and Nevis	1	CT + FB	2035	0.032	2.351%	0.001	0.068%		6.789%	2.419%
St. Lucia	1	CT	2035	0.180	6.300%	0.006	0.212%	555.603%	30.134%	6.512%
St. Lucia	1	CT + FB	2035	0.102	3.562%	0.002	0.068%	309.633%	16.793%	3.629%
St. Vincent and the Grenadin	1	CT	2035	0.043	3.357%	0.003	0.212%	292.084%	12.978%	3.569%
St. Vincent and the Grenadin	1	CT + FB	2035	0.025	1.986%	0.001	0.068%	168.067%	7.468%	2.054%
Sudan	0	CT	2035	0.328	0.987%	0.186	0.560%	33.017%	19.725%	1.547%
Sudan	0	CT + FB	2035	0.208	0.626%	0.059	0.178%	17.167%	10.256%	0.805%
Suriname	0	CT	2035	0.141	2.626%	0.011	0.212%	278.128%	13.886%	2.838%
Suriname	0	CT + FB	2035	0.093	1.727%	0.004	0.068%	175.908%	8.783%	1.795%
Sweden	0	CT	2035	0.000	0.000%	0.000	0.000%		0.000%	0.000%
Sweden	0	CT + FB	2035	0.000	0.000%	0.000	0.000%		0.000%	0.000%
Switzerland	0	CT	2035	0.000	0.000%	0.000	0.000%		0.000%	0.000%
Switzerland	0	CT + FB	2035	0.000	0.000%	0.000	0.000%		0.000%	0.000%
Syria	0	CT	2035							
Syria	0	CT + FB	2035							
São Tomé and Príncipe	1	CT	2035	0.015	1.626%	0.005	0.560%	36.998%	9.938%	2.186%
São Tomé and Príncipe	1	CT + FB	2035	0.008	0.904%	0.002	0.178%	18.320%	4.921%	1.082%
Taiwan Province of China	0	CT	2035	0.000	0.000%	0.000	0.000%		0.000%	0.000%
Taiwan Province of China	0	CT + FB	2035	0.000	0.000%	0.000	0.000%		0.000%	0.000%
Tajikistan	0	CT	2035	0.074	0.413%	0.081	0.453%	26.359%	3.233%	0.866%
Tajikistan	0	CT + FB	2035	0.045	0.252%	0.026	0.144%	12.073%	1.481%	0.396%
Tanzania	0	CT	2035	0.888	0.700%	0.711	0.560%	60.060%	8.608%	1.260%
Tanzania	0	CT + FB	2035	0.529	0.417%	0.226	0.178%	28.376%	4.067%	0.596%
Thailand	0	CT	2035	16.341	2.485%	1.582	0.241%	3235.175%	13.042%	2.726%
Thailand	0	CT + FB	2035	9.782	1.488%	0.504	0.077%	1856.608%	7.485%	1.564%
Timor-Leste	1	CT	2035	0.086	2.976%	0.007	0.241%	41.781%	6.240%	3.217%
Timor-Leste	1	CT + FB	2035	0.053	1.842%	0.002	0.077%	24.917%	3.722%	1.919%
Togo	0	CT	2035	0.162	1.214%	0.075	0.560%	55.236%	10.049%	1.774%
Togo	0	CT + FB	2035	0.102	0.765%	0.024	0.178%	29.361%	5.342%	0.943%
Tonga	1	CT	2035	0.017	2.853%	0.001	0.241%	6.070%	7.415%	3.094%
Tonga	1	CT + FB	2035	0.010	1.665%	0.000	0.077%	3.417%	4.174%	1.741%
Trinidad and Tobago	1	CT	2035	0.410	1.584%	0.055	0.212%		6.665%	1.796%
Trinidad and Tobago	1	CT + FB	2035	0.262	1.013%	0.017	0.068%		4.008%	1.080%
Tunisia	0	CT	2035	0.399	0.912%	0.112	0.256%	42.126%	4.489%	1.168%
Tunisia	0	CT + FB	2035	0.256	0.586%	0.036	0.081%	24.076%	2.566%	0.667%
Turkiye	0	CT	2035	4.960	0.485%	4.627	0.453%	1197.991%	3.035%	0.938%
Turkiye	0	CT + FB	2035	3.253	0.318%	1.473	0.144%	590.561%	1.496%	0.463%
Turkmenistan	0	CT	2035	0.319	0.279%	0.519	0.453%	5555.296%	6.506%	0.731%
Turkmenistan	0	CT + FB	2035	0.205	0.179%	0.165	0.144%	2454.161%	2.874%	0.323%
Tuvalu	1	CT	2035	0.004	5.177%	0.000	0.241%	7.001%	4.850%	5.417%
Tuvalu	1	CT + FB	2035	0.002	2.946%	0.000	0.077%	3.906%	2.706%	3.022%
Uganda	0	CT	2035	0.339	0.414%	0.459	0.560%	37.767%	7.238%	0.975%
Uganda	0	CT + FB	2035	0.200	0.245%	0.146	0.178%	16.390%	3.141%	0.423%
Ukraine	0	CT	2035	1.972	0.752%	1.188	0.453%	10.996%	3.058%	1.204%
Ukraine	0	CT + FB	2035	1.281	0.488%	0.378	0.144%	5.775%	1.606%	0.633%
United Arab Emirates	0	CT	2035	0.000	0.000%	0.000	0.000%		0.000%	0.000%
United Arab Emirates	0	CT + FB	2035	0.000	0.000%	0.000	0.000%		0.000%	0.000%
United Kingdom	0	CT	2035	0.000	0.000%	0.000	0.000%		0.000%	0.000%
United Kingdom	0	CT + FB	2035	0.000	0.000%	0.000	0.000%		0.000%	0.000%
United States	0	CT	2035	0.000	0.000%	0.000	0.000%		0.000%	0.000%
United States	0	CT + FB	2035	0.000	0.000%	0.000	0.000%		0.000%	0.000%
Uruguay	0	CT	2035	0.000	0.000%	0.000	0.000%		0.000%	0.000%
Uruguay	0	CT + FB	2035	0.000	0.000%	0.000	0.000%		0.000%	0.000%

