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Research article

Taking the slow route to decarbonisation? Developing climate governance for international transport

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ABSTRACT

Despite their significant, growing contribution to global emissions, international aviation and shipping have avoided a significant climate governance response until recently. This paper outlines the urgent need for, but major barriers to, decarbonisation of these industries, including various market failures and sensitivities over restraining demand. The need and potential for international governance to address these issues is seen to vary across aviation and shipping, given different industry structures and characteristics. A range of relevant inter- and transnational governance institutions is highlighted and an assessment of their overall adequacy offered. With a 2018 commitment to significant emission reduction, maritime governance effort has progressed further, although significant implementation challenges remain. Meanwhile aviation-related commitments rely more on out-of-sector offsets. Options for enhancing governance for decarbonisation are outlined, highlighting the importance of, *inter alia*, coordination between the UNFCCC and sectoral bodies, mechanisms to finance R&D and incentivise investment, and openness in key decision-making fora.

1. Introduction

Driven by increasing demand for international transport, carbon emissions from aviation and shipping have grown significantly in recent decades. Having increased around 80% between 1990 and 2010, CO_2 emissions have been forecast to rise by 50–250% by 2050 for shipping (IMO, 2014), and could triple for aviation (IEA, 2019). Although aviation and shipping currently each emit around 3% of global CO2 (Energy Transitions Commission, 2018), international transport's share looks set to grow as other sectoral systems' mitigation plans take effect.

Governance efforts to tackle these trends face a range of difficulties, not least the need to allocate responsibility for international emissions not covered by domestic policies. Determining what constitutes a fair contribution to delivering long-term temperature goals is complex. Nevertheless, the long-term temperature goal enshrined in the Paris Agreement (PA) effectively requires all sectors to decarbonise as rapidly as possible. More specifically, 'Paris compliance' by international shipping arguably requires 70–100% emissions reduction by 2050, from 2008 levels (T&E, 2018a), while according to Lee (2018), any continued fossil fuel usage by aviation will become irreconcilable with a 1.5 °C warming target around mid-century, assuming no further measures (such as implementing negative emissions technologies).

Against this challenging sectoral backdrop, this paper assesses the potential of international governance to contribute to adequate mitigation effort, and the extent to which it has been utilized. It does so by applying a framework for sectoral system analysis in which international institutions are understood to establish substantive rules and norms that can prescribe, proscribe, permit or direct relevant behaviour of state and non-state actors, and to entail procedural rules for making and implementing related decisions (Oberthür et al., this issue). In addition to inter-governmental bodies, it includes transnational institutions run exclusively by non-state actors, as well as hybrids featuring both non-state and state actors. In this way, the paper contributes original analysis of the state of climate governance in the international transport sectors which, when combined with other contributions to this special issue, allows broader conclusions on the adequacy of global climate governance to be derived (see Rayner et al., this issue).

In addition to extensive desk-based research and literature review, the paper draws on three elite interviews to derive its assessment of the most important sectorally-specific governance

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needs, and inform its judgement regarding the extent to which they are met by existing arrangements. Research for this paper was conducted primarily in 2018–19, and associated judgments regarding adequacy of 'governance supply' largely reflect the state of affairs as of that period.

The paper is structured as follows. In section 2, sectoral transformation challenges and related governance needs are set out, highlighting what needs to change to deliver decarbonisation, and key barriers to those changes. The potential benefits, in principle, of international cooperation are set out. Potentially relevant institutions/initiatives are outlined in section 3, followed by an assessment of the extent to which, in combination, they fulfil key governance functions (section 4). Potential options to improve the adequacy of governance are then sketched (section 5), before conclusions are offered (section 6).

2. Transformation challenges and governance needs

In setting out various potential means of decarbonisation, and challenges they face, this section distinguishes between technology (including alternative fuels) and operational/demand-side aspects. Mitigation potentials vary significantly: while shipping has various effective short-to medium-term options available, aviation does not (making off-setting or emissions trading attractive propositions). In exploring barriers to decarbonisation, the section pays particular attention to respective industry structures and how these relate to wider economic and societal trends. The potential benefits, in principle, of international cooperation in addressing these barriers and challenges, are then set out.

2.1. Means of decarbonisation

For international shipping, near-full decarbonisation as early as 2035 is widely considered technically possible, through the maximum deployment of currently known technologies (ITF, 2018). For short distances, concepts and prototypes exist for electric and hydrogen fuel cell-powered vessels. Over longer distances, biofuels, renewable hydrogen and other hydrogen-derived fuels such as ammonia are being considered. Liquefied natural gas (LNG) use can reduce current emissions intensity, but a fleet-wide switch would risk further carbon lock-in and deliver insufficient decarbonisation (Bows-Larkin, 2015). Although experience is limited, and wider sustainability concerns from their production endure, biofuels (preferably second and third generation) have been considered the most viable alternative for replacing, or blending with, the heavy fuel oil commonly used to power ships (IMO, 2015). Pending greater clarity regarding which systems will dominate shipping's low-carbon transition, it is likely that different niche opportunities will be exploited by different actors.

Decarbonising international shipping is increasingly recognised as requiring cross-sectoral effort (UMAS and ETC, 2019). Since fossil fuels constitute around 40% of seaborne cargo (Sharmina et al., 2017), growth of renewable electricity and bioenergy use in other sectors could reduce demand for shipping significantly. Significantly, decarbonisation of electricity supply is also necessary for the sustainable manufacture of alternative fuels, notably hydrogen and ammonia. Operationally, ports can contribute by providing, *inter-alia*, power, charging systems and bunkering for alternative fuels. To allow emissions to peak and decline sooner, 'slow steaming' (speed limits) could reduce emissions by around a third with little economic impact on long-distance exporters (CE Delft, 2017).

Overall, successful mitigation requires consideration of the interdependencies between ship speed, level and pattern of demand for services, and the extent and rate of innovation in propulsion technology (Walsh et al., 2017). Given relatively slow rates of (adoption of) technological innovation, 'it is difficult to foresee how deep decarbonisation can be achieved without an immediate, fleet-wide speed reduction' (Walsh et al., 2017: 32).

For (international) aviation, while cost considerations have long driven efficiency gains, opportunities for further technological improvements are scarce, at least in the short term. The industry's own targets (see section 3.2 below) imply on-going technological developments offering a 1–2% annual efficiency improvement. More fundamental innovations could halve fuel intensity, but require fleet renewal (which, with aircraft life averaging 30 years, is slow). Currently, 'drop-in' sustainable aviation fuel (SAF) (comprising either biofuel or synthetic fuel) is more practicable. According to the IEA (2017a), achievement of its 2030 Sustainable Development Scenario would require tripling use of sustainable biofuels. While commercial short-distance hybrid-electric flight is a near-term prospect, fuller electrification requires significant advances in battery technology (Schäfer et al., 2019). Latterly, hopes have been raised that use of hydrogen fuel cells can achieve 75–90% emission reductions from short-medium distance flights (Clean Sky 2 JU, 2020).

