INTERNATIONAL MONETARY FUND

Market-Based Instruments for International Aviation and Shipping as a Source of Climate Finance

Background Paper for the Report to the G20 on "Mobilizing Sources of Climate Finance"

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Glossary of Terms

AGF. UN high-level advisory group on climate change financing.

BSA. Bilateral air service agreement.

Bunker fuel. Fuel for international aviation and maritime transport.

Demand elasticity. Percent change in the demand for a commodity or service in response to a one percent increase in its consumer price.

ETS. Emissions trading system (or scheme).

EU-ETS. The ETS of the European Union.

Developed countries. Following the usage of the synthesis report, the term is used here to indicate European Union countries that are members of the OECD and other Annex II countries that have pledged fast start climate finance. This includes 19 EU Member States as well as Australia, Canada, Iceland, Japan, New Zealand, Norway, Switzerland, and the United States.

Developing countries. All countries other than developed countries defined as above.

ICAO. International Civil Aviation Organization.

IMO. International Maritime Organization.

IOPC Funds. International Oil Pollution Compensation Funds.

'Legal' incidence (or burden). Whoever is formally required, by law, to pay a charge or hold emissions allowances.

MBI. Market-based instrument (an emissions tax or ETS).

'Real' incidence (or burden). Measures whose real income is actually reduced as a result of a new policy.

Supply elasticity. Percent change in the amount supplied of a commodity or service in response to a one percent increase in the price received by producers.

Charges, taxes, and levies. As used here, the term 'charge' 'refers to a mandatory payment of an amount related to carbon emissions, whether implemented as a tax, as a levy or through an emissions trading system. By a 'tax' is meant a compulsory payment that is not fully requited to those paying it. (Thus payment for a service, including to a public agency, is not a tax if it covers the cost of providing that service: such payments are 'user fees'). By 'levy' is meant a charge that is fully rebated to the payer, in cash or in kind; since the focus here is on raising climate finance, the term will be rarely used, though this is not intended to prejudge the use of revenue in practice.

EXECUTIVE SUMMARY

This paper responds to the request from the G20 to explore the potential for providing climate finance from carbon-related charges on international aviation and maritime transport—with a particular focus on minimizing the impact on developing countries[1] and on issues of implementation.[2] It extends the work of the High-level Advisory Group on Climate Change Financing to the U.N. Secretary General (AGF, 2010a, b) by (1) clarifying key issues of incidence and compensation, paying particular attention to the impact on lower income countries; (2) examining key challenges to implementation; and (3) placing these charges in the context of the overall tax treatment and wider circumstances of these sectors.

The potential for climate finance and environmental gain

Market-based instruments (MBIs) for international aviation and maritime fuels—either emissions (fuel) taxes or emissions trading schemes (ETS)—have appeal as an 'innovative' source of climate finance. These activities are currently under-charged[3] from an environmental perspective: unlike domestic transportation fuels, they are subject to no excise tax to reflect environmental damages in fuel prices. Since they correct an unpriced distortion rather than exacerbating those from pre-existing taxes, MBIs for jet and international marine fuels are likely a much more cost-effective way to raise finance for climate (or other) purposes than are broader fiscal instruments. Furthermore, national governments do not have an obvious claim to the tax base for these fuels, given their use for international activities. While there is in principle no reason why any funds raised by such a charge should not be used for other purposes, the concern here is with their potential as a source of climate finance.

By 2020, a globally implemented carbon charge of \$25 per tonne of CO_2 on these fuels could raise around \$12 billion from international aviation and around \$26 billion for shipping, while moderately reducing CO_2 emissions from each sector by reducing fuel demand.[4] Once in place, presumably the fuel charges would increase gradually over time to promote more aggressive emissions mitigation.

Compensating developing countries for the economic harm they might suffer from such charges—ensuring that they bear 'no net incidence'—is widely recognized as critical to their acceptability. Such compensation seems to require—at most—40 percent of global revenues, which would leave about \$23 billion or more for climate finance or other uses.[5] There is an important trade off here: the more extensive is compensation, the less public revenue will remain for climate finance or other productive purposes.

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[1] The distinction between developed and developing countries as made here is defined in the Glossary.

[2] A companion paper (IMF, 2011) responds to the request to look at domestic instruments for climate finance.

[3] Usage of the terms 'charge', 'tax', and 'levy' are explained in the Glossary.

[4] All \$ figures refer to U.S. dollars.

[5] Some part of the revenue (perhaps 5–10 percent) should also be retained by the collecting agency to cover administrative costs and provide performance incentives.

Under a more flexible approach with a floor price of $15 per tonne, annual revenues raised would be approximately $14 billion (after setting aside the same proportion for compensation). Conversely, revenues would be higher under more aggressive emissions pricing, say $40 per tonne of $CO_{2;}$ but securing international agreement would doubtless be correspondingly more challenging.

MBIs are the best instruments from an environmental perspective. Under the auspices of the International Civil Aviation Organization (ICAO) and the International Maritime Organization (IMO), both industries are taking important steps to improve the fuel efficiency of new planes and vessels and economize on fuel use during operations. Nonetheless, raising fuel prices through MBIs would reinforce these efforts while also reducing the demand for transportation (relative to trend) and promoting retirement of older, more polluting vehicles.

The principles of good design of MBIs for international aviation and maritime activities are the same for other sectors. For emissions trading, this means auctioning allowances to provide a valuable source of revenue, and including provisions to limit price volatility. For emissions taxes, it means keeping the focus on environmental considerations and applying the tax to fuel (rather than passenger tickets, or arrivals/departures). In either case, a critical issue in containing policy costs is to use revenues (whether for climate finance or other purposes) productively, for socially desirable spending, fiscal consolidation, or to reduce broader taxes that distort incentives for work effort and capital accumulation.

Failure to price emissions from either industry should not preclude pricing emissions in the other. Though commonly discussed in combination, the two sectors are not only different in important respects—for example, ships primarily carry freight while airlines primarily serve passengers—but they also compete directly only to a limited degree. Nonetheless, simultaneous application to both is preferable, and could enable a common charging regime (further enhancing efficiency).

Cooperation, incidence, and compensation

Extensive cooperation in designing and implementing international transportation fuel charges would be needed—especially for shipping—to avoid revenue erosion and distortions. Underlying the current tax-exempt status of fuels used in international transportation fuels is a fear that unilateral taxation would harm local tourism, commerce, and the competitiveness of national carriers, raise import prices and reduce the demand for exports, as well as leading fuelling to take place in countries without similar policy measures. When governments set emission charges unilaterally, they are under pressure to set lower rates than in other countries, so as to protect their domestic industries and revenues. Some degree of international coordination is thus needed. In the case of international aviation, even an agreement with substantially less than universal coverage—for example one that exempted some vulnerable developing countries—could still have a significant effect on global emissions and considerable revenue potential, given the relatively limited possibilities for carriers to simply re-fuel wherever taxes are lowest. For maritime fuels, however, globally comprehensive pricing is more critical, since vessels can more easily avoid a charge by re-fueling at ports where charges do not apply.

Globally imposed charges combined with compensation of adversely affected developing countries appears consistent with both industry and UNFCCC principles. Both the IMO and ICAO are firmly committed to principles of uniform treatment of ships and flag States, and carriers and nations, respectively. A globally applied charge would be consistent with this, and could be reconciled with the UNFCCC principle of common but differentiated responsibilities and respective capabilities by appropriate compensation schemes. More generally, combining a global charge with targeted compensation provides an effective way to pursue both efficiency and equity objectives.

Ensuring 'no net incidence' for developing countries requires close consideration of the 'real' incidence of these charges. That real incidence—who it is that suffers the consequent loss of real income—can be quite different from who it is that bears legal responsibility for the payment of the charge; and they may well be resident in different countries. It is the real incidence that matters for appropriate compensation, and this is sensitive to demand and supply responses that will vary across countries according to their share of trade by sea and air, the importance of tourism, and so on.

Jet and marine fuel prices might not rise by the full amount of any new charge on their use. Some portion of the real burden is likely to be passed back to oil refiners and oil producers. However, if refiners can shift production from these fuels to other oil products fairly easily (which seems plausible), this pass back is likely to be modest; a charge of 10 cents per liter on fuels used in both sectors might then increase the price to operators by about 9.5 cents per liter.[6]

Even with full pass-through to fuel prices, however, the impact on final prices of aviation services and landed import prices—and on the profitability of the aviation and maritime industries—is unlikely to be large. A charge of \$25 per tonne of CO_2 might raise average air ticket prices by around 2–4 percent and the price of typical seaborne imports by around 0.2–0.3 percent. The modest scale of these effects means that the real burden on the international aviation and shipping industries is likely to be small—and, in any case, reflects a scaling back of unusually favorable fuel tax treatment (see below) rather than the introduction of unfavorable treatment. The overall burden imposed by a \$25 per tonne CO_2 price is thus likely to be small. Further work is needed to identify possible outlying cases, but the broad picture is one of very modest impacts.

Nonetheless, there may be a need to provide adequate assurance of no net incidence on developing countries by providing explicit compensation. Significant challenges arise in designing such a scheme because of the potential jurisdictional disconnect between the points at which a charge is levied and the resulting economic impacts—especially for maritime transport. Practicable compensation schemes require some verifiable proxy for the economic

[6] For consistency, the fuel unit is taken to be a liter throughout the paper. In practice, maritime fuel is priced and bought in metric tonnes.

impact as a key for compensation. While more work is needed to identify good (i.e. reasonably accurate and acceptably verifiable) proxies, enough has been done to give confidence that they can be found. Fuel take-up provides a good initial basis in aviation, and simple measures of trade values may have a role in relation to maritime. The prior and in some respects deeper issue is to understand the extent of compensation required.

Fully rebating aviation fuel taxes to tourist destinations in developing countries (or giving them free allowance allocations) may be over-compensation—that is, would make them better off by participating in such an international tax agreement (prior to even receiving any climate finance). Most of the incidence of taxes paid on jet fuel disbursed in developing countries is likely borne by passengers from other countries. Developing countries—including tourist destinations—might then receive more than adequate recompense if revenues collected in those countries were fully passed to them. However, additional analysis is required to arrive at a fully confident assessment of the overall economic impact on developing countries and how this may vary between tourist and other destinations.

In contrast, rebating maritime fuel taxes to developing countries may not provide adequate compensation. Unlike airlines, shipping companies cannot be expected normally to tank up when they reach their destination. Some countries—hub ports like Singapore—disperse a disproportionately large amount of bunker fuel relative to their imports, while the converse applies in importing countries that supply little or no bunker fuel, including landlocked countries.[7] Revenues from charges on international maritime fuels could instead be passed to or retained in developing countries in proportions that reflect the extent and perhaps nature of their trade activities.[8]

More generally, compensation could be could also be linked to relative per capita income; and could be larger for low-income countries in which higher fuel prices are a particular concern. Much detailed work remains to be done to design compensation schemes, but practicable approaches can surely be found.

Implementation

Implementing globally coordinated charges on international aviation and/or maritime fuels would raise significant governance and practical issues. New frameworks would be needed to govern the use of funds raised, to determine how and when charges (or emissions levels) are set and changed, to provide appropriate verification of tax paid or permits held and

[7] In principle, this problem can be addressed if hub ports only claimed fuel tax rebates when ships unload, or if importing countries could claim rebates for fuel purchases by unloading ships associated with that trip. But this approach is administratively complex when one shipping voyage has multiple country destinations.

[8] As for instance in the import-based rebate mechanism proposed by IUCN (2010) and WWF (2011). Stochniol (2011) also provides country-specific estimates of the compensation implied by this scheme based on a country's share of imports by sea and air. For instance, Ethiopia's annual rebate would be $6 million if the revenue raised by carbon pricing for international maritime transport were $10 billion (i.e. 0.06 percent of $10 billion). The rebate and attribution keys for all countries have been submitted to the IMO in WWF (2011).

to monitor and implement any compensation arrangements. While the EU experience indicates that agreements on taxation can be reached, it also shows how sensitive are the sovereignty issues at stake. One possibility is to link an emissions charge on international transportation to the average carbon price of the largest economy-wide emission reduction scheme, for instance, so limiting the need for a separate decision process. The various detailed proposals being considered by the IMO suggest that practical issues can be resolved. There could indeed be some role for the ICAO and IMO, with their unparalleled technical expertise in these sectors, in implementing these charges, though there are other possibilities.

The familiarity of operators and national authorities with fuel excises suggests that implementation costs would be lower with a tax-based approach than with an ETS. Collecting fuel taxes is a staple of almost all tax administrations, and very familiar to business; implementing trading schemes is not. Ideally, taxes would be levied to minimize the number of points to control—which, broadly, means as upstream in the production process as possible. If taxation at the refinery level is not possible, the tax could be collected as fuel is disbursed from depots at airports and ports, or directly from aircraft and ship operators. Implementation would be simplest—and environmental efficiency greatest—if no distinction were made between fuels in domestic and international use. Indeed, eliminating the differentiation imposed at present should in itself be a simplification.

Policies could be administered nationally, through international coordination or in some combination of the two—with the appropriate institutions for monitoring and verification depending on the approach taken. For example, national governments might be responsible for implementing aviation fuel charges or trading schemes on companies distributing fuel to airlines, with some of the receipts transferred to a climate finance fund. All revenue-raising MBI proposals being considered by IMO, on the other hand, assume a global charge or ETS.[9] Flexibility may well be needed to accommodate various national circumstances by, for example, allowing certain countries to opt for national collection that is linked to an international approach.

For aviation, the current fuel tax exemptions are built into multilateral agreements within the ICAO framework and bilateral air service agreements, which operate on a basis of reciprocity.[10] Though consideration of the challenges these present is needed, amending the Chicago Convention and associated resolutions would remove these obstacles, although the EU experience on intra-union charging seems to suggest the possibility of overcoming them without doing so. An alternative approach would be to use an ETS in this sector, although the consistency of this with international aviation agreements is currently the subject of litigation. For marine fuels, there are no formal agreements prohibiting excise taxes, so there appear to be no legal obstacles to fuel charges in this sector.

If regional emissions trading programs develop for international transportation (e.g., in the European Union) giving away free allowances is especially problematic. Not only

[9] A precedent is the International Oil Pollution Compensation Funds of the IMO.

[10] See ICAO (2000).

does this forego revenue, it provides windfall profits for covered airlines or ships that would likely increase resistance to the introduction of fuel charges in other countries.

While implementation details need further study, especially in terms of governance, it is clear that feasible operational proposals for pricing international aviation and maritime emissions can be developed.

I. INTRODUCTION

1. **This paper responds to the request from the G20 to explore the potential for raising climate finance from charges on fuels used in international aviation and maritime transport—with a particular focus on minimizing the impact on low-income countries and on issues of implementation.** The paper makes but does not linger on the case for introducing some form of carbon pricing in these sectors. This is widely recognized, given their growing share of emissions and their exclusion from both national fuel tax regimes and from the quantified country-level emissions targets under the 1997 Kyoto Protocol.[11] In part, this reflects the difficulty of allocating emissions from sources that are internationally mobile and, moreover, arise largely in international waters and airspace.[12] The focus here, instead, is on the consequences of, and possibilities for, introducing such charges.

2. **In doing so, the paper extends the analysis of such charges by the High-level Advisory Group on Climate Change Financing to the U.N. Secretary General** (AGF, 2010a and b). That analysis was focused on the revenue potential of these charges. The analysis here, consistent with the request from the G20, takes forward the debate in three main ways.

3. **First, the paper clarifies and, where possible quantifies, the key issue of 'incidence,' paying particular attention to the impact on lower income countries**. Specifically, it examines whether reasonably practicable compensation rules can be found that would be sufficient to ensure that developing countries are made no worse off by the global adoption of such charges.

4. **Second, the paper examines key challenges to implementation and reaches broad conclusions on how these might best be addressed.** These range from fundamental issues of sovereignty and governance that can be no more than raised here through to questions of routine administration and legal frameworks, on which clearer views can be reached.

5. **Third, the analysis places these charges in the context of the wider circumstances and characteristics of these sectors**. It stresses that, while the sectors are commonly grouped together and do indeed have important similarities relevant to carbon pricing issues, they also have important differences, including their treatment under national tax systems.

6. **The focus is entirely on MBIs, whether in the form of carbon taxes or emissions trading schemes (ETSs)**. Under the auspices of the ICAO and the IMO, and as will be summarized below, efforts are underway to reduce CO_2 emissions through technical and operational measures; by, for example, efficiency improvements to new planes and ships. While constructive and important, such efforts can—as in other sectors—have only limited environmental effectiveness, and will need to be supported by carbon pricing schemes. More

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[11] Article 2(2) requires Annex I countries to "...pursue limitation or reduction of greenhouse gases...working through the International Civil Aviation Organization and the International Maritime Organization, respectively."

[12] These difficulties were evident in the attempt of the Subsidiary Body for Scientific and Technical Advice of the UNFCCC to provide such an allocation, arriving at eight possibilities, none fully satisfactory (see, e.g., Heitmann and Khalilian 2011, who estimate the pattern of payment by country that these would imply).

to the point in addressing the request from the G20, existing measures do not raise revenue for climate finance.