Country	SDS	Policy	Year	Compensation (USD billion)	Compensation (% of GDP)	Climate finance (USD billion)	Climate finance (% of GDP)	Compensation + climate finance (% of current ODA)	Compensation + climate finance (% of current revenue)	Compensation + climate finance (% of GDP)
Uzbekistan	0	CT	2035	0.780	0.599%	0.590	0.453%	86.084%	3.773%	1.052%
Uzbekistan	0	CT + FB	2035	0.484	0.372%	0.188	0.144%	42.231%	1.851%	0.516%
Vanuatu	1	CT	2035	0.077	4.507%	0.004	0.241%	64.959%	11.137%	4.748%
Vanuatu	1	CT + FB	2035	0.045	2.604%	0.001	0.077%	36.674%	6.287%	2.680%
Venezuela	0	CT	2035	0.582	0.525%	0.235	0.212%	300.266%		0.737%
Venezuela	0	CT + FB	2035	0.376	0.339%	0.075	0.068%	165.735%		0.407%
Vietnam	0	CT	2035	12.421	1.767%	1.692	0.241%	28848.413%	10.219%	2.008%
Vietnam	0	CT + FB	2035	7.665	1.090%	0.538	0.077%	16768.137%	5.940%	1.167%
West Bank and Gaza	0	CT	2035	0.110	0.496%	0.056	0.256%	7.429%	3.327%	0.752%
West Bank and Gaza	0	CT + FB	2035	0.072	0.326%	0.018	0.081%	4.028%	1.804%	0.408%
Yemen	0	CT	2035	0.259	0.919%	0.072	0.256%	9.115%	16.038%	1.174%
Yemen	0	CT + FB	2035	0.166	0.590%	0.023	0.081%	5.208%	9.165%	0.671%
Zambia	0	CT	2035	0.250	0.614%	0.228	0.560%	26.140%	5.754%	1.175%
Zambia	0	CT + FB	2035	0.156	0.383%	0.073	0.178%	12.496%	2.751%	0.561%
Zimbabwe	0	CT	2035	0.123	0.451%	0.153	0.560%	35.339%	8.255%	1.012%
Zimbabwe	0	CT + FB	2035	0.079	0.287%	0.049	0.178%	16.273%	3.801%	0.466%

Note: The term "country" does not in all cases refer to a territorial entity that is a state as understood by international law and practice. The term also covers some territorial entities that are not states.

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