In operational terms, efficiency-optimised routing has some potential (Larsson et al., 2019). Much more could be achieved through demand management, especially as nearly 90% of aviation emissions are from (often highly discretionary) passenger traffic. High-speed rail's potential as an alternative mode is limited, however, since around 80% of all aviation emissions are from flights over 1500 km (ATAG, 2014). Improved videoconferencing has potential, but raising ticket prices may be the most effective demand management instrument.

Although more challenging than shipping, recent analyses have suggested that aviation decarbonisation by 2050 is technically feasible, and that prospects are maximised by pursuing some combination of electrical (or hydrogen) propulsion, demand reduction, and limited (temporary) offsetting, with increased use of SAF in the meantime (Energy Transitions Commission, 2018; Cames et al., 2015: 41).

2.2. Barriers to decarbonisation

Of the two, the simpler industrial structure of aviation – two dominant manufacturers and a few key airlines – is more conducive, in principle, to decarbonisation. For shipping, multiple builders, financers, owners, operators, shippers, charterers and end-users complicate the regulatory landscape (Bows-Larkin, 2015). Arguably, shipping's low public profile has shielded it from public pressure. Globalisation has driven emissions growth in both sectors. Between 1970 and 2013, total international seaborne cargo rose from 2.6 to 9.5 bn. tonnes (Gençsü and Hino, 2015), and subsequent growth rates have continued to exceed global GDP increase (DNV GL, 2019). Meanwhile, burgeoning global tourism has driven rapid growth in air travel (Piera, 2015).

With shipping, a complex set of organisational/structural, behavioural, market and non-market barriers to decarbonisation exists (ITF, 2018). The fundamental market failure, split incentives between ship owners and hirers (the 'landlord-tenant' problem), limits owners' motivation to invest in solutions benefiting others. Non-market barriers include the diversity of ship class and size, the markets and trade routes served and (non-)access to capital. For their part, investors tend to be risk averse, while many banks have reduced their ship financing commitments, restricting access to capital and credit necessary for technology retrofits (Gençsü and Hino, 2015). While increased uptake of innovative technologies can bring capital costs down, perceived technical risk can further increase such cost. Significant rates of fleet turnover and/or retrofitting are necessary (Walsh et al., 2017). Moreover, widespread

uptake and correct operation of new technology requires extensive demonstration and knowledge exchange. Lack of reliable cost-related information deters ship owners (Gençsü and Hino, 2015).

Shipping R&D, particularly for initial proofs-of-concept, has been chronically under-funded, with neither firms nor governments (for the most part) stepping up (Smith, interview). Incentives to fund risky technological R&D unilaterally on the world's behalf are not clear.

Halving international shipping's GHG emissions by 2050 may require $1 trillion of capital investment, the overwhelming majority of which would be devoted to land-based infrastructure, including fuel production and storage facilities (UMAS and ETC, 2019). This implies that the necessary effort can be shared to some extent with other sectors, including land-based transport, but also that low-carbon electricity to power fuel production processes must be abundant and affordable. Regarding biofuels, the IEA (2017a) has reported that current supply only covers about 15% of the total demand. The potential of advanced biofuels ultimately depends on a number of factors, including the global availability of sustainable feedstock.

Operationally, acceptability of slow steaming may depend on steps to maintain freight flows through increases in ship size or number, and potentially some form of compensation if supply chains cannot be suitably adapted (Walsh et al., 2017).

While the simpler industry structure of aviation is more conducive to regulating for decarbonisation, significant commercial, technological and cultural barriers exist here too. For example, complete decarbonisation of air transport could require 30–60% of the total global sustainable biofuels supply (Victor et al., 2019) - against strong competition from other uses (including shipping). But with costs around three times those of conventional fuel, and uncertain market demand, SAF production has been sluggish (IEA, 2017a), constituting just 0.1% of fuel used (IEA, 2019). Mandating of its use by one airport may cause re-routing. As with shipping, wider social and environmental impacts of biofuel production provoke great concern, particularly if cost considerations and lack of scalable alternatives lead to reliance on palm oil, for example. As with many low-carbon alternative fuels for shipping, SAF production at scale requires abundant supplies of affordable, low-carbon electricity. Although the industry favours off-setting measures, here too uncertainty looms over long-term availability, integrity and/or cost of credits, particularly in view of demand from other sectors (Gençsü and Hino, 2015). Aviation demand management is a sensitive issue.

Regulatory uncertainty and inconsistency, and lack of demand for alternatives are commonly highlighted as critical barriers to decarbonisation by both aviation and shipping industries (on the latter, see e.g. Shell and Deloitte, 2020, on the former Victor et al., 2019). For both sectors, the incentive to reduce fuel use, or develop and switch to alternatives, is significantly undermined by the absence of taxation of aviation and shipping fuels (for reasons outlined below).

Lobbying weight of incumbent players represents a further, rather formidable institutional and political challenge for both shipping and aviation. Shipping trade associations, in particular the International Chamber of Shipping (representing over 80% of the global merchant fleet), while ostensibly accepting the need to deliver a 'fair share' of emissions reduction (Platten, 2019), insist that policy instruments must not inhibit development. Large developing or emerging countries have also tended to resist ambitious target-setting (as do developed countries such as Japan. For its part, the International Air Transport Association (IATA) has promoted relatively limited kinds of change – particularly off-setting - to pre-empt more fundamental, costly interventions (Peeters et al., 2016).

2.3. The promise and potential of international cooperation

Since the vast majority of aviation and shipping activity takes place across national borders,[1] international-level action is essential to effective governance of decarbonisation. Imposition of stricter requirements on ships in one state's registry, for example, may simply prompt owners to re-register (or build) elsewhere, using 'flags of convenience'. International shipping decarbonisation is arguably most effectively steered by a combination of global and port-state-level measures (Bows-Larkin, 2015; ITF, 2018).[2] Strong global competition also necessitates international cooperation regarding aviation, to overcome the aforementioned disincentives to unilateral action by e.g. airlines or airports (Victor et al., 2019). For both shipping and aviation, adequately addressing the regulatory uncertainty, inconsistency and lack of demand that impede the scaling up of alternative fuels requires *international, cross-sectoral* action. International cooperation is also required to underpin the integrity and effectiveness of any off-setting or carbon trading schemes.