7. **Both the ICAO and the IMO are discussing the potential use of MBIs**. In October 2010 the ICAO General Assembly adopted Resolution A37-19 establishing broad principles for the design and implementation of MBIs that could be introduced at a regional level for international aviation. Within IMO, MBIs have been considered in depth for a number of years and various countries and observer organizations have developed proposals on MBIs for shipping and these proposals are to be considered and developed further at the next MEPC meeting of March 2012, when also continued impact assessments will be considered. This paper therefore draws on the important work already undertaken by both organizations (see Box 1 for additional discussion).

Box 1. Recent Emissions Mitigation Efforts in the Aviation and Maritime Sectors

Aviation

In October 2010, the ICAO Assembly adopted Resolution A37-19, a comprehensive policy to reduce GHG emissions. Aspirational goals under this resolution include a 2 percent annual fuel efficiency improvement up to year 2050 and a medium-term goal of stabilizing global CO_2 emissions at 2020 levels. Aside from MBIs (see below), measures to meet these targets include improving the fuel economy of new planes; replacing less efficient aircraft; improving the operation of existing flights in ways that economise on fuel; development of a global CO_2 certification standard for aircraft; and facilitating the development and deployment of sustainable alternative fuels for aviation.[1] The Resolution also emphasizes the development and submission of States' action plans, covering information on CO_2 emissions reduction activities and assistance needs, and the development of processes and mechanisms to assist States in contributing to the global efforts.

The Assembly also agreed on a set of guiding principles for the design and implementation of MBIs, such as minimizing carbon leakage and market distortions, avoiding double charging for aviation emissions, and fair treatment of aviation relative to other sectors. Based on further studies, the 2013 Assembly will explore the possibility of a global MBI scheme for international aviation.

Maritime

The IMO has been pursuing the control of greenhouse gas (GHG) emissions from international shipping through a global approach to ensure a level playing field and avoid carbon leakage. As a result, mandatory treaty provisions to reduce GHG emissions from international shipping were adopted at IMO in July 2011 by adding a new chapter on energy efficiency to the regulations on prevention of air pollution from ships contained in MARPOL Annex VI, and making mandatory the Energy Efficiency Design Index (EEDI) for new ships and the Ship Energy Efficiency Management Plan (SEEMP) for all ships in operation.[2] These regulations apply to all ships of 400 gross tonnage and above and are expected to enter into force on 1 January 2013. By 2020, it is estimated there will be annual emission reductions of up to 180 million tonnes of CO_2, about 10 percent or more below baseline levels (IMO, 2011b).

IMO has also made noteworthy progress towards establishing an MBI. The report of an expert group established to undertake a feasibility study and impact assessment of a number of proposed schemes (see below) was presented to the Marine Environment Protection Committee (MEPC) in September 2010. The ten proposals under review range from levy/charge type of instruments with global collection and administration, via emission trading systems with 100 percent auctioning (global or national), to schemes based on individual ships' efficiency in fuel use and operation. There are also proposals for compensatory schemes and other ways to ensure no net incidence for consumers and industries in developing countries. In 2009, the MEPC indicated a general preference for the greater part of revenues generated by an MBI for international shipping to be used for climate change purposes in developing countries.

[1] Prior fuel economy improvements have reduced the fuel consumption rate of modern aircraft by 20–40 percent below that of aircraft produced 20–30 years ago (Giblin report, 2005).

[2] The EEDI is a non-prescriptive, performance-based standard that leaves the choice of technologies in a specific ship design to the industry as long as the required level is met. The level will be tightened every five years to match technical development and is agreed as a 10 percent reduction for ships built from 2015 to 2020; 20 percent reduction for ships built between 2020 and 2025; and a 30 percent reduction for those built after 2025, calculated over the average efficiency level for ships built between year 2000 and 2010.

8. **The focus throughout is on globally applied charges**. Previous work has stressed the potentially significant distortions that could follow from applying any charge differentially, whether by country, carrier, vessel, or route.[13] Reinforcing these technical considerations—especially salient, as discussed below, for international maritime transport—established principles of the international aviation and maritime industries also attach considerable importance to non-discrimination and equality of treatment. Rather than revisit these issues, it will simply be assumed here, except as indicated, that charges are applied in a uniform manner to all fuels used in international aviation or maritime transport.

9. **A strategy combining globally imposed charges with compensation to adversely affected developing countries is consistent with both industry standards and UNFCCC principles**. Both the IMO and the ICAO are firmly committed to principles of uniform treatment of carriers and nations. A globally applied charge would be consistent with this, and could be reconciled with the UNFCCC principle of common but differentiated responsibilities and respective capabilities by a system of compensatory transfers. More generally, combining a global charge with targeted compensation provides an effective way to pursue both efficiency and equity objectives.

10. **The structure of the paper is as follows**. The next section compares and contrasts key features of the international aviation and maritime industries, discusses the rationale and feasibility of MBIs, and examines core issues of 'incidence.' Sections III and IV examine specific policy scenarios for the two sectors, taken individually, and the implications for revenue and developing country incidence. Section V discusses specifics in the choice among MBIs and in the implementation of these policies. Section VI briefly sums up.

[13] See for instance AGF (2010b), IMO (2010), and Keen and Strand (2007).

II. Background

A. Similarities and Differences: International Aviation and Shipping

11. **There are important similarities between these two sectors**. Both industries

- ***Account for a sizable and likely growing share of global emissions***. In 2007, international aviation accounted for around 1.5 percent of global emissions and international shipping for around 2–3 percent.[14] The share of the sectors in global emissions could expand rapidly.[15]

- ***Are effectively exempt from any charge on their fuel use***, in contrast to normal practice for domestic transportation activities.

- ***Pay various 'user fees' for services received***. In the aviation sector, such fees include airport landing and take-off fees, slot charges, costs of using airport facilities, air traffic control, and security charges.[16] In maritime, payment is made for an analogous range of services, such as anchorage dues, channeling dues and pilotage charges. User fees of these kinds, though important and appropriate in practice, are essentially a cost of doing business like any other. They are not discussed further here as they are not designed to raise public revenue for the government (net of the costs of ancillary services).

- ***Provide potential tax bases that are hard to allocate to particular countries***. This and the fact that such activities are currently undertaxed from an environmental perspective have made fuel use in these sectors a prominent candidate as source of international finance.

- ***Are subject to other tax rules that differ from normal practice***. As discussed in Box 2, aviation receives favorable treatment under VAT regimes, while shipping receives favorable corporate tax treatment. To varying degrees therefore, emissions from both industries are too high for two distinct reasons: the failure to charge for environmental damages and the excessive demand for transportation due to special tax exemptions.

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[14] See (AGF, 2010b) and IMO (2009).

[15] According to AWG-LCA (2008), CO_2 emissions from the aviation and maritime sectors (domestic as well as international) could, if unchecked, account for 10-15 percent of the global total by 2050. Accurately projecting the future emissions growth is difficult however, not least because the industries themselves are taking measures to reduce emissions intensity.

[16] The 'taxes and charges' item shown on air tickets is often misleading, as it can contain a plethora of items including surcharges for high fuel prices, landing fees, and airport security services that are not 'taxes' in the sense of being unrequited payments to a sovereign power.

Box 2. Other Features of the Tax Regimes for International Aviation and Maritime

Aviation. In most countries, international ticket sales are zero-rated under the VAT or general sales taxes (any value added tax airlines pay on their inputs is fully refundable), while domestic air travel is not.[1] This reflects a view of the services provided as being essentially exports, and partly too wider difficulties in taxing international services that are especially acute in international transport. [2] Exclusion of services provided to businesses is not of great concern, in that the logic of sales taxation is that business use should in any event not be taxed, so as not to distort production decisions: VAT charged to business users, in particular, would in principle be credited or refunded. It is a general principle of tax design to avoid charges on input purchases by businesses (other than those reflecting externalities from their activities—precisely the purpose of a carbon charge): such taxes distort input choices and can lead to tax-driven vertical integration. Excluding purchases by final consumer from sales taxation is more problematic.

Maritime. Shipping is now often subject to 'tonnage' tax regimes: they are taxed, that is, not on accounting-based profits but by a presumptive charge related to a vessel's net tonnage.[3] These special regimes are in practice seen as more favorable than the normal corporate tax regime. They have become increasingly common, and are now applied by several major countries (including, for instance, Denmark, Greece, the Netherlands, Norway, the United Kingdom, and the United States).[4] The proliferation of these regimes—recognized as a form of state aid in the European Union, but permitted under stated conditions[5]—is a clear and in many cases explicit response to intense tax competition in the sector, initially in response to favorable tax regimes in countries maintaining open registers[6] but now more general.[7]

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[1] In contrast, domestically application of the VAT or sales tax is common, though sometimes at reduced rates: most EU member charge below the standard VAT rate on domestic aviation (an exception being Germany which charges the normal rate of 19 percent), though Argentina, India and Pakistan charge ad valorem ticket taxes on domestic flights in the range 10-20 percent, and Peru charges ad valorem taxes on both domestic flights and international flights departing from the country (see Keen and Strand 2007). It is a conventional presumption of sales tax design that the consumption of all goods and services is best taxed at a uniform proportionate rate; there are some exceptions to this general theoretical proposition, but nonetheless it serves as a practicable benchmark for policy design (as discussed for instance in Crawford et al., 2010).

[2] The emerging norm is to tax international services according to the place of residence of the purchaser (see for instance Keen and Hellerstein, 2010), which raises particular difficulties of implementation in relation to sales to final consumers. The alternative approach of zero rating only sales to businesses is made difficult by the need for the jurisdiction of sale to verify the status of taxpayers abroad.

[3] 'Net' tonnage refers to a ship's displacement space for holding cargo (whereas 'gross' tonnage refers to its total displacement space). The precise form of such taxes, and conditions attached, vary, but common features include a rate that falls with tonnage (on the grounds that smaller ships on shorter routes tend to be more profitable). Many countries also provide exemption for capital gains on ships, and preferential personal tax and social contributions for labor.

[4] A more complete listing is in Ernst and Young (undated), which notes that "The main advantage of tonnage tax regimes is the very low effective tax rate of on average less than 1 percent when the shipping industry is doing well."

[5] Commission Communication (2004) 43—Community Guidelines on State Aid to Maritime Transport.

[6] Sometimes referred to as 'flags of convenience'.

[7] That analogous regimes have not appeared in international aviation may reflect the standard principle in double tax treaties that airlines are taxed only by the country of residence.

- ***Are governed by international treaties (under the auspices of the ICAO and IMO), and are subject to close control for safety and security reasons***. The ICAO and the IMO may also (but need not) play a role in monitoring emissions pricing policies for international transportation.

- ***Cause local pollution and other adverse side effects***. Take-offs and landings at airports contribute to local air pollution, noise, and congestion. Maritime operations can have a range of negative environmental impacts, such as oils spills and transport of invasive species in ballast water, and also contribute to local air quality problems, for example in port cities.[17] A charge on fuel use could go some way towards addressing these problems, but would not be the best-targeted instrument; this aspect is therefore considered no further.[18]

- ***The bulk of emissions from the two sectors (especially for shipping) are associated with international activities and the majority of emissions are from services to developed countries***. As indicated in the top panels of Figure 1, an estimated 83 percent of maritime emissions are from international activities while for aviation this share is 62 percent. The main reason for this is that goods transport, which is overwhelmingly international, dominates shipping while people transport dominates aviation (middle panels of Figure 1).[19] Fuel disbursed in developed countries accounted for about 65 percent of total aviation emissions (35 percent is from disbursements in developing countries) and 60 percent for maritime.[20] In aviation, about 12 percent of all flight activity (in terms of fuel consumption) consists of pure cargo flights, but a similar fraction of fuel consumption can be ascribed to freight carried by passenger planes.[21]

- ***Make an essential contribution to a well-functioning global economy***. Around 90 percent of all world trade, by tonne-kilometer, for instance, is carried by ship.

[17] See Keen and Strand (2007) and Corbett and Fishbeck (2001) respectively for a discussion of these broader side effects from aviation and maritime.

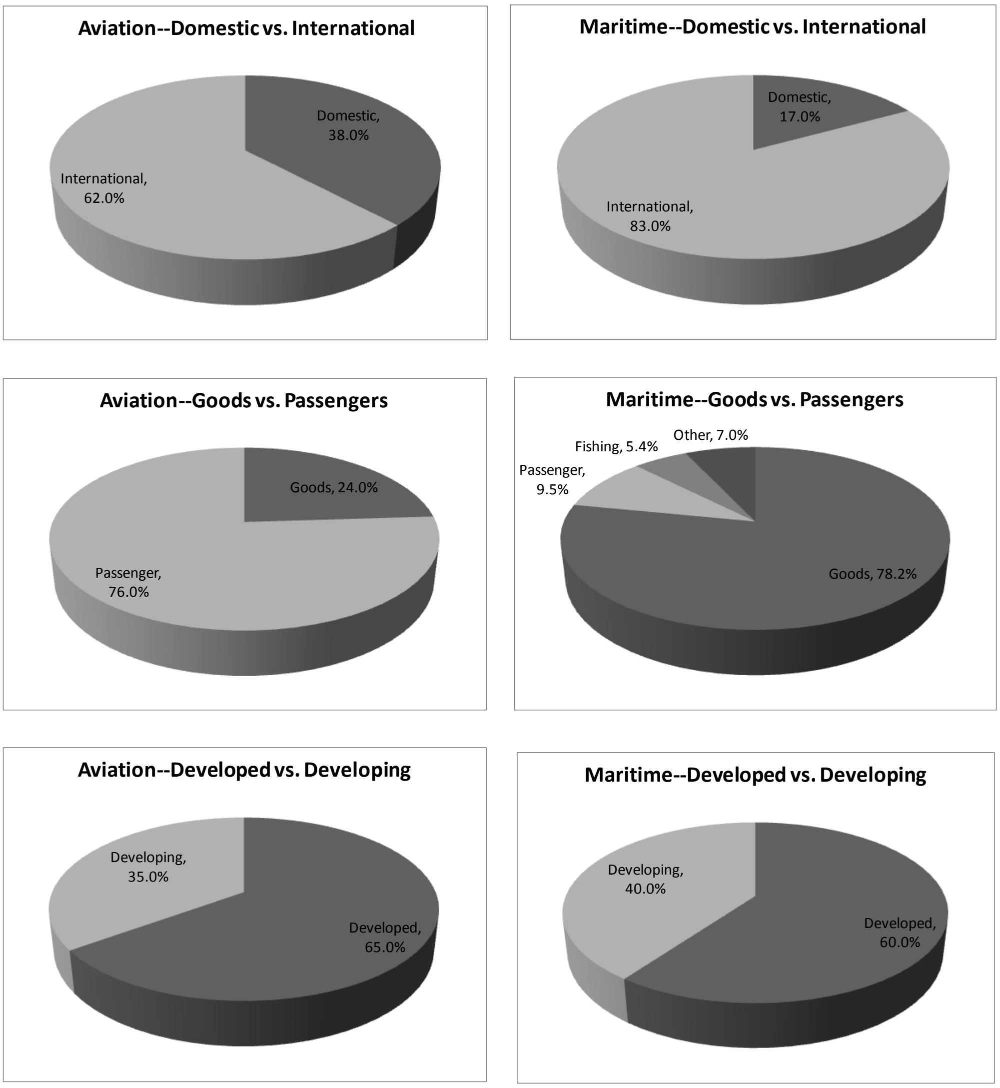
[18] For example, location-specific, peak-peak pricing is generally far more effective for alleviating congestion, and vehicle emissions standards for reducing local pollution (see Parry et al. (2007) for a discussion of appropriate instruments in the context of automobile problems). In any case, IMO is introducing requirements that will reduce considerably the sulphur content of heavy fuel oil from 2.7 percent to 0.5 percent by 2020, which will encourage new refining processes.

[19] Fishing, while largely conducted in international waters, is considered a domestic activity (as it pertains to particular nations; and catches are largely landed in the individual nations). Most ferry traffic is international. Cruise traffic where cruisers travel to at least two nations is considered international.

[20] There is some disagreement over these shares for maritime activity. Faber et al. (2010) suggest that about one-third of emissions are attributed to ships arriving in non-Annex 1 countries, suggesting that about one-third might be allocated to their own use. AGF (2010b), Table 6, on the other hand claims that more than 50 percent of maritime emissions should be attributed to non-Annex I countries. Stochniol (2011b) calculates the overall share of global imports by ‘developing’ (non-Annex II) countries to 40 percent, which is that assumed here.

[21] See Bofinger (2011), Appendix II.

Figure 1. CO_2 Emissions from Aviation and Maritime by Source, 2007



Sources: ICAO (2009a), IMO (2009, 2010).

12. **But there are also important differences**:

- ***Maritime services are an input to production, rather than final consumption, to a greater extent than is international air travel.*** More than 90 percent of international maritime activity is goods transport and less than 10 percent is people transport (IMO, 2009). For aviation, in contrast, 88 percent is people transport and only 12 percent freight; some of this people transport will be for business use, but only about 10 percent of global passenger kilometers are flown in first or business class (even though 30 percent of airline passenger revenue comes from these classes).[22] Recognizing too that some business travelers fly economy, perhaps as much as 80 percent of transport by air is for leisure and is thus final consumption, while the corresponding share of transport by sea is no more (perhaps less) than 10 percent. This distinction has implications for the appropriate treatment of these industries in the broader fiscal

[22] See Keen and Strand (2007), table 12.

system (Box 2). It also implies that competition between the two sectors is fairly limited. So that failure to levy a carbon charge in one industry does not significantly weaken the case for charging one on the other.[23]

- ***Reflecting this, key aspects of the impact on developing countries are different in the two cases***. For maritime, the key concern is the effect on import and export prices; for aviation, a central concern has been the impact on tourism. Though there are other dimensions of interest, the focus below will be on these and (since this will affect some low income countries) the impact on fuel prices.