The introductory article of this special issue (Oberthür et al., this issue) sets out five general functions that international institutions can in principle perform, contributing to effective decarbonisation (summarised in Table 1). In the following, the importance of these functions to decarbonisation of international transport is identified, highlighting international institutions' theoretical potential to overcome the barriers and challenges discussed above.

Issues related to research and development (R&D) are covered under both 'means of implementation' and 'knowledge and learning' functions. This is because R&D requires both finance (potentially involving government subsidy), and also a degree of collaboration in conducting it, and demonstrating any resulting innovations.

2.3.1. Guidance and signal

Given their high projected growth – potentially taking up as much as 40% of a global 2 °C carbon budget by mid-century (Cames et al., 2015) - there is a significant need for a global-level signal of roughly what level of emissions constitutes international transport's 'fair share' in achieving the PA's long-term goal. Furthermore, a clear definition of (net) zero carbon needs to be signalled, clarifying for example that alternative fuel production processes should be fossil-free, and that indirect emissions from biofuels need accounting for.

2.3.2. Setting rules to facilitate collective action

There is also a significant need to incentivise and facilitate international-scale action through regulation. Emission limits could be implemented internationally by market-based instruments or more direct technological regulation – or some combination thereof. International agreement to tax aviation and shipping fuel (potentially with revenues recycled to support R&D), or otherwise stimulate market demand for alternatives, could greatly facilitate collective action. As means of managing demand, price-signals of this kind are more feasible than other theoretical measures, such as international moratoriums on airport expansion.

New technologies will likely require new standards, agreed upon by global certifying institutions and classification companies. Requiring verified vessel efficiency ratings may incentivise

[1] Domestic flights make up around 35% of total emissions from aviation. These are covered under Nationally Determined Contributions (NDCs) (Fleming and Ziegler 2016).

[2] *Port State* refers to countries of entry, with whose laws visiting ships must comply when in port.

Table 1
Overview of main functions of international governance institutions.

Functions	Key features	Main added value
Guidance & Signal	• Results from overall agreement, including targets/objectives	• Aligns actors across countries
Setting Rules	• Various forms of obligations and standards	• Enables action by addressing interdependence & competitiveness concerns
Transparency & Accountability	• Reporting, review/verification, compliance	• Contributes to effective reciprocity and implementation and mutual trust
Means of Implementation	• Capacity building, technology transfer and finance (North-South)	• Facilitates pooling of donors/investors' resources and reducing transaction costs
Knowledge & Learning	• Generation and collective appraisal of information/knowledge	• Improved and shared understanding (authoritative knowledge)
	• Science and policy learning	• Improved policies (learning)

Source: Oberthür et al. a (this issue).

installation of new technologies by enhancing resale value. Niches for alternative fuels for both shipping and aviation could be more easily established through coordination of national mandates for particular blends, and coordination of requirements for their use by ports and airports either within a regional zone, or on key long-haul routes (Victor et al., 2019). Inter-governmental coordination could remove the risk of aircraft re-routing. International rules ensuring that any offset schemes and/or production of alternative fuels adhere to high quality and sustainability standards are critical to achieve full lifecycle emission reductions and avoid side-effects.

Acceptable, successful international agreements require consideration of distributional equity, potentially through slower phasing-in of some measures for certain actors, or substantial finance and technology transfer (see also 'means of implementation' below). Compensating developing countries for any harm suffered is widely recognised as critical to the acceptability of instruments like carbon taxation (IMF, 2011).

2.3.3. Transparency and accountability

To the extent that regulation is introduced, adequate implementation would require appropriate transparency (monitoring and verification) and accountability (enforcement). A degree of transparency over distances and fuel use is also required *before* transport-related rules can be set, in order to judge appropriate policy targets.

In order to assess progress toward global goals, industry-wide (international) efforts are needed to ensure transparency, for example on alternative fuel use and associated emissions over the full lifecycle. Transparency over industry performance also empowers civil society to pressure identifiable laggards. Effective international carbon trading also relies on preventing multiple entities claiming the same emission reduction ('double counting').

2.3.4. Means of implementation (Capacity building, technology and finance)

In shipping, both state and private sector actions can improve availability and cost of capital, incentivising innovation and overcoming the 'landlord-tenant' problem. The scale and effectiveness of action will increase with international coordination. In addition, developing countries have a particular need to access financial resources and technology. A proportion of revenues from global carbon pricing could in principle be earmarked to this purpose, and/or to R&D (ITF, 2018) (see also 'knowledge and learning', below).

Chronic underfunding of R&D, including for advanced biofuels (IMO, 2017a & b), suggests the need for international governance, for example to marshal effort towards particular technological roadmaps. Mobilising the effort to decarbonise shipping, in particular its associated energy value chains, requires collaboration and deliberate collective action involving not just maritime, but also energy, infrastructure and finance sectors, supported by governments and intergovernmental organisations.

For aviation too, scaling up advanced biofuels is a key cross-sectoral R&D challenge. The scale of policy, technological, and supply-chain support necessary for bio-jet fuel development may match levels that were required to establish conventional biofuels for road transport in the U.S. and Brazil (IRENA, 2017). Industry has therefore called for global subsidies as well as extension - even *diversion* - of existing national-level support for road transport to aviation. International coordination would make this more effective. This also applies to electrification, where government support for R&D could be combined with increased public procurement (Victor et al., 2019).

There is also a significant need to build institutional capacity in developing and emerging countries, where aviation growth is highest (Piera, 2015) to implement mitigation initiatives. This might, *inter alia*, enable more effective participation in market-based mechanisms.

2.3.5. Knowledge and learning

For shipping, international-level measures can help overcome lack of reliable information on costs, correct operation and potential savings from specific operational measures or available technological solutions. Demonstration of low- or zero-carbon technologies (including fuels) is a key R&D challenge (IEA, 2017b: 91) that could benefit from international coordination.

Aviation breakthroughs are also likely to require joint R&D, involving airlines, governments and other stakeholders. Internationally coordinated public sector involvement is desirable, due to industry concerns over commercial confidentiality (Piera, interview).

Also related to learning, there is a need to sensitise actors in rapidly developing and emerging economies, where growth rates are highest, to the significance of climate change and potential co-benefits from aviation mitigation policies.

2.3.6. Summary

As summarised in Table 2, guidance and signal, rules to facilitate collective action, and transparency and accountability may be regarded as of particularly high importance to both shipping and aviation. So too is ensuring adequate means of implementation, including R&D support. It should be noted, however, that according high priority to this last aspect (particularly concerning aviation) entails a judgment that political unacceptability of demand management policies (and certainly the international coordination thereof) means the search for technical solutions, rather than behavioural, should remain the primary focus.

3. The governance landscape

Based on a screening of existing databases of international climate-related institutions (Rayner et al., 2018: 15–18), further

Table 2
Type and strength of international governance needs and in-principle contribution by international institutions.

Importance	Guidance and Signal	Setting Rules	Transparency and Accountability	Means of implementation	Knowledge and Learning
	High	High	High	High	Medium-high
Potential contribution	• Signal global limits and phase-out of (net) emissions. • Define Net Zero	• Global limits on emissions • Internalisation of externalities • Operational prescriptions (e.g. speed limits) • Technological prescriptions (e.g. coordinated mandates/ standards for new fuel types). • Phase-in periods for developing countries/ compensation for cost-raising measures.	• To ensure effective implementation of international rules (including avoiding double counting) • Full life-cycle accountability	• Technical cooperation/ technology transfer (shipping) • Access to capital/finance, e.g. to transform energy supply chains or implement retrofits (shipping) • Finance/subsidy of R&D • Institutional capacity building	• (Joint/coordinated) R&D and demonstration for low-carbon technologies/fuels. • information on costs/savings/ correct operation of new technologies and operational measures (shipping). • Sensitising opinion in developing/emerging countries to climate threats and policy co-benefits.

research, and three expert interviews, this section identifies institutions performing relevant international governance functions (reflecting the period over which research was conducted). Findings are summarised in on-line supplemental material (here); judgments over adequacy are left until section 4.

Decarbonisation of international aviation and shipping has been subject to international governance since 1997, when the Kyoto Protocol (Art. 2.2) assigned responsibility to the International Civil Aviation Authority (ICAO) and International Maritime Organization (IMO) respectively. International transport emissions continue to be handled primarily by these two UN bodies. While neither has climate protection as its primary function, each has in principle the authority to impose legally-binding, enforceable sectoral standards. Each maintains links to the United Nations Framework Convention on Climate Change (UNFCCC), to whom international aviation and shipping emissions are reported as 'international bunker fuels', separately from national totals. In the following, the governance 'landscapes' pertaining to shipping and aviation are described in turn.

3.1. Shipping

In addition to Kyoto, the **Convention on the International Maritime Organization**, and the UN Convention on the Law of the Sea (UNCLOS) arguably also provide the IMO with competence to regulate GHG emissions. The 1973 International Convention for the Prevention of Pollution from Ships, as amended by and incorporated in the Protocol of 1978 (MARPOL), is the most important international convention covering vessel-source pollution. The Marine Environment Protection Committee (MEPC) takes decisions affecting the IMO's 173 member countries, and debates proposals for technical, operational and market-based measures (Shi, 2016). The significant decisions it has taken (as of 2019) are described in section 4.

Although involvement of the **UNFCCC** is relatively limited, Parties to the PA have discretion to include international shipping in their Nationally Determined Contributions (NDCs). Shipping emissions are also captured under the PA's collective, economy-wide goals and Global Stocktake. The IMO is expected to facilitate the determination of international shipping's fair contribution, within the spirit of the PA (Chircop et al., 2018).

The regulatory role of the **European Union** is also significant, particularly on account of its (potential or actual) extra-territorial reach, and impetus it potentially provides to the IMO. After the creation of an emissions monitoring, reporting, and verification (MRV) system for ships using EU ports (step one, whose first reporting period started in January 2018), and maritime reduction targets (step two), a third step contemplates some form of market-based measure. The EU's emissions trading scheme is able to include maritime emissions of vessels travelling between EU ports, and potentially beyond.

Various transnational private standard-setting ('green shipping') initiatives have emerged in response to increased consumer concern, retail shipper demands, and regulation. The industry-led **Clean Cargo Working Group (CCWG)** and the NGO-led **Sustainable Shipping Initiative** are increasing business knowledge and transparency, with a view to changing behaviour. The CCWG works with around 50 ocean freight carriers and cargo owners to analyse/ compare efficiency. **RightShip** and **Carbon War Room** operate a jointly developed rating system, grading individual ships on design efficiency, while the **Clean Shipping Index** covers several key pollutants.

Under the auspices of the Large Cities Climate Leadership Group (C40 Cities), the **World Ports Climate Initiative** has promoted information sharing, established a framework for CO_2 footprint inventory and management, and increased support for ship indexing.

The ***Getting to Zero* Coalition** formed in 2019 under the auspices of the **Global Maritime Forum** and the World Economic Forum, comprises over 90 companies within maritime, energy, infrastructure and finance sectors, supported by intergovernmental organisations and 14 governments. Its ambition is to commercially operationalise deep-sea zero emission vessels by 2030 (Global Maritime Forum, 2019). The Global Maritime Forum was also instrumental in establishing the ***Poseidon Principles***, the first sector-specific and self-governing global climate-alignment agreement among financial institutions, aimed at channelling finance towards lower-carbon shipping (World Economic Forum, 2019).

3.2. Aviation

As the leading sectoral governance institution, founded by the 1944 Chicago Convention, the **ICAO** sets standards and recommended practices (SARPs) to facilitate coordinated evolution of international civil aviation, potentially incorporating decarbonisation. In developing relevant SARPs, a dedicated Committee on International Aviation Environmental Protection (CAEP) (est. 1983) has a mandate to work closely with the UNFCCC Secretariat and the IPCC.

In 2010, the ICAO agreed two aspirational goals: 2% annual fuel

efficiency improvement, maintained from 2020 to 2050; and 'carbon-neutral growth' from 2020. A system of State Action Plans, essentially seeking to induce governments to monitor countries' aviation emissions and identify reduction measures, was adopted to facilitate achievement of the aspirational goals (Piera, 2016). A CO2 standard, adopted in 2016, will apply to new aircraft designs from 2020, and those already in production as of 2023. The ICAO's adoption of a framework for market-based mechanisms has led to a 3-stage scheme dubbed **CORSIA** ('Carbon Offsetting and Reduction Scheme for International Aviation'). This aims to stabilise CO2 emissions by 2020, principally by off-setting post-2020 emissions growth or using approved biofuels (ICAO, 2016a).

As with shipping, the **EU** is a noteworthy actor. The controversial decision to include international aviation in the emissions trading scheme (first mooted in 2005) significantly shifted the global regulatory landscape, prompting industry commitments led by the **International Air Transport Association (IATA)**. In 2009, the **Air Transport Action Group (ATAG)** which includes airports, airlines, air traffic management organisations, and manufacturers, committed to improving fleet fuel efficiency by 1.5% annually (2008–2020), cap net sectoral emissions at 2020 levels, and halve net emissions from 2005 levels by 2050 (ATAG, 2014).

Since 2019, the World Economic Forum's public-private ***Clean Skies for Tomorrow*** initiative has offered a purpose-built platform for actors throughout the aviation value chain to facilitate the transition to commercial net-zero flying by mid-century, with SAF production at scale by 2030 as a key objective (World Economic Forum, 2020).