- ***The proximate reasons for zero fuel taxation are different.*** There are significant legal obstacles to taxing fuel used in international aviation: Box 3 elaborates. There appear to be no similar legal obstacles to charging for fuels used in international shipping, there being no formal bilateral agreements prohibiting excise taxes (IMO, 2011). Instead, the zero taxation of international maritime fuel appears to reflect informal convention and tax competition for a highly mobile tax base.[24] It could be that the same tax competition would result in zero fuel taxes on international aviation even in the absence of legal prohibitions: dealing with the bilateral agreements, while necessary to impose taxes in the sector, may well not be sufficient.

- ***The location at which fuel is taken up (one candidate point of collection for any charge) is internationally mobile making widespread adoption of any charge important—especially for maritime fuels***. Large ships, which account for the bulk of carbon emissions in shipping, can undertake very long voyages on a single bunkering of fuel, and carrying fuel need not add substantially to their costs.[25] For aviation, the tax base is less than perfectly mobile because bunkering excess fuel in low-tax jurisdictions can be costly.[26] Moreover, tourist destinations have, to varying degrees, some elements of uniqueness, so taxing flights to some country destinations, but not others, may only cause a moderate re-location of flight activity.

[23] The emissions-intensity per dollar of cargo is broadly similar for both modes: although the emissions per tonne of cargo are much higher for airlines, the value per tonne is also much higher (Stochniol 2011, pp. 10). Therefore if, for example, a minor portion of the value of shipping cargo (in response to higher maritime fuel prices) were instead shifted as additional air cargo, the offsetting increase in emissions would be modest.

[24] The only attempt to impose a tax on bunker fuels appears to have been that in California in 1991, when an 8.5 percent sales tax was imposed. In the course of only two months, more than 70 percent of the bunker market disappeared from California, as ships switched to fuelling elsewhere, notably in Panama. The tax was removed in 1992 (Michaelowa and Krause, 2000).

[25] A Panamax bulk carrier can travel between Sydney and Singapore four times on a single fuelling (AGF, 2010b). Container ships and other volume carriers may take fuel for an entire round-the-world voyage tanking in ports with competitive prices because these ships use fuel as ballast and replace it with water as the fuel is consumed.

[26] A plane travelling from Singapore to Saudi Arabia can carry only 25 percent of the fuel needed for the return trip (AGF 2010b). Also, excess fuel can add substantial weigh to planes which in itself increases fuel consumption.

Box 3. Legal Obstacles to Pricing Fuels Used in International Aviation

These arise from both multilateral and bilateral agreements:

- The 1944 Chicago Convention, under the auspices of the ICAO, itself prohibits only the taxation of fuel arriving in aircrafts' tanks. But subsequent ICAO resolutions, consolidated in 1999—having essentially the same effect as treaty provisions—enjoin contracting States to grant reciprocal exemption of fuels taken up for international aviation (commercial and private).[1] The rationale for these provisions is the "development and expansion of international trade and travel."
- Bilateral Air Service Agreements (BSAs)—of which there around 4,000—differ, but generally provide similar exemption.[2]

Amendment of the Chicago convention requires approval by a two-thirds majority (128 States), and would not be binding on States that did not subsequently ratify it. Importantly, the ICAO Council has indicated that it would review its policies if its present position on environmental charges and taxes were to change in some relevant way.[3]

Amending BSAs to allow for the reciprocal taxation of fuels, however, can be straightforward—it would not be necessary to reopen or renegotiate them all. Where a BSA is silent over its own amendment (as for instance is the model US BSA), Vienna Convention rules apply and reciprocal taxation could simply be introduced by mutual consent. EU Member States have the right to tax fuel used on flights between them, by mutual consent.[4]

The 1999 ICAO resolution also requires contracting States "…to reduce …and make plans to eliminate…all forms of taxation on…international transport by air, including taxes on gross receipts…and taxes levied directly on passengers or shippers." In practice, many countries maintain and indeed have increased such taxes.

Whether the Chicago Convention and related instruments apply to ETS permit prices as they do to taxes is currently the subject of litigation, prompted by proposals to include non-EU carriers in the EU-ETS.

[1] The intention is to preclude any charge that is compulsory and not used for airports or air navigation facilitates and services: see commentary to ICAO (2000).

[2] Similar exemption applies to other supplies, such as de-icing fluid, but this is less of an issue to the extent that these cause no climate damage; and, as business inputs, they would in any event be effectively excluded from a sales tax such as the VAT.

[3]Foreword to ICAO (2000).

[4]Directive 2003/96/EC.

- ***Fuel costs are a larger share of all costs in shipping, even though the heavy fuel oil predominantly used in shipping is relatively inexpensive***.[27] A given carbon price therefore represents a larger proportional increase in fuel costs, and total per unit costs, for shipping than for aviation.

- ***Emissions from aviation are generally higher per tonne kilometer***. Emissions from aviation have been put at 3 to 60 grams of CO_2 per tonne-km, compared to 15 for transport by sea.[28] High-altitude fuel combustion may also have a greater 'forcing effect' on climate, through the formation of cirrus clouds and ozone from non-CO_2 gases, though the magnitude of this effect, and even its direction, is uncertain.[29]

[27] The average delivered bunker fuel price is approximately equal to the average crude oil price; see http://www.bunkerworld.com/prices/. Jet fuel prices are higher, by a margin of 25-30 percent on the average; see http://www.indexmundi.com/commodities/?commodity=jet-fuel.

[28] See Stochniol (2011) and IMO (2009).

[29] See IPCC (1999), Komuss and Crimmins (2009), Kolmuss and Lane (2009). The ICAO has requested the IPCC to further investigate the effects of non-CO_2 emissions from aviation. For shipping, sulfur emissions could

- ***Efforts are underway to include international aviation in the EU ETS***, though these are currently under legal challenge—including on the grounds that they run counter to agreements discussed in Box 3.[30] There is also provision to work towards including shipping in the EU-ETS, failing progress in international fora.

B. Overarching Issues

The case for MBIs in international aviation and shipping

13. **The case for distinct pricing measures in international aviation and shipping on climate mitigation grounds would mostly disappear if comprehensive carbon pricing policies were widely adopted**. With appropriately scaled carbon taxes (or emissions trading systems) applied upstream, the carbon content of aviation and maritime fuels would already be reflected in fuel prices paid by airlines and shippers. However, even in major emissions pricing schemes introduced to date (e.g., in the EU ETS and prospective ETS in Australia) these fuels are not covered. The analysis below therefore proceeds on the assumption that such generalized carbon pricing measures are not widely in place for the foreseeable future.

14. **By directly targeting fuels, MBIs exploit all of the possible behavioural responses for reducing emissions**. For shipping, these include building more fuel-efficient vessels (hull, engines, and propulsions systems), optimising routes and vessel speeds to economize on fuel use, better utilizing individual ships and fleets as well as improving scheduling to reduce idling time at ports. Similarly, for aviation higher fuel prices would reduce emissions by rewarding use of more fuel efficient planes and, as charges are passed forward into ticket prices, reducing the demand for flights. As stressed in Box 1, the ICAO and IMO are already pursuing some of these options; MBIs will reinforce these efforts as well as exploiting other mitigation channels, such as reducing the overall demand for travel and hastening retirement of older planes and ships. Taxes on shipping tonnage or turnover, or on airline ticket purchases, in contrast, are less effective than emissions pricing from an environmental perspective as they do not promote better fuel economy nor, in the case of shipping, do they encourage the uptake of more sophisticated technologies and improved practices.[31]

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cause a cooling effect as they deflect incoming sunlight (IMO, 2009), though any effect will presumably decline over time as low-sulfur requirements are phased in.

[30] Even though US carriers are challenging the expansion of the ETS, both US and EU airlines could reap windfall profits from joining the EU-ETS as they would receive large allocations of free allowances, at least initially (see below).

[31] In principle, the tax (or emissions trading equivalent) should be on the average carbon content of fuel, to provide incentives for the use or blending of non-oil based fuels (e.g., bio-diesel, hydrogen). However, there is uncertainty about the commercial viability of these fuels for both planes and ships, and measuring the lifecycle emissions from alternative fuels is contentious to the extent their production entails energy inputs and changes in land use. Nonetheless, there have been advances in the production of biofuels for use by ships (less so for aviation fuel). The use of biofuels in marine diesel engines is technically feasible, so the challenge for this to happen is on the sustainable production of the needed quantities, and to do so to competitive prices.

15. **Not the least of the advantages of MBIs is as a source of public revenue, whether in the form of taxation or receipts from auctioning allowance rights**. Given the zero levels of fuel taxes in international aviation and maritime at present, these are likely to be especially efficient sources of revenue, whether for general purposes or, as is taken to be the case here, for climate finance.

Prospects for promoting participation

16. **Implementing effective MBIs for international aviation and shipping will require significant international coordination, including from lower income countries—especially for shipping**. Underlying the tax-exempt status of international transportation fuels—in addition to the legal obstacles in aviation—are natural fears that unilateral taxation (or pricing) would result in little revenue as fuel is taken up elsewhere, harm local tourism, undermine the competitiveness of national carriers, raise import prices and/or reduce the competitiveness of exports. If governments set taxes unilaterally, they would be under pressure to set lower rates than in other countries. Although there is need for a multilateral approach to aviation taxation, something less than universal agreement—for example exempting some vulnerable developing countries—could still have significant effects on global emissions. For maritime fuels, including developing countries is more important, because of the extremely high mobility of the tax base.

17. **With lower income countries needing to participate in order for these schemes to have maximal environmental and revenue effects, consideration needs to be given to make sure they are not harmed by participating**.[32]

18. **There is a tension between setting ambitious fuel charges and promoting policy compliance**. Setting aggressive emissions prices encourages avoidance and evasion. In turn, greater non-compliance will undermine the environmental effectiveness of and, even more importantly, support for, an international fuel pricing agreement. Large charges (e.g., corresponding to the high climate damage scenario in AGF 2010) are therefore not considered in the main text here.

19. **Although on a much smaller scale, experience with the air ticket solidarity levy and the International Oil Pollution Compensation (IOPC) Funds suggest a cooperative approach to pricing emissions from international transportation can be aspired to**. As discussed in Box 4, these schemes involve agreements among countries to raise funds for a collective purpose.

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[32] This paper does not consider precisely which countries might be compensated, or whether and how the use made of compensation might be restricted (to ensure, for instance, that they are not used to support policies that increase emissions).

Box 4. Current International Taxes and Levies: The Air Ticket Solidarity Levy and the International Oil Pollution Compensation Funds

The *Air Ticket Solidarity Levy* is an example of financing global public goods by a levy on international aviation. Eleven countries have imposed an 'air ticket solidarity levy' on airline tickets, receipts from which are passed to UNITAID to finance health improvements in low income countries.[1] It provides 70 percent of UNITAID's financial base and is complemented by multi-year budgetary contributions from a number of member countries. Several developing countries participate in this scheme.

The levy is applied to all flights departing from countries that impose it and is paid by passengers when purchasing their tickets, normally as an addition to existing airport taxes. Passengers in transit are exempt.

The levy ranges from US $1 for economy-class tickets to US $10 and US $40 for business- and first-class travel. Different rates can be set according to a country's level of development, and there is an option to vary the charge according to the distance travelled. For example, some countries in Africa have chosen to impose the levy only on international flights or on business- and first-class tickets.

The *International Oil Pollution Compensation* (IOPC) *Funds*. These Funds, which were established under the Civil Liability Convention of IMO, are financed by contributions paid by any person, company or organization, who has received, during the preceding calendar year, more than 150,000 tonnes of crude oil or heavy fuel-oil after sea transport. The contributors are generally oil companies and the contributions are channelled directly to the Funds with no government involvement. The obligations of the Member States are to implement the needed legal regime and to ensure compliance by entities within their territories. States may collect the contribution nationally and pass it on to the Funds, but no party to the IOPC has chosen this option. The annual funds collected and paid out amounted to a total of $54 million in 2010.[2]

[1] See http://www.leadinggroup.org/rubrique177.html.

[2] See www.iopcfunds.org for more details.

20. **Aviation fuel used domestically is already widely taxed, though typically at much lower rates than other fuels**. For example, the federal government in the United States imposes a tax of about 1 cent per liter for domestic jet fuel used in commercial operations. This tax is far lower than motor fuel taxes in the United States.[33] However, other countries with major domestic flight activity have higher rates; notably Japan at more than US$0.25 per liter.[34] Moreover, the fact that taxes on domestic aviation fuel already exist suggest that fuel charges for international aviation would be administratively feasible. Indeed imposing the same rate on domestic and international fuel might simplify administration by obviating the controls needed for differentially imposed taxes.

C. Key Concepts: Incidence and Compensation

21. **By the 'incidence' of a tax is meant the answer to question: "Whose real income is reduced by this tax, and by how much?"** While charges on international aviation and shipping raise issues of incidence *within* countries—it may matter, for instance, whether import prices rise more for goods consumed by the rich or by the poor—the primary concern

[33] Combining federal and average state taxes, excises on gasoline and diesel fuel are about 10.5 and 11.5 cents per liter (Parry, 2011).

[34] See Keen and Strand (2007), Table 1.

in this paper is with incidence *across* countries. It is clearly preferable to avoid regimes that are 'regressive' in the sense of imposing a larger incidence relative to GDP on poorer countries that heavily rely on international transport (including small island States). A stronger notion of fairness—to the fore in the present context—is to ensure that developing countries are made no worse off, which likely requires explicit *compensation*.

22. **The 'real' incidence of a tax can be quite different from its 'legal' incidence**. Fuel refiners, distributors, or vehicle operators may be legally responsible for paying the tax. However, to the extent that an aviation or maritime fuel tax is 'passed forward' into higher selling prices, the real incidence of the tax will fall on their customers; to the extent they are 'passed backwards,' they will result in lower world oil prices and reduced revenues for oil producers. And to the extent that they remain with aviation and shipping companies, the real incidence falls on their owners or employees. Precisely who is legally responsible for remitting the tax in itself generally makes little or no difference to its real incidence: whether a tax is levied on the output of a refinery or the use of the same products by final consumer (perhaps in a quite different country) may matter for the practical implementation of the charge, but should make no difference to the prices each ultimately faces.[35]

23. **Establishing the real incidence of a tax is only one element in assessing its economic welfare impact—and it is the latter that matters for compensation issues.** Any tax causes a loss of economic welfare simply by transferring resources from private to public sector (though there may of course be more than offsetting benefits from the public spending this enables). But it typically also distorts the prices that consumers and perhaps also producers face away from those they would otherwise face, distorting their behaviour and leading to another source of 'deadweight' or 'welfare' loss. If it is then desired to compensate a taxpayer—or country—for the effects of some tax, account needs to be taken of this indirect loss too. An artificial increase in import prices, for instance, will cause a welfare loss in part by impeding citizens access to goods that are produced more cheaply abroad than at home; and, by the same token, by extending artificial protection to domestic industries.

24. **In broad terms, the welfare impact of any country of charges on fuels used in international transport depends on three factors** (Box 5):

- ***The proportionate impact on transport costs***, meaning here primarily ticket prices for aviation and freight costs for maritime.
- ***The relative importance to the wider economy of the goods affected***. Even a large increase in transport costs will have little impact, for instance, if the affected good is small relative to GDP.
- ***Elasticities of import demand and export supply both in the affected country and in the rest of the world.*** Increased transportation costs for a country's exports, for instance, will be largely borne by purchasers of those exports, not citizens of the country itself, if their demand for those exports is highly inelastic and/or the supply of those exports is highly elastic.

[35] In the absence of price controls.

Box 5. Assessing the Welfare Impact of Increased Transportation Costs

It is shown in Appendix 1 that the compensation required by country A to offset the welfare loss from (small) proportionate increases τ_X and τ_M in the prices of an imported good M and an exported good X (ignoring cross-price effects between them) is given by

$$\tau_X V_X \left(\frac{E_M^{ROW}}{E_M^{ROW} + E_X^A} \right) + \tau_M V_M \left(\frac{\eta_X^{ROW}}{\eta_X^{ROW} + E_M^A} \right) \qquad (5.1)$$

where η_X^j denotes the elasticity of export supply in country j and E_M^j the elasticity of import demand, while V_X and V_M denotes the values of affected imports and exports. If, for instance, country A's demand for imports is infinitely high, it will bear none of the burden of increased transport costs bearing on its imports: this will all be passed back to the country supplying those imports.

One important limitation of (5.1), and the related expression in Box 11 later, is that it assumes there to be no pre-existing distortions. The presence of import tariffs and export taxes, for instance, is likely to amplify the welfare loss from increased transportation costs.