3.3. Potential conflicts among institutions and principles

Decarbonisation governance is undertaken in an institutional context that isn't always conducive. In international shipping, two important international law principles, Common but Differentiated Responsibilities and Respective Capabilities (CBDR) and No More Favourable Treatment' (NMFT), can at times appear at cross-purposes. CBDR, enshrined in the UNFCCC, requires developed states to bear greater responsibility (Martinez-Romera, 2017), while NMFT, consistently applied to all IMO treaty instruments (Shi, 2016), requires port states to enforce applicable standards *uniformly*. While developing states have mostly insisted on CBDR-based regulation, developed countries have tended to favour NMFT as the basis. Exempting or giving preferential treatment to developing country-registered ships, however, risks undermining the 'whole purpose of reducing emissions from international shipping' (Chircop et al., 2018: 50).

Similarly, in aviation the ICAO must also navigate the competing principles of CBDR (derived from the UNFCCC) and non-discrimination, derived from the Chicago Convention ("Martinez-Romera, 2017). It has done so, with varying degrees of success, through its own principle of 'special circumstances and respective capabilities' (Piera, 2015).

Finally, the Chicago Convention, designed in the 1940s expressly to facilitate the expansion of global civil aviation, does not mention environment. Despite environmental protection being recognised in updated strategic objectives for 2013–16, in cases of conflict development has been seen to take precedence (Piera, 2016).

4. Assessing the governance complex

Having set out the sectorally relevant institutions and initiatives, and mapped them against key governance needs (see supplemental material), this section assesses how far existing arrangements contribute to fulfilling the critical governance functions. To arrive at an overall evaluation, assessments for all institutions have been aggregated (taking due account of any overlaps and conflicts) and compared to the previously derived hypothetical needs and potentials of international cooperation (summarised in Table 2). Where possible, three levels of governance supply are distinguished: *high* (where needs/potential are largely met), *medium* (partially met), and *low* (largely unmet). Where details are lacking, or further more in-depth research was not possible, a more qualitative judgment is offered.

4.1. Shipping

4.1.1. Guidance and signal

While conspicuously omitting international shipping, the PA set a clear expectation that the IMO should act for the sector.[3] After years of relative inaction, the IMO has begun to offer significant guidance and signal of its own. Its Initial Strategy (IMO, 2018), agreed in 2018 (to be revised in 2023) promises GHG reduction by *at least* 50% on 2008 levels by 2050. Though falling short of calls for complete decarbonisation by 2035 (ITF, 2018), and setting a CO2-intensity reduction goal (40% by 2030 compared to 2008 levels) that was already three-quarters met (ICCT, 2018), the wording usefully signals possible ratcheting in future, and envisages an eventual total phase out. Subsequent adoption of 'science-based targets' by high-profile shipping companies (Milne, 2018), and founding of the *Getting to Zero* coalition, suggest a signal being widely received. *Getting to Zero* has in addition set out a clear definition of 'zero', clarifying that alternative fuels must avoid fossil fuels at all stages of their supply chain (Global Maritime Forum, 2019). These recent advances suggest that overall delivery of this crucial function by the existing governance complex has moved from low to medium.

4.1.2. Rules to facilitate collective action

The Initial Strategy proposes candidate measures, yet to be agreed, including market-based and enhanced efficiency regulations. Judgments as to their adequacy must await the revised (2023) Strategy's precise selection of the promised short-, mid- and long-term 'further measures', and accompanying implementation schedule. Past obstruction, however, from the likes of Saudi Arabia, Brazil, Japan and the US, presage difficult negotiations.

Technical and operational measures have been agreed through MARPOL, notably the Energy Efficiency Design Index (EEDI) adopted in 2011. This requires progressively less CO2 emitted per unit of work, eventually requiring vessels built after 2025 to be 30% more efficient. The precise means are left to designers and ship-owners. The IMO also requires all sea-going ships above 400 tonnes to use a Ship Energy Efficiency Management Plan (SEEMP) to identify energy-saving measures already undertaken and potential further steps, and to have monitoring and evaluation procedures.

Though positive, EEDI requirements are weakened by their application solely to new vessels.[4] In effect, just 1% annual improvement in global efficiency can be expected by 2025 (IMO, 2017a/b). For its part, the SEEMP does not require actual implementation of identified measures. Even with full implementation of EEDI and SEEMP, shipping emissions could still increase fourfold compared with 1990 (Shi, 2016). Speed remains unregulated, and the failure to levy any tax on international marine fuels represents a further, major weakness in the instrument portfolio.

[3] The *Tony de Brum Declaration*, announced at the 'One Planet' Paris follow-up summit (2017) specifically urges IMO action. As of April 2018, 44 IMO member countries had signed this informal declaration.

[4] An equivalent instrument applying to existing ships was in under negotiation during 2020.

Action on fuel consumption is being taken through a separate 'three-step approach' (IMO, 2015), moving from data collection, to analysis, then potentially further regulations. Since 2019, ships over 5000 tonnes have had to report fuel consumption figures. The requirement to report distance and time travelled may itself promote energy savings and therefore emissions reduction.

Transnational private standards initiatives, while constituting progress and achieving impressive coverage in some cases (CCWG represents 85% of global ocean container capacity), fall short in their ambition particularly by focusing on emissions intensity, not absolute or cumulative emissions (Scott et al., 2017). Data reliability and transparency can also be problematic (ibid).

Overall, despite a degree of recent progress, the delivery by the existing governance complex of this critically important governance function must still be considered low.

4.1.3. Transparency and accountability

Transparency aspects have gradually improved, notably through the on-going parallel IMO and EU data collection processes. But the IMO's new system lacks the detail originally envisaged in the EU's MRV proposals, using metrics too limited to establish real operational efficiency of individual ships. Furthermore it lacks the third-party verification and public disclosure provisions of the EU's initial proposal (T&E, 2019). Moreover, to harmonise with the IMO, the EU Commission subsequently removed the requirement for collection of cargo data (essential for establishing actual operational efficiency), lessening the incentive to improve efficiency.

Regarding switching to alternative fuels, the IMO is yet to establish firm rules on transparency to ensure accurate reporting of full lifecycle emissions, avoiding double counting, and could learn from the more advanced ICAO (Rehmatulla et al., 2020).

Among transnational initiatives, while the CCWG aims to provide reliable year-on-year emissions data from signatory carriers, this information is only available to members. While rating schemes developed by RightShip and the Environmental Ship Index do grant public access to vessel-level emission data, these initiatives lack industry-wide influence, and a single, standardised methodology (Scott et al., 2017).

Overall, delivery of this important governance function, although showing some improvement over time, could be scored at best as low-medium.