25. **Projecting incidence and welfare effects is extremely difficult**. While the second of the factors just mentioned may be reasonably straightforward to establish with reasonable confidence, there can be considerable uncertainty as to the first and third. The impact on transportation costs will depend, for instance, on the extent to which the charge is passed forward to purchasers of these fuels rather than being borne by their producer—which is considered below. It will also depend on the degree of competition in the transport market, the ability of suppliers to economize on the use of fuels and, in the maritime context, the nature of the goods imported or exported and the distance and manner in which they travel. Assessing the elasticities appearing in the third factor is potentially even more difficult. They will depend, for instance, on the time period under consideration (being greater in the longer than in the shorter run). Moreover, at issue here are charges that would have effects on international aviation and shipping throughout the world, so that a full analysis requires looking beyond the impact on any single country to take into account how the charge would affect trading patterns and prices in a more general setting—which means that the relevant elasticites are for prices changes in many countries, not just that under examination. While it is likely to be difficult to explicitly condition compensation schemes on trade elasticities, their relevance to welfare effects is such that they need some consideration in determining whether practicable approaches provide a good approximation to factors that economic analysis suggest shape the amount that is in principle required.

26. **The more extensive is compensation, the less additional revenue will be made available for climate finance or other worthwhile expenditure**. This is an obvious but critical trade-off that can only be assessed in the context of the full package of charges and the spending they enable.

27. **Other concerns may also be relevant**. The aggregate perspective taken in Box 5 does not capture particular concerns that may arise if the change in transport costs affects different income groups differently: higher import prices may hurt domestic consumers, for instance,

but benefit but benefit import-competing producers. Nor does it capture potentially, concerns with the impact not simply on the impact on profits and wage payments in the tourist sector but also on the volume of tourism travel. Importantly, where better-targeted instruments are available, these concerns may be best met by other means (such as a subsidy to the tourism sector).

D. The Impact on Oil Prices

28. **The critical first step in all incidence and compensation issues is: How far would charges on jet or maritime fuels be passed on to purchasers?** This is key to the first factor identified above: to the extent that the impact is not passed forward, so that aviation and maritime fuel prices rise by less than the full amount of the charge, so its impact on and through the sectors will be muted. Part of the impact would then be felt by suppliers of crude oil—including a number of low income countries that are new oil producers.

29. **The determinants of the degree of pass forward into fuel prices are complex—one key issue being the degree to which refiners can substitute between the production of taxed and untaxed fuels**. Box 6 considers the likely impact of a charge when such substitution is completely costless. The degree of pass forward is then likely to be high since producers can readily escape the tax by instead producing other fuels. As a rough order of magnitude, on average over 90 percent of a charge imposed on both marine and jet fuel might be passed on.

Box 6. The Impact on Oil Prices from Taxing International Aviation and Maritime Fuels

Suppose first that 'oil' is a homogenous product, and consider a specific charge of T levied on its use in only one activity (aviation and or maritime). In this case, assuming the relevant industries are reasonably competitive and that the elasticity of demand is the same (E) for both 'taxed' and 'untaxed' uses, the impact on the pre-tax oil price P is approximately

$$\Delta P = \alpha \left(\frac{E}{E+\eta}\right) T \qquad (6.1)$$

where α is proportion of all oil consumed in the taxed sector and η the elasticity of oil supply. The impact is thus smaller (i.e. less of the charge passed back to oil producers): (1) the smaller the amount of aviation/maritime fuel produced from the average barrel of crude oil input; (2) the smaller the share of global aviation/maritime fuel production that is covered by the charge (i.e., the greater the extent of developing country exemptions); and (3) the less elastic is the demand for these fuels and the more elastic is the supply of crude oil.

Broadly speaking, the impact is the same as that of a tax on all oil uses but scaled down by the share of oil covered by the tax in all oil production. The empirical evidence suggests that the elasticities of demand for and supply of oil are of broadly the same magnitude: according to IMF (2011), Ch. 3, the magnitude of oil demand and supply elasticities are both around 0.05 to 0.1 in the short run, though both are larger over the longer run.

This suggests that the bracketed term in equation (6.1) is around 0.5. Supposing that the share of aviation and maritime in global oil demands is 11 percent[1] and international fuel taxes are implemented globally (i.e., $\alpha =$ 0.11), then a fuel tax of 10 cents per liter imposed on all aviation and maritime fuel demand would reduce the world oil price by around 0.55 cents and, conversely, increase the price to fuel purchasers by around 9.4 cents per liter.

[1] This is based on EIA (2011b) and IMO (2009).

Box 6. The Impact on Oil Prices from Taxing International Aviation and Maritime Fuels
(concluded)

This simple analysis also highlights that taxing the use of oil in some particular use results in a *fall* in its prices in other uses. Thus low-income oil importing countries, for instance, would derive some benefit to the extent that prices of fuels in other uses fall. This effect also means that total emissions fall by less than do those in the affected sector, since the reduced price in other sectors leads there to higher emissions.

Total emissions will fall (so long as the supply curve is upward-sloping), but the fall will be smaller the more elastic is the demand for oil in untaxed uses.

All this assumes oil in distinct uses to be perfect substitutes.[2] Appendix 2 provides a general treatment of the case in which, as in practice, they are not, on which the calculations in Table 1 are based.

[2] There are other limitations too. The ultimate exhaustibility of oil, for instance, means that a full incidence analysis would recognize that a reduction in supply today may be associated with increased supply tomorrow (see for instance Sinn, 2008). Imperfect competition too can significantly affect the impact of taxation: it may even lead to over-shifting (tax-inclusive price rising by more than the tax) and to an increase in profitability, as the tax serves to coordinate an output reduction that firms are unable to collude on directly (e.g., Stern, 1987).

30. **Even allowing for possible difficulties of re-configuring refineries to alter the portions of different fuel products produced from crude oil, pass-back to oil producers is likely to be modest**. In effect, costs of reconfiguration mean that the supply of taxed fuel is more inelastic, so that producers bear more of the burden of the tax. Nonetheless, even allowing for somewhat more limited substitution possibilities, simulations in Table 1 (based on formulae given in Appendix 3) suggest that the passback into lower oil prices is still modest—again at about 6 cents per liter for a $1 per liter fuel charge.[36] It is noticeable, nonetheless, that the amount of the tax passed forward is far from complete: A $1 tax increase leads to an increase in the tax inclusive price of 'only' 65–84 cents per liter. The reason is that the price impacts for the untaxed fuels are in many cases sizable, in the order of 10 percent—implying a benefit to users of these fuels that needs to be weighed against any loss from the impact on the taxed fuel.

Table 1. Impact on Fuel and Oil Prices of $1 Charge on a Subset of Fuels

Elasticity of substitution	1				∞	
Elasticity of fuel demands and oil supply	0.1	0.5	0.1	0.5	0.1	0.5
Price change (in cents) of [1]						
Taxed fuel [2]	+0.86	+0.65	+0.93	+0.86	+0.94	+0.94
Untaxed Fuel	-0.08	-0.10	-0.06	-0.07	-0.06	-0.06
Crude Oil	-0.06	-0.06	-0.06	-0.06	-0.06	-0.06

Notes: See Appendix 3 for underlying formulae. Taxed fuels are assumed to be 12 percent (by tax-exclusive value) of oil sales, and the elasticities of demand for the two fuels are assumed equal to one another and to the elasticity of supply of oil in the notation of Appendix 2, $E^A = E^B = \eta \equiv E$. (The invariance of the impact on the oil price is a consequence of this assumption).

[1] Price effects do not sum to unity, reflecting the differing shares of taxed and untaxed fuels in the derived demands for oil.

[2] Tax-inclusive price.

[36] For marine fuels in particular, there is probably a high degree of substitution with other oil products. Even with no retrofits to refinery capacity, heavy fuel oil may be further refined into higher quality and higher price products, or sold on global markets for use in industry or power stations.

III. Policy Scenarios: International Aviation

31. **This section outlines several fuel pricing scenarios—including emissions taxes or their auctioned cap-and-trade equivalents—that vary by the emissions price and the extent of developing country compensation, and discusses their implications for emissions, revenue, costs and cross-country incidence**. For the most part, the pricing policies could be implemented via a tax or an emissions trading regime with allowance auctions—Section V discusses the choice between these instruments in more detail. Further impacts of concern (e.g., effects on productivity, trade performance, innovation) are not discussed, not least because of the difficulty of quantifying impacts.

A. Scenarios

32. **A natural way to seek to protect more vulnerable countries is by their retaining the amounts collected for fuel charges for air transport in and out of the country**. Data are not available, however, for jet fuel use in all countries by country of origin or departure. There are then two ways of approximating the fuel used in travel to and from such countries:

(1) *In proportion to fuel purchases*, data on which are available by country. In its simplest form, this approach would allow developing countries to keep receipts from charges imposed on fuel disbursements within their country for international flights. These fuel disbursements would amount to about half of the total fuel consumed for a flight from a developed country to a developing country and back again.

(2) *In proportion to passenger kilometers (or passenger, freight, and mail, in tonne-km).* Under this approach, each country would be allocated a share of revenue from the global fuel tax—perhaps that part prorated to passenger travel—corresponding to the proportion of all inward passenger kilometers.

Each approach causes potential distortions: under (1), countries have an additional incentive to establish themselves as hubs; under (2), perhaps less of a concern, they have an incentive to encourage passenger numbers. But any compensation scheme linked to future outcomes will create distortions, and these seem likely to be manageable. Below the focus is on the first type compensation scheme, given its relative simplicity, close connection to the base of the charge and limitations on data available on passenger kilometers.

33. **Although not considered here, more sophisticated compensation schemes could be designed to account for relative income growth over time, or to entice participation by low-income countries (like tourist destinations) especially vulnerable to high fuel prices**. For example, it would be possible to adjust the amount of compensation for a country's per capita income relative to that of the average developed country (indeed some such adjustment would presumably be needed to phase out compensation across countries at different levels of development and vulnerability). Thus the compensation would progressively decline as a country's per capita income caught up to that of wealthier countries.

34. **The following illustrative policy scenarios are considered**:

1. ***A uniform, globally applied CO_2 price of \$25 per tonne, with no special compensation for developing countries***.[37] The emissions price corresponds to the medium damage scenario studied in AGF (2010) and is approximately consistent with a recent US inter-agency assessment of environmental damages per tonne (US IAWG 2010). The CO_2 price is higher, but only moderately so, than the current (September 2011) emissions price in the EU ETS of about \$19 (EUR 13) per tonne of CO_2.[38] A \$25 per tonne emissions price would add about US 6 cents per liter, or about 8 percent, to the price of jet fuel.[39] Although unlikely perhaps for the foreseeable future (not least because it provides no developing country compensation), this policy scenario still serves as a useful benchmark as it representations a 'worst case' scenario (given the emissions price) in terms of potential adverse impacts on low-income countries.

2. ***As (1) but developing countries keep all revenues from fuels taken up in their jurisdiction (through rebating of receipts from taxes or allowance auctions)***. In terms of potential revenue for climate finance, this policy scenario is very similar to scenarios when developing countries are either exempt from the pricing regime or could join voluntarily (but keep revenues they collect). The environmental effectiveness of the policy would be somewhat weaker in these latter cases, however.

3. ***As (2) but with an emissions price of \$15 per tonne of CO_2.*** This policy could reflect a scenario with lower assumed environmental damages. Alternatively, from a climate finance perspective, it could approximate a case when countries agree on a minimum price floor, but with individual countries free to impose higher prices (through higher taxes or more stringent trading schemes) and keep extra revenues for themselves.

4. ***As (1) but with a CO_2 price of \$40 per tonne.*** This policy reflects a higher scenario for environmental damages or more aggressive target for climate stabilization. For practical purposes however, this scenario is even less realistic than policy (1), given the tension between aggressive pricing and reaching international agreement (the price level is about double the prevailing price in the EU ETS).

B. Environmental Effectiveness

35. **A price of \$25 per tonne of CO_2 might reduce travel demand by 2–4 percent below baseline levels**. An 8 percent increase in aviation fuel costs would add about 2–4

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[37] All prices are expressed in year 2011 units.

[38] See www.pointcarbon.com.

[39] Combusting a litre of jet fuel produces 0.0025 tonnes of CO_2 emissions (EIA 2011a).

percent to the average airline ticket price.[40] Based on the studies summarized in Table 2, it is assumed that the price elasticity of demand (i.e., the percent change in travel demand in response to a one percent increase in the ticket price) is -1.0. In this case, a general 2–4 percent increase in ticket prices might therefore be expected to reduce overall travel demand for affected airlines by around 2–4 percent.

Table 2. Estimates of the Price Responsiveness of International Air Travel by Trip Type

Type of trip	Median price-elasticity estimate[a]	Range
Long-haul international business	-0.27	-0.48 to -0.20
Long-haul international lesiure	-1.00	-1.70 to -0.56
Long-haul domestic business	-1.15	-1.43 to -0.84
Long-haul domestic leisure	-1.10	-1.23 to -0.79
Short-haul business	-0.70	-0.78 to -0.60
Short-haul leisure	-1.52	-1.74 to -1.29

Source: Gillen et al. (2002).
Note: [a] Price elasticity refers to the percent change in travel demand in response to a 1 percent increase in ticket price.

36. **Emissions pricing would induce other mitigation options beyond this reduction in demand**. These include more efficient operations (e.g., optimizing flight paths and reducing airport congestion, reducing average time spent idling on runways or circulating airports through advanced communication, navigation, and air traffic management) and improved efficiency of new planes (e.g., improving aerodynamics to reduce drag, more efficient engines, incorporation of lighter materials into the airframe). It is difficult to estimate the future development and deployment costs of many of these strategies, and hence the extent to which they would be incentivized by higher fuel prices over the longer run.[41] For cars and light trucks (at least in the United States), it seems reasonable to assume that a 1 percent increase in fuel prices will ultimately increase fuel economy by something in the order of about 0.2 percent (e.g., Small and Van Dender, 2006). For airlines the responsiveness might be lower, given already strong incentives to economize on fuel (which is expensive to carry) and ongoing efforts by ICAO to promote better fuel economy. Simply by way of illustration, suppose the fuel economy response is 0.1 percent (per 1 percent increase in the fuel price). Combining this with the assumed reduction in travel demand implies an overall fuel (and emissions) reduction in response to an 8 percent increase in fuel price of 3–5 percent. Given

[40] Assuming that fuel costs comprise between 25 and 35 percent of total costs of airline (see GAO 2009), and assuming that the carbon charge is fully passed on to customers, an 8 percent increase in fuel costs leads to 2–4 percent increase in ticket price.

[41] See, for example, Morris et al. (2009).

that developing countries account for 35 percent of fuel use (see above), their exemption from the agreement might limit the global emissions reduction to about 2–3 percent.[42] A similar level of emissions reductions might occur if all countries participated, but at a price of $15 per tonne rather than $25. On the other hand, the emissions reduction might be around 5–8 percent under a CO_2 price of $40 per tonne, encompassing all countries.[43]

C. Revenue

37. **Total projected revenues in 2020 are $12 billion under the $25 per tonne pricing scenarios, $7.5 billion for the $15 per tonne scenario, and $18.7 billion under the $40 per tonne scenario** (Figure 2a). Revenues are calculated as follows. Baseline emissions in 2020 are taken to be 500 million tonnes.[44] This is scaled back by the midpoint of the range of proportionate emissions reductions for the different pricing scenarios just discussed, and multiplied by the corresponding emissions price.

38. **With compensation schemes, developing countries would raise significant amounts of domestic revenue** (Figure 2b). For example, with a $25 per tonne CO_2 price developing countries as a group raise revenues of $4.2 billion and even with the $15 per tonne price, they raise revenues of $2.6 billion (potential compensation relative to countries' GDP is discussed below).

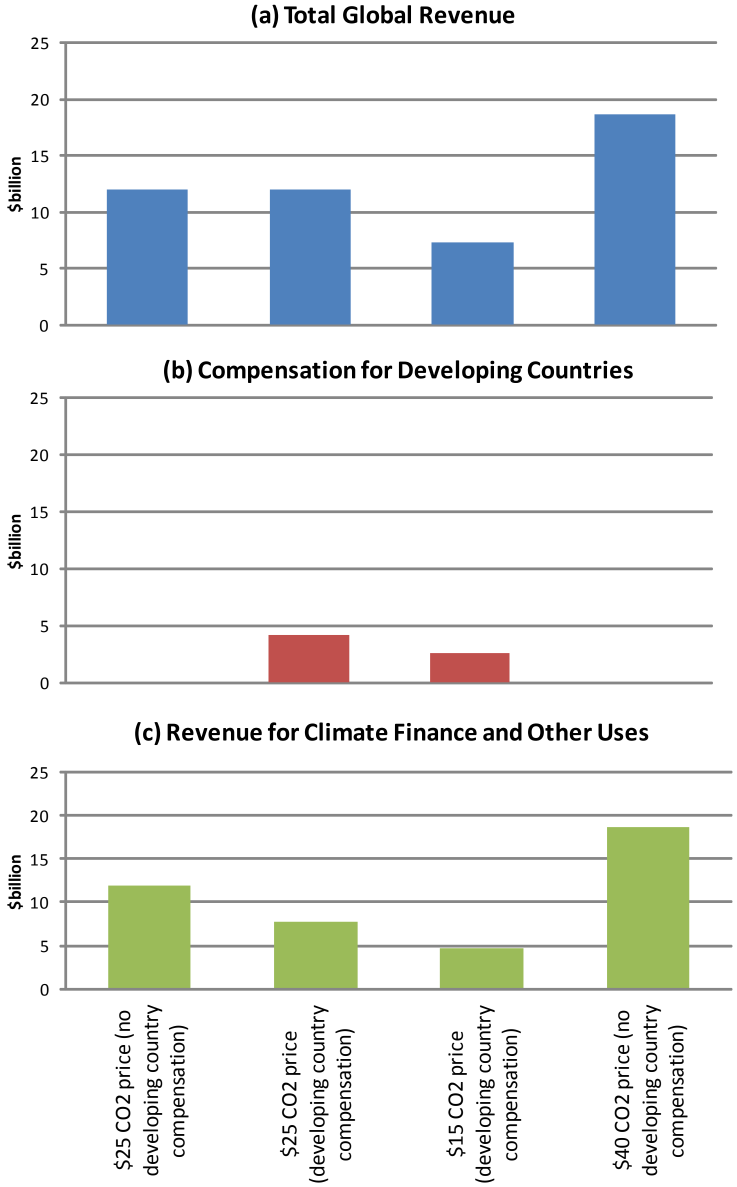
39. **Revenues for climate finance and other uses total $4.8–$7.8 billion in the more realistic pricing scenarios ($15 to $25 per tonne of CO_2) with developing country compensation** (Figure 2c). Of these, perhaps 5–10 percent might be remitted to implementing agencies, national or international, a precedent being that EU Member States are allowed to keep 10 percent of customs revenue to cover administration costs. Some might also fund clean technology development programs for the aviation and maritime industries. However, the amount that might be warranted on economic grounds to correct market failures, that is, the potential inability of innovators to appropriate spill over benefits of new technologies to other firms, would likely be a small fraction of the revenue raised. At most, therefore, international aviation might contribute around $4–7 billion for climate finance in these scenarios.

[42] This ignores the (small) risk of offsetting emissions increases as the pattern of flights shifts from developed to developing countries.

[43] For comparison, AGF (2010b) assumed no emissions reductions in response to similar charges to aviation.

[44] This is based approximately on the projection in ICAO (2009a), scaled back by 20 percent on the assumption that ICAO's aspirational emissions mitigation goals (see above) will be met. It is assumed that charges are levied on flights that it is proposed to include in the EU-ETS. Issues arising from the coordination of such a charge with the EU-ETS are discussed in Section V.

Figure 2. Revenue from Taxes on International Aviation



Source: See text.

40. **These numbers are broadly consistent with those presented in AGF (2010b)**. Workstream II reports revenue estimates for climate finance of approximately $1–6 billion. The lowest figure is for a $15 per tonne CO_2 price, with 25 percent of the revenue raised in developed countries going toward climate finance, while the highest figure is for a 50 percent climate finance share and a carbon price of $40 per tonne CO_2. Intra-EU flights are excluded from the revenue base in AGF (2010b), implying a somewhat lower revenue figure than above.

D. Cost Considerations

41. **Pricing aviation fuel would be a highly cost effective source of revenue compared with broader fiscal instruments**, in the absence of comprehensive, upstream pricing across all fossil fuel products and countries. The tax would reduce carbon emissions by suppressing fuel demand and (moderately) alleviate local air quality, noise, and congestion problems

around airports. It would also help to offset excessive demand for air travel caused by the under-taxation of this sector relative to other goods and services. Most likely, aviation fuel taxes at the level considered here are a much more cost-effective way to raise climate finance than broader tax instruments (which do not target environmental damages).

42. **The difficulty of taxing the final consumption of international aviation services could point to a carbon charge above that called for by climate considerations**. A fully appropriate tax structure would levy both a fuel tax to address environmental concerns and a tax on the final consumption of aviation services to raise revenue efficiently and fairly within the overall tax system. In the absence of such explicit sales taxation, a tax on fuel acquires also a role in correcting the potential over-consumption of aviation services and enhancing revenue. This can plausibly call for larger fuel taxes—and hence to potentially substantially more revenue—as described in Box 7.

Box 7. Second Best Taxation of International Aviation Fuel

In a simple partial equilibrium model, Keen and Strand (2007) show that in the absence of a tax on final consumption the optimal fuel charge T is given by

$$\frac{T}{P+T} = \left(\frac{\delta-1}{\delta}\right)\frac{1}{(1-\beta)\sigma+\beta E} + \frac{MSC}{\delta(P+T)}$$

where P is the pre-tax fuel price, β is the share of fuel in total costs, σ the elasticity of substitution between fuel and other inputs, E the elasticity of final demand, MSC the marginal social cost of emissions, and $\delta > 1$ the marginal cost of public funds. The extent to which this last exceeds unity can be interpreted as an indicator of the urgency of the need for revenue. A table presented in Appendix 2 reports illustrative calculations, assuming a unit elasticity of demand, and assuming a globally uniform optimal tax (on both international and domestic aviation).

43. **A distance-based (non-creditable) ticket tax, while inferior to a fuel tax, could also have merit**. The air ticket levy in the U.K. is of broadly this form, being chargeable in an amount that varies with distance (within and outside of EU) and by travel class. The weaknesses of such a tax—most notably that it discourages emissions only by discouraging travel—are stressed in AGF (2010b). The force of these is diminished, however, by the recognition that the absence of sales taxation means that such a tax would at least serve to correct current tax distortions that likely lead to excessive international aviation transport.

E. Incidence

44. **As discussed in Section II.D above, some of the incidence of a fuel tax may be passed back to oil producers through a reduction in crude oil prices**. However, this effect is likely modest and is ignored below.

Impact on the aviation industry

45. **A uniform tax on international aviation fuel, applied globally, would not impact competitiveness within the sector—and would level the playing field relative to other**

sectors. Since all airlines would face the same increase in fuel prices, there would be no distortion of competition between them. This is not to say that there would no impact on their competitive positions relative to one another: 'no frills' airlines for instance—for whom fuel costs tend to be a larger part of the ticket price—will lose some edge. But none is privileged by facing different input prices. In the absence of broader emissions pricing, all airlines would face an increase in costs not falling on other sectors, whether other transport modes in direct competition with aviation or simply other forms of consumption and inputs to production. However, this would largely alleviate (rather than introduce) distortions of competition to the extent that these other sectors already pay fuel taxes.

46. **There may be some windfall loss to owners of airlines, and it is conceivable that some airlines may be caused to fail—but with less of a long run impact on capital owners or workers.** To the extent that the tax is not fully passed forward to airlines' customers, it will fall on profits or labor remuneration. Airlines earning profits in excess of the minimum required may absorb some loss in reduced super-normal profits, an effect that will materialize in lower share prices as the charge becomes anticipated (some capitalization may have already occurred). In the longer term, capital owners are not likely to be burdened by the tax, since they can simply invest elsewhere instead. Though the modest increase in costs suggest that this is unlikely to be major issue, airlines at the margin of profitability may suffer difficulty. The main long-run impact on the sector is likely to be a slightly lower overall business volume.

47. **If it is desired for some reason to protect such airlines, the best targeted instrument would be an outright subsidy, leaving their incentive to cut emissions unchanged**. The subsidy could take the form of a lump-sum payment, or allocation of free emissions allowances—though only a small portion of the allowances would be needed to keep airlines whole given that most of the incidence is borne by passengers rather than airline companies.[45] These compensation schemes may run foul of state-aid and export subsidy prohibitions (unless explicit override provisions were introduced). The economic case for support of such airlines seems weak, however: their closure, in principle, would simply mean that they are unable to break even when they pay the full social costs of the environmental harm from their operations. Workers too will bear a minor burden of the tax in so far as they can earn similar wages elsewhere; to the extent they cannot, adjustment can be eased through standard tools for strengthening labor market participation.

48. **If developing countries do not participate in the pricing agreement, there could be some relocation of flights away from developed and towards developing countries**. However, as mentioned above, the increase in the ticket price (for developed countries) is likely to be modest. Moreover, as noted in Section II.A, the tax base is imperfectly mobile given practical constraints on the ability to divert flights to tank up at airports of tax exempt countries, and limited willingness of passengers to change their country of destination.

[45] Note however that a large share of free quota allocations given to airlines over the long run may undermine their incentives to abate, given that free future allocations are related to current emissions; see Rosendahl (2008).

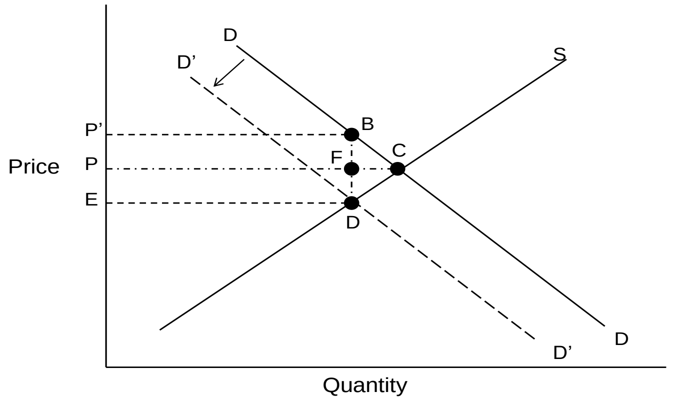
Impact on low income countries—and their compensation

49. **The real incidence of any increase in the price of air travel to lower income countries is likely to fall largely on citizens of developed countries**. Though there would doubtless be some impact on travel costs of poorer groups in lower income countries, including for instance migrant workers, the main burden is likely to fall on travelers from higher income countries and better-off domestic residents. The impact, both across and within countries, is thus likely to be progressive. Indeed it is notable that a number of lower income countries are among those that have imposed solidarity levies referred to above, suggesting few reservations on this account.[46]

50. **To offset the impact on tourist destinations—which has been a particular concern—returning all revenue raised domestically could be more than adequate**. That is, the part of the revenue that is in effect a transfer from citizens of developed countries exceeds the harm suffered by the domestic tourism industry. Box 8 elaborates.

Box 8. Tourism and the Welfare Impact of a Fuel Charge

The figure provides a simple illustration of the impact of an aviation tax on a tourism-providing developing country. The upward-sloping curve shows the domestic supply of tourism services; the downward sloping curve is the demand for these services, assumed to come entirely from residents of developed countries. Imposing a charge on fuel use shifts the demand curve for tourism services down, from *DD* to $D'D'$, by an amount that—assuming full pass-through to the price of tourism services—reflects the underlying charge. The equilibrium price of these services to tourists themselves rises to P', causing them a loss of consumer surplus given by the area $PP'BC$. But since these are by definition resident in foreign countries, this welfare loss is presumably of no direct concern to the tourism-providing country. What is of concern is the loss of producer surplus in the domestic tourism industry, given by the area $PCDE$—and the fate of the revenue raised $P'BDE$.



Roughly half of this revenue will be collected by the tourist destination for flight legs *from* that country, so that the question is whether half of the area $P'BDE$ is greater than that of *PCDE*. This clearly depends on the relative elasticities of the demand and supply curves. More precisely, from equation (1) of Box 5, a transfer of $(\frac{1}{2})(\tau_X V_X)$ will be more than adequate compensation if and only if $E_M^{ROW} < E_X^A$. Estimates of the size of this elasticity of demand for tourism vary widely, from around 0.15 to 7.0 (Lim, 2006), with figures in the lower part of this range likely more appropriate if—as would be the case if the charge were globally applied—the increased transport costs apply to all destinations. Where tourism capacity is fairly easily extended, it is thus fairly plausible that the net effect will be a welfare gain for the tourist destination. This cannot be taken for granted, however, and where capacity is essentially fixed (if beaches are already fully developed for instance), the possibility remains that full return of revenue collected on one leg of the flight may be inadequate compensation.

[46] Furthermore, on behalf of the Group of Least Developed Countries the Maldives proposed a global levy (for climate finance) on international air trips at the 2008 climate change meetings in Bali.

51. **The charge has similarities to an export tax levied collectively by tourism destinations**, though with the difference that only half of the revenue is collected (assuming fuel is taken up there for only one leg of the journey). This can be beneficial for countries with some power in world markets; as, collectively—the relevant dimension in this case—tourism centers in developing countries surely do. A small charge, with full return of revenue, can for this reason plausibly be positively beneficial for tourism destinations. But why, if developing countries can benefit by imposing a tax of this kind, do they not already do so? Part of the answer may be that to some extent they already attempt to do so, in the form of departure taxes[47] but that they feel limited in so doing due to tax competition arguments. Most likely, tourist destinations have collectively much greater power in world markets than do any single destination is isolation: that is, the supply curve is much more elastic when viewed collectively than individually. Thus, a global tax would in effect provide a coordinating device for charging an export tax that—as a standard problem of tax competition—tourist destinations have previously found hard to enforce.

52. **Using the finance obtained from the scheme, measures can be taken, if desired, to cushion any impact on the tourism industry**. This finance would provide room, for instance, to reduce any departure tax, to better promote the industry or improve its infrastructure. Such measures might to some degree undo the emissions impact of the charge, but the extent of relevant travel is sufficiently limited that this is unlikely to be a major concern.

53. **Some small island States could receive particularly large compensation (relative to their GDP) if they retain collected revenues**. Table 3 indicates the amounts that would have been received by selected developing countries if a global charge of \$25 per tonne of CO_2 had applied to countries' jet fuel disbursements in 2007. A number of small island developing States receive relatively large compensation such as Fiji (0.35 percent of GDP); Bahrain (0.11); Seychelles (0.09); Mauritius (0.08); Singapore (0.07); Jamaica (0.06); Maldives (0.4); Barbados (0.03); and Papua New Guinea (0.03).

[47] Only a small number of countries mostly in Latin America (Chile, Colombia, Mexico, Peru and Venezuela; plus Pakistan and the Philippines) impose substantial departure taxes; Peru also levies an arrival tax.

Table 3. Receipts in Developing Countries Under $25/ton CO_2 Levy on International Aviation Fuel
(applied to year 2007)

Country	Revenue	
	% of GDP	$million
Fiji	0.345	13
Bahrain	0.112	28
Seychelles	0.090	2
Mauritius	0.083	12
Senegal	0.080	17
Hong Kong	0.075	221
United Arab Emirates	0.073	179
Singapore	0.069	168
Cyprus	0.061	14
Kenya	0.058	34
Jamaica	0.056	12
Turkmenistan	0.055	16
Jordan	0.048	14
Qatar	0.042	38
Iraq	0.041	39
Maldives	0.039	1
Thailand	0.034	177
Azerbaijan	0.032	22
Panama	0.032	12
Oman	0.032	20
Barbados	0.030	2
Papua New Guinea	0.030	4
Malaysia	0.028	100
Kuwait	0.022	29
Russia	0.021	513
Saudi Arabia	0.021	114
Philippines	0.020	61
Egypt	0.019	79
South Africa	0.019	91
Sri Lanka	0.019	16
Morocco	0.018	23
Ecuador	0.017	17
Korea, South	0.016	209
Ukraine	0.015	50
Angola	0.015	13
Tunisia	0.014	11
Kazakhstan	0.012	20
Brazil	0.011	210
Tonga	0.011	0.05
Comoros	0.013	0
Argentina	0.011	58
Belarus	0.010	11
Mexico	0.010	147
Pakistan	0.009	133
Haiti	0.009	1
Indonesia	0.008	64
China	0.007	536
India	0.007	222
Algeria	0.006	17
Peru	0.006	14
Colombia	0.006	23
Iran	0.006	48
Bangladesh	0.006	11
Nigeria	0.004	11
Total		3,898

Source: EIA (2011b) and WB (2011).
Note: The tax is $25 per tonne of CO_2, applied to all international flights. The above figures do not account for the (modest) reduction in fuel use in response to any charge, and assume that 60 percent of reported jet fuel consumption (domestic plus international) is for international flights for all countries (resulting in an understatement of receipts in small island developing States).

IV. Policy Scenarios: Maritime

A. Scenarios

54. **The same four policy scenarios are considered for international maritime as for international aviation**. These are *(1) a uniform, globally applied CO_2 price of \$25 per tonne, with no compensation for developing countries; (2) as (1) but with developing countries as a group retaining the amount collected on that 40 percent of global fuel disbursed in developing countries; (3) as (2) but with an emissions price of \$15 per tonne; and (4) as (1) but with an emissions price of \$40 per tonne*. Since emissions per liter are somewhat higher for maritime than for aviation fuels (due to the former's higher calorific value),[48] this translates into a corresponding larger absolute price increase: about 8 cents per liter, under the \$25 per tonne CO_2 price (though recall that the two sectors are not really competing with each other, aside from in some marginal segments). And since maritime fuel is cheaper than aviation fuel, it implies a still larger proportional increase: with current average costs of around US\$0.67 per liter,[49] this means that this price will increase by about 11 percent at current rates.[50]

B. Environmental Effectiveness

55. **Higher fuel prices might reduce emissions from international maritime activities, through a variety of channels, by perhaps around 5 percent**. On average, the impact of maritime fuel charges on the demand for traded goods is likely very modest due to the small effect on landed import prices (see below). However, other emissions reduction channels include modifying operations (e.g., reducing speed to reduce resistance of the ship's hull, faster loading techniques, improved routing, decreased turnaround times and improved maintenance including hull and propeller cleaning with adequate intervals); technology adoption to improve the efficiency of new ships (e.g., larger ships, hull and propeller optimization, more efficient engines that include waste heat recovery systems), and novel, low-resistance hull coatings); and replacing heavy fuel oil with less carbon-intensive marine diesel or liquefied natural gas. There is much uncertainty over the extent to which higher fuel prices will encourage these mitigation possibilities, though large responses are not projected for the scale of emissions prices considered here.[51] A reasonable conjecture is that emissions will decline by up to 5 percent over the medium term in response to the \$25 per tonne price, and proportionately more/less for the higher/lower carbon price scenarios.