4.1.4. Means of implementation

Technical cooperation and transfer of technology relating to energy efficiency is currently delivered (on state request) through the IMO's Integrated Technical Co-operation Programme, and related Ad Hoc Expert Working Group on Facilitation of Transfer of Technology for Ships. In cooperation with other international bodies, the IMO has also operated (since 2015) various technical cooperation (GLOMEEP) and capacity building (Capacity Building for Climate Mitigation in the Maritime Shipping Industry) programmes. The performance of these has not been reported publicly, but the sums involved appear relatively low. The IMO's Initial Strategy refers to further technical cooperation, research and development and capacity-building activities as candidate future measures.

Lack of finance for retrofitting existing ships is partially addressed by transnational initiatives such as the Sustainable Shipping Initiative's 'Save As You Sail' and Carbon War Room's Self-Financing Fuel Saving Mechanism. These have potential to facilitate retrofits without capital expenditure, and are supported by the European Investment Bank's Green Shipping Guarantee (GSG) pilot programme. However, lack of industry demand has hampered their diffusion (Smith, interview).

The launch of the Poseidon Principles in 2019 constitutes another positive development with further potential. Signatory financial institutions, representing around a third of the global ship finance portfolio, have committed to consider alignment with IMO decarbonisation goals in lending decisions (World Economic Forum, 2019). However, big Asian lenders have been conspicuously absent (Bakhsh, 2020). Moreover, targets for individual signatories regarding 'climate alignment' are not specified.

R&D finance for advanced low-carbon fuels remains significantly under-funded (Smith, interview). How far the *Getting to Zero* coalition will provide impetus remains to be seen, but its cross-sectoral reach is welcome. In terms of improving access to capital and finance for R&D, international development banks have been generally slow to respond. As well as committing greater resources to alternative fuels, meaningful decarbonisation will require them to reduce (currently generous) support to short-term - but ultimately counter-productive - solutions, namely LNG infrastructure (Smith, interview).

For these reasons, although the need for this governance function is high, to date the overall level of delivery by the existing governance complex, whilst gradually improving, has been low (particularly given continued mis-allocation of resources to LNG and relatively low financing of R&D).

4.1.5. Knowledge and learning

Gaps in delivering this particular governance function centre on *clear demonstration* of the benefits of currently available technologies, and coordinated R&D and demonstration for new ones. Here, *Getting to Zero's* commitment to catalyze demonstrations, pilot projects etc. represent a notable recent advance, at least on paper, but coordinated activity elsewhere is less evident.

The World Ports Climate Initiative's information sharing regarding on-shore measures also merits recognition.

4.2. Aviation

4.2.1. Guidance and signal

A global-level signal of roughly what level of emissions constitutes international aviation's 'fair share' in achieving the PA's long-term goal is conspicuously lacking. Relative to the daunting challenge of 'Paris-compliance', the signal sent by relevant governance institutions falls well short. Factoring in aviation's *non-CO2* emissions, which more than double overall warming (IPCC, 1999), the gap widens. The ICAO has never set a long-term absolute reduction target, while the significance of the industry's own commitment to halve net emissions by 2050 is debatable, given its apparent reliance on offsetting and potentially unscalable or unsustainable sources of biofuel.

4.2.2. Rules to facilitate collective action

Although other rules exist, the CO2 standard and CORSIA are the most significant (Piera, 2016: 2).[5] As currently conceived, neither is capable of reducing aviation emissions in absolute terms. The CO2 standard reflects the industry's own commitment to 2% annual efficiency improvement. Recent implementation has fallen short, slowing to 0.6% in the years 2014–2016 (IEA, 2019). No assessment has apparently ever been conducted into what the standard implies for absolute emission levels from the global fleet (Lee, 2018).

CORSIA envisaged post-2020 aviation growth beyond a baseline (calculated as the average of 2019 and 2020 emissions) being offset, primarily by investments in out-of-sector mitigation projects. By leaving baseline emissions unregulated, potentially only 6% of

[5] Piera also lists State Action Plans, considered here mainly under 'transparency and accountability' and 'means of implementation' headings.

international aviation emissions will be covered between 2015 and 2050 (ICSA, 2018). Significant uncertainties over CORSIA's ultimate design and effectiveness were exacerbated in 2020 by the Covid-19 pandemic, when ICAO's Council opted to shift the baseline year to 2019, ensuring less demanding targets for the scheme's pilot phase up to 2023, and potentially beyond (Climate Action Tracker, 2020).

During the pilot phase and first implementation period (2024–2026), participation is voluntary; several G20 states have opted out. From the second phase (2027–2035), with limited exceptions all states are due to participate. But ICAO's non-binding goals are not assigned or 'attributed' to particular states or operators. Instead, all states are encouraged to strive collectively to achieve them, with the effect of reducing incentives for individual actors to implement technological or operational measures (rather than purchasing more economical offsets, effectively 'free-riding' on other sectors' efforts). Moreover, if governments prefer income from sales of credits for emission reductions over including them in national mitigation programmes, offsetting projects could even weaken developing countries' Nationally Determined Contributions to the PA (Larsson et al., 2019).

Concerns over reliance on forestry and credits from past, less robust CDM projects (Stay Grounded, 2018) were partially allayed by the decision to exclude projects started before 2016 from Eligible Emissions Units for the pilot stage (ICAO, 2020). Reliance on biofuels remains risky, however; standards designed to ensure sustainability have remained under development (behind closed doors).

Meaningful demand management, required as part of the policy portfolio if aviation is to become Paris-compliant (see section 2.1), is absent. Although potentially key to *internalising externalities*, the Chicago Convention's prohibition of taxation on arrival of fuel already onboard aircraft has been widely extended to become a general exemption for fuel on international flights, and enshrined in numerous bilateral agreements. ICAO's Council has endorsed charges (for use of facilities) rather than taxes; the Assembly's subsequent endorsement has effectively ruled out kerosene taxation at international level (Piera, 2016).[6]

Overall, although ICAO has made a degree of progress in recent years, the flaws, weaknesses and significant uncertainties described above mean that achievement of this critically important governance function is still rather low.

4.2.3. Transparency and accountability

ICAO's State Action Plans were designed in part to improve monitoring, and thereby transparency of implementation, of various commitments. Whilst representing significant progress, concerns have been expressed about accuracy of data or, in some cases, lack of evidence of implementation (Piera, 2016: 19). Enforcement is also problematic, especially where states lack capacity and/or commitment (Piera, interview). Countries cannot be made to enforce SARPs on airlines, and there is a lack of publicly available information on related compliance.