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[48] A liter of bunker fuel produces 0.003 tonnes of CO_2 (EIA, 2011a) which is about 22 percent higher than the CO_2 coefficient for jet fuel.

[49] Data taken from Platts, August 29, 2011, see http://www.platts.com/Shipping/BunkerFuel/?WT.srch=1&gclid=CP_0hLHT9KoCFeMD5QodLkuIOw

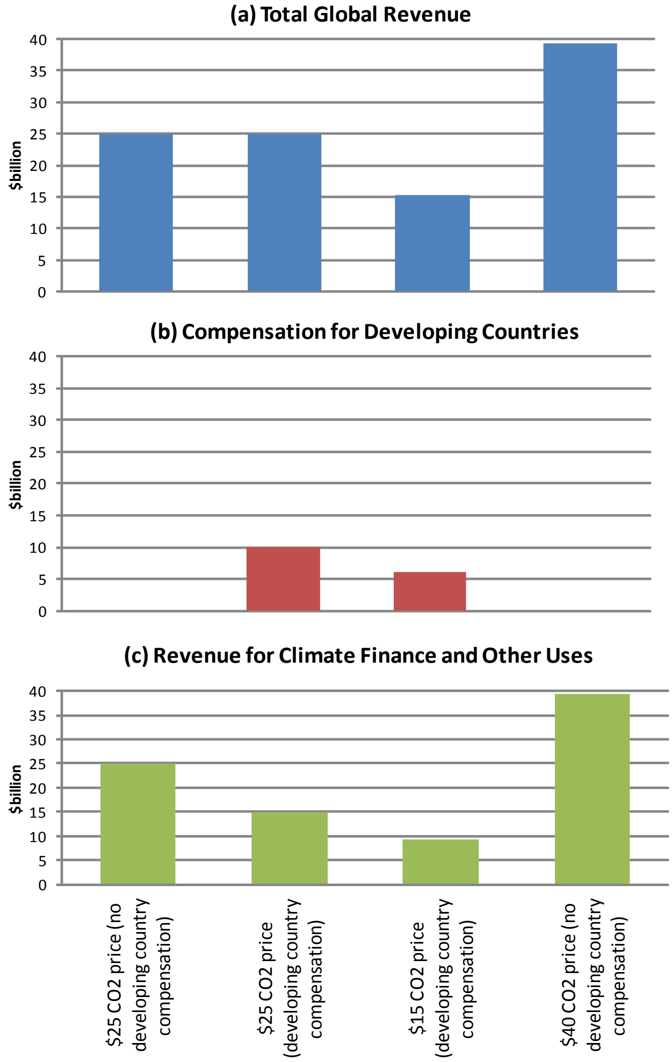
[50] Given the potential increase of marine fuel prices by 2020, including a likely significant increase due to the upcoming low sulphur regulations, the anticipated price impact (increase) will likely be below 10 percent.

[51] See, for example, McCollum et al. (2009). IMO (2009) concluded that a significant potential for CO_2 reduction exists through technical and operational measures, many of which appear to be cost-effective, although both financial and nonfinancial barriers may discourage their implementation. IMO (2011) suggest a smaller emissions reduction than assumed above, however.

C. Revenue

56. **Total projected revenues from international maritime fuels in 2020 are $26.2 billion under the $25 per tonne CO_2 pricing scenarios, $15.7 billion for the $15 per tonne scenario, and $42 billion under the $40 per tonne scenario** (Figure 3a). Revenues are calculated using the same procedure as for aviation, assuming baseline 2020 emissions (without carbon pricing) of 1,050 million tonnes.[52] Again, with compensation schemes, developing countries would raise significant amounts of domestic revenue (Figure 3b). For example, with a $25 per tonne CO_2 price developing countries raise estimated revenues of $10.0 billion and even with the $15 per tonne price, they raise an estimated $6.1 billion. Estimated revenues for climate finance and other uses total $9.2–$15.0 billion in the more realistic pricing scenarios ($15 and $25 per tonne of CO_2), net of developing country compensation (Figure 3c).

Figure 3. Revenue from Taxes on International Maritime



Source: See text.

[52] IMO (2009) projects baseline emissions of about 1,100 million tonnes in 2020, not accounting for expected reductions due to mandatory efficiency and operational improvements discussed in Box 1 (the exact figure is not well established).

57. **These estimates are again broadly consistent with those in AGF (2010b)**, which were \$2.4–5.6 billion and US\$4.1–9.3 billion for the \$15 per tonne CO_2 and US\$25 per tonne CO_2 carbon charge alternatives, respectively, but with the assumption that 50 percent of revenues are allocated for climate finance.

D. Efficiency and Second Best Considerations

58. **As with aviation, putting a carbon price on maritime fuels could be highly cost effective when account is taken of environmental benefits**. Alternatives, such as broader fiscal instruments, do not correct so directly for the market failure of excessive emissions.

59. **Absent a charge on fuel use, alternative instruments—that have some, albeit weaker, environmental benefit—include taxes on turnover or tonnage**. The lesser importance of final consumer demand implies a weaker case for a tax on sales to final consumers or, at the cost of including business use, turnover than in international aviation. Nonetheless, a similar argument for a tax on the use of service to correct for the absent charge on fuel use applies. Indeed if fuel use were proportional to the value of goods carried, a turnover tax would be equivalent to a charge on fuel. In practice, however, while substitution between fuel and other inputs may indeed be limited, the value of goods carried is a bad proxy for the volume and distance travelled, and hence for the underlying fuel use. Vessels' tonnage would likely be a better proxy. A common collective tax on net tonnage, calibrated to a reasonable estimate of distance travelled, might indeed fit well into current tonnage tax regimes. If passed on to consumers, this might be a reasonable proxy for a fuel tax. And if borne by shipping companies, though the impact on emissions would be muted, such a charge would arguably reap collective gains by to some degree rectifying the mutual harm suffered from the particularly intense corporate tax competition in this area.

60. **A charge on freight arrival (or departure), varied by weight and distance travelled, has great appeal in principle but would be problematic in practice**. A merit would be that collection of the levy would be closely tied to the benefit enjoyed from the underlying fuel use: trade to countries that it is desired to shield from damage from the charge could simply be exempted or refunded a corresponding amount on fuel use. Like a tonnage tax, however, it would take no account of vessels' differing fuel efficiencies. Moreover, it lacks the simplicity of a tonnage tax in that account would in principle need to be taken, for instance, not just of the port of origin but also of the route travelled.

E. Incidence

The likely impact on oil prices being small (on the order of a few percent of any charge), it is assumed from now that a fuel charge is fully passed on into maritime fuel costs.

Impact on the maritime industry

61. **The low elasticity of demand for freight services suggests a high degree of pass-through to purchasers of freight services—and little impact on profitability**. This is likely to hold in the short run, and even more so in the long run that is most relevant here—as any

fuel charge scheme will be presumed to be permanent from the time it is imposed—given the expectation that long-run supply will be even more elastic than short-run supply, when compared to demand. The impact of higher bunker fuel prices on freight rates will vary with economic structure of the importing and exporting country; the trade route; ship size; and the supply and demand, not only for the product, but also for cargo space on the ship.[53] Typically, however, the impact is likely to be modest. Measures to protect any companies falling in distress are subject to the same difficulties as noted in connection with aviation.

62. **Some caution may be warranted in levying a carbon charge on marine fuels unless competing sectors are similarly charged**. Sea transport is one of the least carbon-intensive modes of transport. To the extent that measures shift freight to other emissions-intensive modes (like rail, trucks, and air), the favorable environmental impact on emissions will be muted.

Impact on lower income countries—and their compensation

63. **While substantial thought has been given to how emissions from international maritime activities might be attributed to individual countries, a more welfare-focused approach to compensations is needed.** Attempts at attribution have been mainly with a view to incorporating emissions in national targets; in essence, that is from the perspective of control.[54] The perspective of understanding and addressing welfare effects, however—as set out in Section II.C—points squarely to a focus on the impact of transport costs on import and export prices,[55] combined with an assessment of the goods whose price will be affected and of demand and supply responses.

64. **The main channel of impact on developing countries from a charge on international maritime fuels will likely be through freight costs**. [56] This corresponds, in effect, to the first of the three factors identified in Section II.C.

65. **Import value may be a good predictor of overall fuel cost involved in imports**. Stochniol (2011c) argues that average fuel consumption per value unit of imports varies little between different types of vessels even though the value of shipped goods per tonne may vary substantially. This is because low-value (bulk) goods tend to be shipped in vessels (bulk vessels and tankers) that are both fuel efficient relative to their weight loads, and run much slower than (container) ships transporting higher-valued, manufactured goods; so that fuel consumption per tonne of freight tends to be proportional to value per tonne. This is however

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[53] For further discussion, see IMO (2011) and UNCTAD (2010).

[54] See Heitmann and Khalilian (2011).

[55] To the extent that the potential impact on tourism in some countries that are destinations for passenger cruises is a concern, the analysis of Section III applies.

[56] Imperfections of competition may matter here: Hummels et al. (2008) argue that imperfect competition in shipping significantly raises shipping costs for developing countries. This potentially important possibility—which would tend to increase the pass-through into freight costs to a greater extent for low than for high income countries—is not pursued in what follows.

not to deny that, for given bulkiness of imports, countries with longer average import routes will tend to have greater fuel costs per value unit associated with imports; although these cost differences may be much less than in proportion to such average distances.[57]

66. **Impacts on landed import prices vary, but are in most cases small**. The determinants of freight costs are complex, varying with a range of factors such as distance and vessel type. While fuel costs are commonly a large part of those costs, however, freight costs themselves are generally a small part of the total cost of imports, around 5-10 percent, though higher, at perhaps 25 percent, for commodities. Estimates reported in AGF (2010b; p.38) suggest an impact from a charge of $25 per tonne of CO_2 of less than 1 percent for most items, though up to 2-3 percent for some commodities.

67. **The impact on food prices is a particular concern, but seems likely to be fairly small**. According to calculations in Table 4 (from Stochniol 2011a) impacts range from about 0.2 to 1.0 percent for a $25 per tonne CO_2 price. Developments in fuel and food prices over the next decade or two could well dwarf the impact on import and export prices of a modest carbon price.

Table 4. Maritime Transport Costs by Product Category and Ship Segment

Food category	AV (percent)	Unit cost $/Tonne	Price increase (percent)	Shipping mode
Live animals	19	821	0.79	Container
Meat	5	168	0.21	Container
Fish	4	172	0.17	Container
Dairy products, birds eggs, honey	3	110	0.13	Container
Live trees, plants, bulbs, cut flowers	8	250	0.34	Container
Vegetables	22	154	0.92	Container
Fruit & nuts	13	123	0.55	Container
Coffee, tea, mate & spices	4	103	0.17	Container
Cereals	21	58	0.88	Clean Bulk
Milling products, malt, starch	11	70	0.44	Container
Oil seeds and oleaginous fruits	16	68	0.67	Clean Bulk
Vegetable plaiting materials	10	65	0.42	Container
Animal or vegetable fats, oils	5	62	0.21	Tanker
Sugars and sugar confectionary	9	52	0.38	Container
Beverages, spirits and vinegar	5	95	0.21	Container
Food industry residues & waste	25	124	1.05	Container
Tobacco	3	193	0.13	Container

Source: Stochniol (2011a), which builds on UNCTAD (2010) and Vivid Economics (2010).
Notes: AV = average transport cost share of total import value; Unit cost = Average absolute transport cost per tonne of transported goods.

68. **Average shipping costs for oil, as fraction of shipped value, are of similar order as for food products**. According to the IMO (2009), the fuel consumption of tankers in

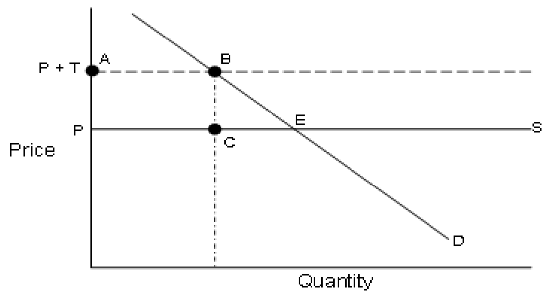
[57] Stochniol (2011b) finds much less difference in average fuel consumption associated with imports, than in average trade distances. This again rests on an argument that goods shipped longer distances are carried predominantly in larger and more fuel efficient vessels.

international oil transport was approximately 60 million tonnes of oil in 2009. The volume of oil exported in 2009 was approximately 38 million barrels per day (or slightly less than half of global oil production), corresponding to total global oil exports of about 1900 million tonnes. Fuel prices are about 90 percent of average crude (non-refined) oil product prices. This implies that fuel transport costs correspond to about 2.7 percent of exported oil values on the average. This means that a US$25 per tonne CO_2 charge (fully passed forward) would raise the fuel price by 12 percent, so that the final import price of oil will rise by about 0.33 percent in importing countries (assuming no back-shifting of a fuel charge on the crude price)—which is about the same proportionate impact as for most food products.[58]

69. **A charge on international maritime fuel would act as a set of import tariffs and export taxes levied simultaneously by all countries—with an incidence and welfare impact more complex than sometimes recognized**. A country that is small in world markets, in the sense that its trade has no impact on prices in world markets—a common first approximation to the position of most developing countries—would bear the full burden of either a tariff on its imports (in the form of increased import prices) or a tax on its exports (in a reduced price to domestic producers of its exportables) that it imposed unilaterally, and so would suffer a welfare loss even if it received an amount corresponding to the increase in freight costs. Box 9 describes this important benchmark result. But at issue here is a charge that would be imposed collectively rather than unilaterally. To the extent that developing countries are collectively not small in the world markets for some goods—as may be the case for some commodities, such as jute and iron ore—part of the incidence would be passed to the other side of the market, in the developed world. Indeed this, presumably, is the assumption in approaches to the compensation issues, such as the rebate mechanism discussed below, that assume the incidence of freight costs to be entirely on the importer and so, for instance, do not see developing countries as suffering any loss from the scheme through a reduced net price of exports.

Box 9. The Welfare Impact of a Charge-induced Increase in Import Freight Costs

The figure below shows the case of an increase in freight costs of the imports of a country that is small in the sense of being unable to affect the price *P* of its importable. With an increase in freight costs increasing the price paid by *T*, the welfare loss suffered exceeds the revenue raised, *ABCP*, by the triangle *BEC*, representing the additional loss of consumer surplus.



It is important to note, however, that this argument assumes perfectly elastic supply from the rest of the world, and ignores what happens in terms of this country's exports, which will also be affected by increased freight costs. The formula in Box 10 takes account of possible effects from these sources. More generally, domestic producers could gain somewhat from (moderately) higher import prices, complicating the next burden on the country as a whole.

[58] See UNCTAD (2010) for further discussion.

70. **It is a reasonable assumption, nonetheless, that (in the absence of compensatory measures) many developing countries will be net losers from the impact on both their import and, perhaps less certainly, export prices**. One reason may be that, even collectively—and here excluding large emerging economies such as China—they are typically small in world markets, albeit with some exceptions is relation to particular commodities. Two other potential reasons are that (1) the import and export activity of developing countries tend to be heavily concentrated on 'bulky' goods with high transport costs relative to their values (although this explanation is somewhat muted by the Stochniol (2011c) argument cited below); and (2) import and export volumes to and from poor countries (with small economies) are in many cases too small to enable fully efficient transport (and so are also subject to greater increases in transport rates when a fuel charge is imposed).

71. **The welfare impact on any country of increased freight costs depends on the elasticity of its demand for imports and the elasticity of export supply from the rest of the world**. Box 10 sets out a simple formula reflecting this consideration. Preliminary calculations, using country-specific estimates of import demand elasticities from Tokarick (2010), suggest two key points. First, the welfare impacts, relative to GDP, of increased transport costs even in the order of 1 percent of goods prices have only a relatively small welfare impact. Second, relative to GDP, these losses are greatest in higher income countries—essentially because they tend to be more open.

Box 10. Compensating for Increased Transport Costs on all Trade

When increased transportation costs apply to the generality of imports and exports, cross-price effects cannot be ignored (as they were in Box 5). The compensation required (expressed in terms of the imported good) is shown in Appendix 2 to be:

$$C = (\tau_X V_X + \tau_M V_M)\left(\frac{\eta_X^{ROW}}{\eta_X^{ROW} + E_M^A}\right) \tag{10.1}$$

One important implication is that, even with full pass-though of fuel charges into transportation costs, full return of all charges on the transportation of all charges bearing on both imports and exports would be over-compensation for any country that does not face perfectly elastic supply from the rest of the world.

72. **Ideally, a charge would be levied by port of arrival that reflects associated fuel use and adjusted to reflect behavioral responses, but for reasons set out above this appears infeasible**. This would correspond to the precise compensation described in Appendix 2. But each step of such a procedure is problematic: the first on practicability grounds, the latter in view of ignorance of the relevant elasticities.

73. **One pragmatic proposal that has attracted attention is rebate mechanisms based on shares of global import value.** This scheme, proposed by the World Wildlife Fund[59] and set out in detail in Stochniol (2011c), is described in Box 11. Though by no means the only possibility, it merits consideration here for both possibilities it suggest and a flavor of the challenges to be addressed in this:

[59] IMO (2010b).

- Perhaps most fundamental in conceptual terms, it assumes that the burden of any increase in transport costs is always on the importer. So, for instance, the implicit assumption is that a fuel charge on exports from developing to developed countries is borne entirely by the latter (and vice versa for exports from developed to developing countries). To the extent that this is not the case—in the strict logic of simple trade models, it cannot possibly be the case in all countries—the scheme will not provide an exact level of compensation (though whether too little or too much is ambiguous). IMO (2011) also concluded that exporters may be affected significantly, in particular, if their main customers are a long distance away and they export high density, low value commodities. This could have a substantial impact on the numbers at stake, potentially in the order of doubling the compensation required. The formula in Box 10 suggests that reimbursement of the charge embodied in the freight costs of imports alone provides exact compensation, for a small charge, if and only if it so happens the elasticity of import demand in the country to be compensated is equal to the elasticity of export supply from the rest of the world. This perhaps suggests that exports should also enter the compensation formula.

- Allocation by reference to shares of global imports means that—unless the charges are proportional to import value in all countries—the compensation received by a country can be affected by changes in trade activities in which it has no part[60]—even though any adverse impact it may suffer remains unchanged. The same difficulty potentially applies to any allocation by reference to shares, though this does have the merit of limiting the extent of compensation relative to revenue raised.

74. **Perfect calibration of compensation to each country's circumstances will not be possible—but, since most effects seem to be small, may not be needed**. Even if the emissions associated with the marine transport a country's imports and exports were known—and experts continue to study if, in the absence of explicit measurement, reasonable proxies can be found—this would need to be combined with information on its trade patterns and responsiveness both domestically and in its trading partners to be sure of accurate compensation. But since most price effects seem likely to be small, it is reasonable to look for simpler approaches based on one or two cases (based say on import values or volumes and trade-weighted distance) that are scaled to build in adequate assurance—and perhaps with a guarantee of some minimum monetary amount—while providing some allowance for truly exceptional cases.[61]

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[60] More precisely, it would receive a large absolute transfer if imports increased in a country whose imports were charged at higher than the global average rate.

[61] In any event, avoiding excessive compensation payments is important for increasing revenues available for socially productive purposes. Beyond climate finance revenues from maritime fuel charges might finance, for example, R&D into energy saving technologies for ships and port infrastructure upgrades in developing countries. Ideally, the costs and benefits of alternative projects would be carefully evaluated in order to prioritize among them.

Box 11. An Illustrative Rebate Mechanism for International Maritime Transport

Stochniol (2011a, c) envisages allocating the revenue raised by some maritime MBI to countries according to their share in the value of world imports, these values being adjusted by (1) including only imports from non-adjacent countries (most of which—in the absence of data on import values by mode of transport—is presumed to be by other modes); (2) further adjustment to reflect the extensive trade between close but non-adjacent countries in Europe, as most of this trade is presumed to be road- and rail-based. The scheme does not envisage Annex I countries retaining some of the proceeds for their own use, but it can be readily adjusted to allow this.

Non-annex I countries would be entitled to a transfer equal to their share of MBI receipts thus calculated, though provision would be made for them to waive this. Annex I countries would treat their allocated receipts as a contribution to climate finance.

Stochniol (2011a, c) provides a full set of country-specific weights had such a scheme been in effect in 2007. These imply that in 2007 about 40 percent of proceeds would have been allocated to non-Annex I countries. Ethiopia for instance, would have had a weight of around 0.06 percent, so would have received around $16 million if total receipts were $26 billion.

V. IMPLEMENTATION

The section reviews overarching issues as to the design of carbon charges for these sectors and practical issues of administration and compliance.[62]

A. Fuel Taxes or an ETS? Economic Principles[63]

75. **The discussion here focuses on the choice between the leading forms of MBIs: fuel charges and ETS schemes**. These are the canonical alternatives, though with wide range of variants and structural differences. Work on these possibilities has been intense in the maritime sector: Box 12 discusses a variety of proposals, some market-based and others not, that have been studied by the IMO.

76. **Tax and emissions trading policies, applied to the same base, and equivalently scaled, have about the same effect on fuel prices, emissions and—so long as emission rights are auctioned—revenue**. Both instruments (applied to carbon content of aviation and maritime fuels) exploit the same behavioral responses for reducing emissions (e.g., encouraging better fuel economy and fewer trips) to the extent that the price on emissions is passed forward into fuel prices (or back into oil prices). This applies regardless of whether some portion of emissions allowances are given away for free rather than auctioned.[64] If they are auctioned then the two schemes in principle raise the same revenue. It is these basic equivalencies that have allowed the sectoral analyses in Sections III and IV to encompass both tax- and ETS-based strategies. However, to the extent that policymakers are tempted to give away free allowances in an ETS, this is a serious drawback of this approach as it squanders a potentially valuable source of revenue for climate-related or other purposes. Important differences between the two approaches arise, however, in the presence of uncertainty.

77. **Certainty as to the emissions price is needed to provide a stable framework for transport decisions and developing long-lived, emissions-saving technologies**. In ETS programs, emissions prices can be volatile: prices are low when the costs of meeting the emissions cap are low (because, for instance, of depressed economic activity) and vice versa when the costs of meeting the cap are high. This problem can be partly alleviated by incorporating price stability provisions (such as banking and borrowing, price ceilings, and price floors) which make an ETS behave more like a tax.

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[62] The transition issues potentially arise in moving towards effective carbon charging are not considered here, but do not appear especially problematic.

[63] There is a large literature comparing the two. For reviews, see for instance, Goulder and Parry (2008), Hepburn (2006), Jones et al. (2011) and Nordhaus (2007).

[64] A trading scheme essentially puts a limit on fuel supply. This drives up fuel prices in the same way that prices are increased when firms with market power limit supply or when firms pass forward fuel taxes. If firms receive free allowances, this simply provides them with a lump-sum windfall gain, without affecting the limit on fuel supply or the fuel price.

Box 12. Overview of Market-Based and Other Proposals for Reducing Ship Emissions

The following proposals were considered by IMO (2011).

GHG Fund (sponsored by Cyprus, Denmark, the Marshall Islands, and Nigeria). This would establish a global reduction target for international shipping. To meet the target a levy would be paid by ships on every tonne of bunker fuel purchased (collected through bunker fuel suppliers or via direct payment from ships) with revenues used to purchase offset credits to match the projected gap between industry emissions and the target. The levy would be regularly adjusted to ensure that adequate funds are available to purchase offset credits. This proposal is essentially focussed on mitigation rather than raising a large amount of new revenue for a new climate fund.

Leveraged Incentive Scheme (Japan). Ships would have to meet mandatory efficiency performance standards or pay a levy. This policy would use some of the contributions to the GHG Fund to pay rebates to ships with energy efficiency better than the standard.

Port State arrangements (Jamaica). Under this scheme, Member States would levy a uniform emissions charge on all vessels calling at their respective ports based on the amount of fuel consumed by the vessel on its voyage to that port. The Port State Levy would be structured to achieve the global reduction targets for GHGs specified by IMO. Revenues raised could easily be devoted to climate finance, though one variant proposes rebates for vessels exceeding efficiency targets.

Ship Efficiency and Credit Trading (United States). Under this scheme, new and existing ships would be subject to respective energy efficiency standards, which would ramp up over time in line with what is achievable with state of the art technologies. Ships that fall short of the standard will have to purchase credits from others that are able to go beyond the standard. The scheme is not designed to raise revenues and, by focussing exclusively on energy efficiency, does not exploit all possibilities for emissions mitigation.

Vessel Efficiency System (World Shipping Council). Again this would establish mandatory efficiency standards for both new and existing ships where the latter may comply by improving their efficiency scores through certifiable technical modifications. Enforcement would be encouraged through a system of penalties for non-compliance, rather than a credit trading scheme, penalties varying with fuel consumed scaled by the shortfall in energy efficiency. A similar proposal, based on mandatory technical and operational measures, was submitted by the Bahamas with specific absolute emissions reduction obligations for ships according to their age.[65]

Global ETS with full auctioning (France, Germany, United Kingdom, and Norway). This policy is a global cap-and-trade system to control maritime emissions with allowances sold in a global auction. In these regards it resembles the ETS variant of the MBI policy discussed here. However, the system would be limited to vessels above a certain size, a portion of the revenues would be used for R&D into clean technologies within the maritime sector (as well as climate finance), exemptions might be provided for specific voyages to Small Island Developing States, and purchase of emissions offsets is also included as a cost-containing measure. A French variant of this scheme sets out additional detail on auction design, while a UK variant suggests that allowances be allocated to national governments for auctioning.

78. **Another price-containing (but also revenue-reducing) option is to allow covered entities to purchase emission offset credits**. For example, a credit against emissions might be awarded for funding a clean energy project in a developing country. While such offsetting is commonly considered in relation to trading schemes, they could also be applied, in the form of tax rebates, under a tax approach. Therefore, this possibility itself need not affect the choice between the two instruments, though offsets lead to lower allowance prices (without affecting emissions) under an ETS while they lead to more mitigation under a tax. Nonetheless, more fundamental are wider issues with offsetting. Verifying whether these projects would have gone ahead anyway without the offset payment, and are not increased by

[65] The proposals of Japan and the World Shipping Council were later consolidated in the Efficiency Incentive scheme.

increased emissions from some other source, can be challenging. If emissions offsets are not 'additional' then the environmental effectiveness (and the credibility) of the emissions trading program is undermined. Offset provisions should therefore be phased in progressively, as institutional capability for verifying emissions reductions matures.

79. **Price stability implies less certainty over meeting annual emissions targets which has a political cost**. What matters for mitigating future global climate change is limiting accumulated global emissions over long periods of time, rather than containing year-to-year variability in emissions from specific sectors. Nonetheless, annual emissions targets for individual countries have political salience. Annual targets, rather than country-level 'carbon budgets' for annual emissions over multi-year periods, or emissions prices, remain the central focus of negotiations at international climate meetings.

80. **Future revenues are uncertain, whichever MBI is used**. Under fuel taxes the tax rate is known, but the quantity of fuel to which it is applied will vary with economic factors like the business cycle. Under a traditional ETS there is more certainty over the base to which the policy is applied, but less certainty over the emissions price, and perhaps the fraction of allowances that will be auctioned.[66] This last though is less of an issue if the ETS is accompanied by price stability provisions.

81. **Once in place, an ETS could have more political momentum**. Firms will have a strong interest in preserving an ETS if they have accumulated a substantial bank of allowances or purchased allowances that can only be used in future periods. In contrast, an emissions tax does not create any natural self-interest among affected parties for sustaining the system.

82. **Tax schemes can risk losing sight of environmental objectives**. If the main motivation for taxes is to meet a revenue target, they may not be set at levels that are appropriate on environmental grounds. Moreover, they may be applied to the wrong base (for instance on airlines tickets rather than fuel use), which would forgo incentives to reduce emissions through better fuel economy. In the specific context of international aviation and maritime, however, it could be argued that the usual tools for pursuing revenue objectives are largely absent, making this less of a concern than otherwise.

83. **An ETS, on the other hand, could create greater political space for influential actors (firms) to argue or lobby for free allocations; and an intended transition to fully auctioned quotas may be difficult to implement**. The revenue-raising ability of cap-and-trade schemes can thus be questioned, even in the long run. A tax will by contrast be expected to be paid as long as it exists and is universal, though there may be pressure for exemptions.

84. **Under a tax regime, participation can be encouraged by leaving tax receipts in the hands of developing countries**. Furthermore, the prospects for participation might be

[66] The emissions trading price under the EU-ETS, for example, has varied widely over the 2005-2010 period, between a low of close to zero, and high of more than $30 per tonne CO_2: see for example Rosendahl (2007), Capoor and Ambrosi (2009), and Point Carbon (2010).

enhanced under a more flexible scheme that set a uniform price, allowing individual countries to voluntarily impose higher taxes and keep the corresponding extra revenues for themselves. This also makes it easier for countries to apply same tax to domestic and international fuel use. Seeking an agreement over a common price floor may be easier than agreeing over a uniform price for all countries. Indeed coordination over price floors is a standard policy recommendation when tax bases are internationally mobile: the EU, for example, sets minimum tax rates for excises. This provides tax floors that guard against tax competition and provide some protection for countries wishing to set relatively higher tax levels.[67]

85. **Valuation and adjustment procedures would be needed under either approach.** Since the appropriate tax is specific (not ad valorem), a tax common to a number of countries would need to be specified in terms of some basket of currencies. In addition, an automatic ramp-up rate needs to be agreed (e.g., say 5 percent annual in real terms), along with periodic reviews of the level, growth rate, and local currency equivalents. Similarly, under an ETS the overall cap (and price stability provisions) would need to be updated periodically.

86. **Cap-and-trade may create more momentum for international linking of permit markets and flows of climate finance to developing countries**. Nonetheless, carbon taxes could easily promote carbon markets through credits against tax liabilities for international emissions offsets. In the maritime context a truly global scheme can be envisaged under which the international shipping sector is treated as a separate ‘bubble’. With a global scheme established under a separate treaty instrument under IMO, the cap would be set and maintained by the parties to the treaty following rules of procedure laid down in the treaty. The ETS proposals under review within IMO have 100 percent auctioning to avoid the need for allocation to individual ships or flag States and not to penalize shipping companies that have taken early actions, or newcomers.

87. **On balance, a (minimum) tax based approach to carbon pricing in international aviation and shipping would likely be the most appealing in principle**. Account though must be taken of initial conditions and practical considerations. These are addressed next.

B. Practical Issues

Governance

88. **Internationally coordinated MBIs for aviation and maritime raise difficult governance issues**. They arise in relation to the charges themselves, and in relation to the ceding of revenue to a global fund outside national treasuries. Precedent does exist in the collection side in the IOPC Funds (Box 4). The climate finance objective would have similarities as the funds are used to compensate for environmental damage. Precedent also exists in a number of IMO treaties in force on the implementation and enforcement side through flag and port state controls where the basis would be to deny ships port entry if they do not participate in the scheme (no more favourable treatment) and detain ships that have not

[67] A slight drawback of this approach is that differentiated prices imply somewhat higher global mitigation costs compared with a uniform price system (for the same global emissions reduction).

paid their contribution or have insufficient allowances to surrender.

89. **Rules would be needed, for instance, for the adjustment of rates or quantities** and to address disputes as to their application. On the tax side, the closest parallel is with excise and VAT arrangements in the EU. These, as noted, are specified mainly in terms of minimum rates. Experience is that the requirement of unanimity has made these very difficult to change, and that the unwillingness of Member States to rely on implementation by others has indeed hindered the development of the VAT. Experience with the EU-ETS is, perhaps, more encouraging. Under a global regime for international shipping, many of these governance issues may be easier to overcome to the extent that countries are content to have decisions made in appropriate bodies established under the new treaty instrument, taking into account rules of procedures and the provisions of the treaty. Countries may also wish to have reasonable assurance that others are themselves applying the charge properly, not least because they may need to give credit against charges they themselves would apply for charges levied by others.

90. **Further issues arise with the ceding of revenues**. These relate not only in the use made of the proceeds but in relation, for instance, to the amounts ceded and whether there will safeguard clauses enabling countries in dire revenue need to maintain a larger amount. Here the closest parallel is perhaps with arrangements for the collection of customs duties and some other charges in the EU: this is delegated to Member States but the proceeds (net of an allowance for collection costs) are a source of finance for the union itself. That this appears to work well doubtless reflecting a sense that these revenues properly belong to all Member States, not just those at which entry happens to occur. A similar sense may come to be held in relation to taxes in international transport, reflecting as they do the exploitation of the common property—belonging to no nation in particular but to all in general—of the international seas and skies.

91. **Resolving these issues will be both critical and difficult**. They cut across existing international governance structures for climate policies and sectoral issues, and touch deeply the concerns of ministries of finance. These issues being more profound than can be addressed here, the rest of the section focuses on more technical aspects of administering fuel taxes and an ETS for the two sectors.

92. **For ships, continuous monitoring could be mandated using utilizing IMO’s Long Range Identification and Tracking system to transmit the ship data**. All merchant ships above 300 GT are mandated under IMO’s SOLAS Convention to provide their position and other information at regular intervals through IMO’s Long Range Identification and Tracking system. And all ships above 400 GT are under IMO’s MARPOL Convention required to keep record of their fuel in the Oil Record Book and to obtain a Bunker Delivery Note for each bunkering which has to be kept onboard for 12 months after the fuel is consumed. This data could be held against the ship’s electronic account in the central register and would give reliable information as to whether a ship is in compliance or not, and could trigger enquiry followed by appropriate action in the next port of call.