For CORSIA, detailed work on monitoring, reporting and verification and registries, is on-going, to enable airlines to track how many credits they need, and governments to check they have bought them. Provisions have been agreed to prevent double counting of emission reductions by airlines and the countries developing offset projects. ICAO's Sustainable Aviation Fuels framework is more robust in its accounting for full lifecycle emissions, and in incentivising production accordingly, than equivalent practice in the shipping sector (Rehmatulla, 2020). Concerns remain, however, regarding consistency of application of agreed Emission Unit Eligibility Criteria for offset credits, and actual savings from SAF use (Climate Action Tracker, 2020).

A 'governance supply' rating of medium seems reasonable, at least as a snapshot of developments as of 2019.

4.2.4. Means of implementation

The key governance need here is to ensure adequate aviation R&D funding, and particularly support for SAF development. While annual civil aerospace industry R&D has been estimated at $15 billion (ICAO/ATAG, 2014), it is hard to judge how well targeted towards decarbonisation this is. The governmental response to calls for global subsidies for SAF production and use remains fragmented. Supply chain development and measures to reduce cost premiums are still lacking (IEA, 2017b).

Regarding necessary institutional capacity building, ICAO runs a comparatively large technical cooperation programme (Piera, 2015). ICAO's requirement for State Action Plans has prompted many countries to address aviation climate impacts for the first time (Piera, 2016). To offer assistance (including finance) for State Action Plans, ICAO has established partnerships with the EU, UN Development Programme and the Global Environment Facility (ICAO, 2016b).

Despite significant efforts to build capacity, given the identified need to fund breakthrough technologies substantially, overall delivery of this function by existing international governance arrangements should arguably be classed as low-medium at best.

4.2.5. Knowledge and learning

Although precise details are hard to obtain, (joint) R&D for low-carbon technologies/fuels, involving airlines, governments and other stakeholders (the key knowledge and learning-related governance need), is reported to be happening to some extent (see the 'Collaborative Climate Action across the Air Transport World' initiative reported to the UNFCCC). ICAO's Global Framework for Aviation Alternative Fuels offers a database for relevant activities and supports initiatives and projects, while the *Clean Skies for Tomorrow* initiative features regular workshops, dialogues, analytical reports and strategic guidance to engage actors throughout the aviation value chain and related industries.

4.3. Summary: significant governance gaps

Despite some notable recent improvements, the most critical decarbonisation governance functions are a long way from fulfilment for international transport (Table 4). For shipping, the IMO's Initial Strategy may be regarded as an overdue breakthrough, offering significantly improved guidance and signal, with potential to translate by 2023 into more meaningful rules to facilitate collective action. However, means of implementation and especially funding for R&D, will also need particular attention. For aviation, the scarcity of acceptable near-term decarbonisation options inclined the industry and its international regulators towards reliance on out-of-sector action, through an instrument (CORSIA), designed essentially to offset, not reduce, emissions. Long-term guidance and signal is weaker than for shipping, and overall the aviation-related governance response carries the risk that development of technological solutions by the industry itself is dis-incentivised by the over-riding concern to operationalise CORSIA (IEA, 2017b). Current policies could still leave international aviation consuming up to 10% of the total global cumulative CO_2 budget available until 2100 if temperature rise is not to exceed 2 °C (Lee, 2018).

5. Towards a more adequate governance response

The following discussion briefly sets out some options worth

[6] In principle, states can remove tax exemption from bilateral air service agreements.

considering in addressing key governance gaps identified, function by function. Space constraints prevent a more in-depth assessment of their feasibility.

5.1. Guidance and signal

The credibility and visibility of the decarbonisation signal over time will be critical to ensuring adequate international action. Further work, both analytic and diplomatic, could usefully clarify and signal an appropriate, fair contribution from aviation and shipping to securing long-term temperature targets, in the context of the broader climate regime centred on the UNFCCC. This should take into account, *inter alia,* sectoral circumstances of each, the likelihood of short-term technological breakthroughs and the relationship to on-going developments in other sectoral systems (recall from section 2.1 the importance to shipping of low-carbon transitions more widely). Periodic adjustments to the long-term sectoral goals for each could be made by ICAO and IMO in conjunction with developments in the UNFCCC, evolving understanding of the likely contribution of negative emissions, and actual progress of decarbonisation (Chircop et al., 2018). Were negative emissions technologies to be reserved for genuine CO2 removal (rather than simply offsetting increased emissions), more ambitious sectoral decarbonisation goals would need to be set. But whatever the means to establish it, the decarbonisation signal for both shipping and aviation needs significant strengthening.

5.2. Setting rules

No measure in isolation will deliver adequate decarbonisation, for either shipping or aviation. To address the identified regulatory gaps for shipping, the IMO needs to adopt new, concrete measures, incorporating review and update procedures. Regulating existing ships' speed and efficiency would be obvious steps (ITF, 2018). A carbon levy on bunker fuels has gained traction as a potential instrument (IIMF, 2016; NewClimate, 2019; Larocca, 2020), for both emission-reduction and revenue raising purposes (with proceeds subsidising alternatives and/or supporting further R&D). Elements of both CBDR and NMFT can be incorporated in new instruments, offering the chance to overcome objections from key developing or emerging countries.

A range of necessary actions cut across several sectoral and governance levels, and require involvement of a corresponding range of regulatory bodies. Traditional IMO-led regulation alone will likely not muster the scale of effort needed. Here, the IMO could be more explicit in defining appropriate roles for its member governments and private actors, and attempting to mobilise sectoral regulators beyond shipping. For example, in developing innovative new low-carbon fuels, the importance of extending regulation further up the supply chain, to ensure *production* is itself effectively decarbonised, is becoming clearer (see e.g. UMAS and ETC, 2019), as is the importance of both economic incentives and regulatory intervention to lower their cost. Steps to co-ordinate port-level charging schemes (see COGEA et al., 2017) could complement carbon pricing at a global level.

Although clearly challenging, and presupposing commitment from key member governments, in principle the IMO possesses many of the 'success factors' required by a would-be orchestrator: a focal institution in the relevant issue area; convening power; the ability to delegate legitimacy; resources to enable; and recognition of the need for reform through greater consultation and engagement of new actors (Lister, 2015: 126; cf. Scott et al., 2017).

For aviation, CORSIA's three-yearly review cycle provides an opportunity to ratchet ambition, and to reconsider ICAO's 2020 decision to weaken the baseline; the 2022 Assembly will be a pivotal moment. Once the emission reductions delivered by CORSIA become more precisely quantified, attention could focus on better alignment of the CO2 standard for new planes with industry targets for carbon neutral growth, 2% annual efficiency improvement and halving of emissions by 2050 (IEA, 2017b).

As Section 2.1 noted, some degree of demand management appears unavoidable if aviation is to do its 'fair share' to meet Paris long-term goals. However, international coordination of this remains problematic, particularly given the *de facto* prohibition on taxation of kerosene. In theory, this and other governance gaps could be addressed by amendments to the Chicago Convention. In practice, however, more frequent meetings of the Assembly, where more progressive states can act as a counterweight to the power of the more conservative ICAO Council offer a more realistic hope (Piera, 2016: 8). Moreover, fuel taxation could still be agreed bilaterally between states. EU Member States, for example, could show leadership here, taxing intra-EU flights, with negligible impact on GDP (CE Delft, 2018), and proclaiming this as part of the EU's Nationally Determined Contribution under the PA (T&E, 2018b).

In both shipping and aviation, steps to coordinate the introduction of alternative fuel blending mandates and standards, with potential to provide demand stability and stimulate production in the relatively near term, deserve investigation (T&E, 2018b; Victor et al., 2019). To overcome inertia at both the IMO and ICAO, greater use could be made of regional level or bilateral agreements, allowing the development of low-carbon trade corridors. For example, given its importance in global trade (and pre-supposing a more climate-engaged post-Trump administration), shipping and aviation travelling to the U.S. could be required to meet stricter emission targets.

5.3. Transparency and accountability

As noted above, Parties to the PA have the discretion to include international transport in their Nationally Determined Contributions. Inclusion in the PA's Global Stocktake of reporting on sectoral emissions by the IMO, ICAO, as well as State Parties' NDC commitments, could usefully enhance transparency and accountability (and potentially also knowledge and learning). It will in any case be important to ensure that accurate and consistent information about emission trajectories is available at regular intervals, to allow an assessment of approaches implemented (Chircop et al., 2018).

Table 4
Summary of governance function importance and fulfilment.

	Guidance and signal		Rules for collective action		Transparency and accountability		Means of Implementation		Knowledge and learning	
	Need	*Actual*	Need	*Actual*	Need	*Actual*	Need	*Actual*	Need	*Actual*
Aviation	High	*Low*	High	*Low*	High	*Medium*	High	*Low-medium?*	Medium-high	*?*
Shipping	High	*Medium*	High	*Low*	High	*Low-medium*	High	*Low*	Medium-high	*?*

5.4. Means of implementation

Energy projects, potentially in developing and middle-income countries where abundant untapped renewable resources could be exploited to produce low-cost zero-carbon energy sources for shipping (and more widely), have potential to bring significant development benefits (Global Maritime Forum, 2019). Here, international development banks could be encouraged to play a significantly bigger role, developing infrastructure and facilitating technology transition both onshore and in ships. National governments might collaborate with such effort, or encourage their own domestic development banks to develop targeted instruments (Walsh et al., 2017).

In late 2019, leading industry body the International Chamber of Shipping proposed a $5 billion (over 10 years) 'International Maritime Research Fund' to finance low-carbon R&D (raised through a €0.6 levy per tonne of CO2). However ostensibly attractive, however, care needs to be taken not to pre-empt potentially more effective economic instruments (involving significantly higher carbon prices) (Abbasov, 2020).

Currently nascent partnerships to develop zero or low-emission fuels through joint R&D across shipping, other harder-to-abate sectors and energy interests, have potential to significantly expand the pool of capital and expertise to innovate, and increase the likelihood that production and transportation infrastructure will be available once commercially viable (Shell and Deloitte, 2020).

In aviation, R&D spending needs a significant boost to encourage technological breakthroughs, such as enhanced battery power or hydrogen, as well as further development of SAFs. A joint fund, potentially under Mission Innovation could leverage existing commitments by some national governments, such as the UK.

Opportunities could also be explored to allow institutions and instruments under the PA to assist implementation of measures agreed by ICAO and IMO. The technology mechanism described under the PA's Article 10, for example, dealing with mitigation technology transfer more broadly, may offer further possibilities for cooperation and coordination.

5.5. Knowledge and learning

For aviation, R&D-related efforts by national governments, airlines, manufacturers and other stakeholders, on low-carbon aircraft design and advanced biofuels, could be more coordinated.

For shipping, in addition to the on-going efforts of *Getting to Zero*, leveraging current entrepreneurial efforts by the likes of the CCWG or the Sustainable Shipping Initiative as part of a wider IMO orchestration strategy could facilitate 'demonstration effects', through pilot projects and other information dissemination (Lister, 2015). The willingness of multiple private stakeholders including energy producers to undertake demonstration projects needs underpinning by stronger engagement from governments and the IMO to help prioritise, and to incentivise wider participation (Victor et al., 2019).

6. Conclusions

If international shipping and aviation were countries, each would be responsible for annual emissions equivalent to those of Germany (Energy Transitions Commission, 2018). Away from the spotlight of the official climate regime, both have responded slowly and selectively to calls to decarbonise. Arguably, however, their unique institutional positions could provide relatively conducive circumstances for doing better, provided political will solidifies. This is because unlike the UNFCCC, the IMO and ICAO have authority to impose legally-binding, enforceable sectoral standards, including for emission reduction. In theory at least, these distinctive features could facilitate progress. There are currently a range of exciting ideas for delivering decarbonisation, particularly for shipping, where the IMO-level agreement of 2018 has catalysed a range of stakeholders into action, across maritime, energy, infrastructure and finance sectors. With further collaboration across these sectors, supported by national governments and international organisations, shipping has the potential to become a catalyst for a broader, global energy transition, unlocking the market for zero-emission fuels more broadly (Global Maritime Forum, 2019).

Casting a shadow over this prospect, however, are poor institutional transparency and evident potential for regulatory capture (InfluenceMap, 2017). Undue influence can be exercised in the IMO by certain flag states, and 'whistle-blowers' punished (Transparency International, 2018). Similarly, for the ICAO, strict secrecy and deference to industry is the norm. This presents challenges to those recognising the urgency of regulatory progress in these key sectoral systems, and specifically how far more regionally led regulation should be encouraged. Arguably, steps to incorporate international transport better into the PA, in parallel with on-going ICAO and IMO activity, could bring greater consistency in the positions adopted by states in different venues (T&E, 2018b) - potentially lessening certain countries' tendency to obstructionism. In the meantime, regional-level action, particularly by the EU through its European Green Deal, is likely to remain critical in demonstrating consistent regulatory leadership, for both shipping and aviation. So too will partnership initiatives led by more progressive sections of industry, as increasingly evident in the *Getting to Zero* and *Clean Skies Tomorrow* coalitions. Such leadership is clearly needed to demonstrate that decarbonisation of international transport need not remain stuck on the slow route.

Declaration of competing interest

The author declares that he has no known competing financial interests or personal relationships that could have influenced the work reported in this paper.

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Appendix A. Supplementary data

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