Fuel taxes

93. **As a standard principle of tax administration, fuel taxes are best levied where the number of collection points is minimized, which usually means at the point of fuel production or distribution**. The precise point at which the tax is levied, recall, in principle makes no difference to the real incidence of the tax (assuming that, wherever it takes place, enforcement is perfect): the impact on the price received by oil producers will be the same whether they enforce the tax themselves or whether it is imposed on final use in some other country. What does differ, however, is of course where the revenue arises—and hence who it is that would be legally responsible for remitting any of this to a central institution of climate finance.[68]

94. **Upstream application is made difficult, however, if fuel taxes are differentiated by use and participation—but may be greater for shipping**. It is a further standard principle of tax administration that goods are easier to tax when their treatment is not conditional on the use to which they are put. The control advantages of taxing aviation and maritime fuels as they leave the refinery would be undermined if the tax needs to be differentiated according to how or where they will be used. Implementing a differential tax on jet fuel used in domestic and international flight is hard to do at refinery level, for instance, requiring exemptions or some form of crediting arrangement relying on a further set of controls. Similar difficulties arise if the tax is to be differentiated by the final destination of the refined product. A further set of control problems arise when the fuels used in the activity it is intended to tax differentially have an alternative use. Jet fuel, for instance, can also be used as kerosene for heating, while the heavy fuel oil used by international maritime may be further refined into higher quality products or used by industry and power stations.[69]

95. **Failing application at refinery level, however, there is considerable experience in levying fuel taxes further down the chain to draw on—suggesting low administration and compliance costs**. Taxes on domestic fuel use are a staple source of revenue in many countries—and have proved among the easiest of taxes to administer. They can be collected, if not at refinery, then at bulk storage points or the depots that are standard at airports and major ports (with withholding and crediting/refund procedures being used to preserve revenue through the distribution chain). Indeed establishing more uniform treatment of fuels used domestically and internationally is likely to be, if anything, an administrative simplification. From the perspective of the shipping companies and airlines too, familiarity with fuel taxation in relation to their domestic and other activities suggests that such taxes should be relatively easy to comply with.

96. **Collection could thus reasonably be left to national tax administration, retaining some revenue to cover costs and preserve incentives**. It is a considerable advantage of the tax approach that heavy reliance can be made on existing national mechanisms. To ensure that they have adequate incentives to devote resources to collecting the tax, and proved assurance

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[68] Another difference, potentially, is the set of participating countries. Upstream producing countries could, in principle, levy the tax on sales to others even if the latter did not formally participate in any scheme.

[69] Coastal and domestic shipping largely uses diesel.

that the costs of doing so are covered, some fixed fraction of receipts might be retained by that administration before any is remitted for the purposes of climate finance. The only new institutional structure needed would thus be that needed to deal with the governance issues raised above.

97. **One interesting option for collection of a maritime charge (or auctioning of allowances under an ETS) is the establishment of a central global fund that companies (ships) remit to directly without intervention of the tax administration—but this raises new questions**. For this approach, the IOPC Funds could be something of a model for collection and administration of the central fund, while the implementation and enforcement regime would follow the well established regulatory IMO framework for safety and environment standards in shipping through flag and port State controls. The purpose of a new MBI treaty would be similar to IOPC as it will provide economic compensation for environmental damage, but is not directly comparable, as participation in the IOPC regime brings some benefit in the form of additional insurance for all participating States, while an MBI may only provide such benefits for developing countries. Enforcement powers of the kind associated uniquely with sovereign tax-raising authority may not be sufficient to enforce collection of the charge from ships operating outside national waters if this is not associated with an international legal framework. At a minimum, controls such as those associated with conditions for port entry may be more necessary with such an approach in order to provide all participants with the assurance that the charge is being properly paid by all.

98. **For shipping, the high concentration of emissions from a limited number of ships and current enforcement mechanisms (flag and port state controls) may be helpful for implementing carbon pricing on bunker fuels**. Around 80 percent of emissions from international shipping are produced by only around 17, 300 vessels (Table 5). Levying a tax only on fuel used by ships over some threshold tonnage would thus capture the bulk of environmental concerns while enabling control to be focused on only a portion of the fleet. While there could be some risk of distorting ship size, this would likely be modest if the threshold were set at a reasonable level. Countries concerned to assure themselves that tax has been collected elsewhere could expand their port entry requirements to include the provision of acceptable documentation, backed if need be by satellite monitoring of ships' prior movements.

Table 5. Ship Sizes, Numbers, and Associated Emissions

Ship size threshold (GT)	No. of ships	No. of ships as percent of ships ≥ 400 GT	Emissions (as percent of emissions from ships ≥ 400 GT)
≥ 400	42,697	100	100
≥ 500	39,180	92	99
≥ 1,000	34,866	82	98
≥ 2,000	30,138	71	96
≥ 4,000	24,267	57	91
≥ 5,000	22,311	52	89
≥ 10,000	17,346	41	81

Source: IMO (2011).

99. **The legal obstacles to taxing fuel used in international aviation may argue for an ETS** approach—but even this may not be clear, given legal challenges to inclusion in the EU-ETS now under way.

Emissions trading schemes

100. **An ETS-based approach would require a new institutional framework.** As with fuel taxes, a question arises as to where in the chain the policy would be imposed: meaning here who—refiners, airlines, shipping operators or actors in between—would be required to hold permits. In this case, the balance of considerations points towards a reasonably large number of players, not as few as possible, so as to ensure competitive auction markets. Even with an upstream requirement, however, this seems unlikely to be a major difficulty. The more serious concern is the need to create a new institutional framework to administer the auctioning of rights, implying higher costs of administration and compliance (at least over some set-up period). There is some comfort, however, in evidence that the 'transactions costs' associated with market trading are typically small relative to the overall costs of the program (Stavins, 1995)—though this does not reflect the deeper governance issues referred to above.

101. **Adoption of an ETS would require decisions as to the allocation of emission rights—and may risk their being allocated to emitters free of charge.** The need to decide an initial allocation of rights is a merit in so far as this provides an additional instrument for encouraging participation, for instance by allocating more rights to poorer countries—though this at the same time will reduce the amount available for the specific objective of climate financing. But this is also a disadvantage of an ETS-based approach, since it introduces an additional item for complex and no doubt time-consuming negotiation.[70] This concern is reinforced by the risk, suggested by much past experience and a feature of many proposals, of their being allocated to emitters largely free of charge—as with current plans to include international aviation in the EU-ETS, discussed below. All the ETS proposals being considered by IMO have 100 percent auctioning to avoid the difficult process of allocating allowances (to individual ships, ship owners/operators or flag States) as well as not to penalize shipping companies that have already taken steps to increase the energy efficiency of their ships and to accommodate for new entrants. The IMO is also considering a global ETS with national auctioning, although the details of how the allowances would be allocated to countries remain to be worked out.

102. **An ETS encompassing both international aviation and maritime would be preferred to separate ETSs for each**. The ideal ETS, of course, would encompass emissions from all sources. Failing this, however, combining the two sectors would have the advantage—relative to a separate scheme for each—of allowing greater efficiency in emission reductions through harmonization of the emissions price. If technological progress were to make mitigation cheaper in one sector than the other, then a combined scheme would enable the aggregate emission target to be met more cheaply. A common scheme with full auctioning would also ensure that the competitive positions of the two sectors reflected their relative climate impacts. Again, allowance auctioning is important, as allocating allowances in a

[70] In an analytical sense, the same issue arises for the tax option: tax revenue could be allocated to countries other than those which collect it. In practice, however, the point is much less salient for taxes.

combined ETS for international aviation and shipping would be very challenging. To split the allowances between the two sectors and then allocate rights to States or operators would be difficult, given that each country will have a strong interest to secure maximum allowances for its own airlines and shipping companies.

103. **The high concentration of emissions in relatively few ships is also helpful for implementation under ETS**. This is likely reduce transactions costs by limiting the number of bidders (without creating an unduly thin market), and the possibility of denying port entry can again be used to ensure compliance.

104. **The prospects for and potential design of an ETS for international aviation will be shaped by current—and controversial—efforts at its inclusion in the ETS of the European Union (EU-ETS)**. These are described in Box 13.

Box 13. International Aviation and the EU-ETS

Beginning in 2012 aviation emissions will be covered by the EU Emissions Trading System. In its first year, the total quantity of allowances will be 97 percent of 'historical emissions' and in each year from 2013 to 2020 the quantity of allowances will be 95 percent of these emissions. Historical emissions are industry-average CO_2 emissions for 2004 to 2006, which was 219 million tonnes of CO_2. Airlines will be able to buy allowances from other sources under the ETS, which essentially puts a ceiling price on airline emissions equal to the ETS allowance price (see ICAO 2011b for a broader discussion of offsets). If actual emissions are below allowances, airlines cannot sell their excess allowances, but can bank them to cover future emissions, which helps to create some cushion under allowance prices. At current emissions prices (EUR 13 or US $19 per tonne), extending the ETS to airlines would cause the effective price of jet fuel to airlines to rise by about 4.5 cents per liter at most.

The EU has passed legislation to include in the ETS emissions from all flights anywhere in the world that arrive or depart from a European airport. Comprehensive coverage of all airlines (rather than just EU carriers) would imply a greater reduction in emissions, besides alleviating the risk of EU carriers losing business to other airlines.[1] Operators will be managed by the country in which they emit the greatest amount of CO_2 or by the EU member state that issued the operator's air carrier certificate. The scheme will cover around 4,000 airline operators.[2]

However, whether non-EU carriers will ultimately be included in the ETS will depend on the outcome of ongoing, legal challenges in the United States and other countries. Some airlines, for example, have argued that the EU law violates US sovereignty and is illegal under international law and the Chicago Convention (a bill to ban US airlines from participating in the scheme has passed the US House of Representatives). But the EU law only holds the US airlines accountable for their emissions if they land in the EU. In this regard, it is similar to US laws that set requirements for aircraft and ships coming in and out of US territory.[3]

Revenues from allowance auctions will be earmarked for climate mitigation projects. The case for earmarking of revenues, for environmental or any other purpose is, as noted earlier, questionable.

[1] There are some minor exemptions to the scheme, including humanitarian and government aircraft flights, aircraft less than 5.7 tonnes, and commercial operators operating fewer than 730 flights per year or with total annual emissions lower than 10,000 tonnes of CO_2. And a small amount of allowances will be withheld to allocate free of charge to new, or rapidly expanding, operators.

[2] Airlines must submit an emissions monitoring plan for approval to the relevant Member State. Airlines can purchase emission offset credits (e.g., through the Clean Development Mechanism) but these can cover only up to 2 percent of emissions from 2013 onwards. For more details, see http://ec.europa.eu/clima/policies/transport/aviation/index_en.htm.

[3] For example, following the Exxon Valdez oil spill, US law now requires all ships carrying oil in US waters to be equipped with a double hull, have sufficient insurance to cover clean up and compensation, and to have a signed agreement with a registered oil spill contingency company.

105. **Any scheme for international aviation—whether tax or ETS—needs to be coordinated with developments in the EU-ETS**. From an environmental perspective, it does not make sense to tax airlines whose emissions are already priced under the ETS or, conversely, to include airlines in the ETS that have already paid a fuel tax. The EU-ETS plans do indeed include provisions to avoid this possibility of double charging.

106. **Most of the options under review within IMO are based on a global approach with the charge collected either by fuel suppliers or levied on individual ships**. Transaction costs for a global regime, as well as administration costs, will likely be significantly lower with a global solution and a single administration than for separate scheme administrators in all flag States (there are about 160 flag States worldwide). There is clear consensus among experts in this field within IMO that a global solution is the only feasible route.

107. **A further concern is that giving large free allowance allocations not only foregoes revenues but could hinder the introduction of revenue-raising charges on aviation more widely**. Under current plans, airlines would receive for free 85 percent of the total quantity of allowances in 2012 and 82 percent of the available quantity in each year from 2013 to 2020; 15 percent of allowances will be auctioned, leaving 3 percent (from 2013 onwards) to be allocated to a reserve for later distribution to fast growing airlines and new entrants into the market).[71] This allocation scheme deprives governments of the valuable revenue source that would be obtained under a tax regime. Moreover, giving EU airlines free allowances could lead to windfall profits to the extent that airlines pass forward emissions prices into higher ticket prices: as noted in Section III, power companies received large windfall profits from free allowance allocations in the initial stages of the ETS. Enhancing the profitability of airlines in this way could increase resistance in other countries to new charges on their airlines.

108. **The European Commission has indicated willingness to include international maritime transport in the EU-ETS if no international agreement is reached by end 2011 (**Directive 2009/29/EC of April 23, 2009). The preamble to this directive indicates the possibility of plans being prepared in 2012.

[71] Allowances will be grandfathered in proportion to the operator's activity in 2010 in tonne-kilometers carried.

VI. CONCLUSION

109. **While details need further study, charges on international aviation and maritime fuels are potentially a promising source of climate finance**. With continued study of the pros and cons of alternative MBIs, issues in their implementation, and schemes for compensating developing countries, it should be feasible to develop acceptable proposals. Moreover, a successful international agreement to price international transportation emissions could serve as a useful pre-cursor for broader international efforts to price greenhouse gases.

Appendix 1. Some Basic Analytics of Compensation for Taxes on International Transport

Consider a world comprising two countries, A (the focus of interest) and *ROW* (the 'rest of the world'), and *L* tradable goods. Denote by P^j the *L*-vector of prices in country *j*, the *i*th element being the c.i.f. (landed) price of good *i* if it is imported by country *j* and the f.o.b. price if it is exported—the point being that these are the prices on which consumer and producer decisions in country *i* depend. The price vectors in the two countries are then related as

$$P^A = P^{ROW} + T \qquad (A1.1)$$

where the *i*th element of the *L*-vector *T* reflects a 'transport tax'[72] levied on transporting good i¸ being positive if is imported by country *A* and negative if it is exported. Preferences and production in country i are characterized by and expenditure function $E^j(P^j, U^j)$, U^j being the welfare of the representative citizen in country *j*, and revenue function $R^j\left(P^j\right)$. [73] Good 1 is taken as numeraire, and taken to bear no transport tax, a point returned to later in interpreting results. Price vectors from now thus refer to goods 2 to *L*.

The income-expenditure identity of country *A*, allowing for a transfer to country *A* of a vector of α units of traded goods, is

$$E^A(P^A, U^A) = R^A(P^A) + P^{A'}\alpha, \qquad (A1.2)$$

the prime indicating transposition, while market-clearing requires

$$E_p^A(P^A, U^A) + E_p^B(P^{ROW}, U^B) - R_p^A(P^A) - R_p^A(P^{ROW}) = 0_L. \qquad (A1.3)$$

The system (A1.2)-(A1.3) being homogenous of degree zero in each of P^A and P^{ROW}, good 1 can be taken to bear no transport costs, and normalized $P^A = P^{ROW} = 1$. It is assumed too that the transfer α is entirely in terms of the numeraire.

Perturbing (A1.2) for a change in the vector of transport taxes *T*, in order for its welfare to be unchanged, *A* then needs to receive a transfer of

$$d\alpha = N^{A'}.dP^A \qquad (A1.4)$$

where $N^A \equiv E_p^A - R_p^A$ is the vector of A's net imports. The compensation required is thus equal to the increase in the c.i.f. value of A's imports plus the increase in the f.o.b. value of its exports (no account being taken of behavioral responses).

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[72] The term 'tax' is used here for convenience to refer to any charge-induced increase in transport costs. (This will be lower, for instance, the more of the burden of any charge is passed back in oil prices).

[73] The analytical approach here is that of Dixit and Norman (1980).

To relate compensation directly to the transport tax, substituting from (A1.1) into the L-1 (by Walras' Law) market-clearing conditions for the non-numeraire goods gives

$$E_p^A(P^A, U^A) + E_p^B(P^A - T, U^{ROW}) - R_p^A(P^A) - R_p^A(P^A - T) = 0_{L-1}. \qquad (A1.5)$$

Assuming that income effects are zero other than for the numeraire,[74] perturbing and rearranging this gives

$$[S^A + S^{ROW}]dP^A - S^{ROW}dT = 0 \qquad (A1.6)$$

where $S^j \equiv E_{pp}^A - R_{pp}^A$. Solving (A1.6),

$$dP^A = [S^A + S^{ROW}]^{-1}S^{ROW}dT \qquad (A1.7)$$

and so, substituting into (A1.4),

$$d\alpha = N^{A'}.dT - N^{A'}(S^A + S^B)^{-1}S^A dT \quad . \qquad (A1.8).$$

The revenue raised by the tax is $R = N^{A'}.T$, so that $dR = N^{A'}.dT + T'dN^A$. Thus

$$d\alpha = dR - T'dN^A - N^{A'}(S^A + S^B)^{-1}S^A dT \qquad (A1.9)$$

In general, the compensation required by *A* is thus: (a) Total revenue raised by the tax (on both A's exports and imports), less (b) An amount reflecting the tax-induced contraction of imports and exports (negligible for a small tax, expected to increase the amount of compensation needed otherwise) plus (c) A term reflecting relative net import demand/export supply responses in the two countries (generally ambiguous in sign).

Expression (5.1) in Box 5 follows on writing (A1.8) as

$$d\alpha = N^{A'}(S^A + S^{ROW})^{-1}S^{ROW}dT\,, \qquad (A1.10)$$

and supposing there to be only two taxed goods, with no cross-price effects in their demand or supply (so that both substitution matrices and hence $S^A + S^{ROW}$ are diagonal).

For expression (A1.11), suppose there to be only one taxed good, and take as numeraire the good exported by *A*. Then (A1.8) becomes

$$d\alpha = dM^A\left(\frac{\eta_X^{ROW}}{E_M^A + \eta_X^{ROW}}\right)dT\,, \qquad (A1.11)$$

the initial tax being assumed negligible. Some care is needed in the practical interpretation of these results, however. Because of the underlying normalization, although *T* in (A1.11) is a scalar it reflects the transport taxes on *both* goods. Taking the numeraire to be *A*'s import, for instance, in obvious notation

[74] So $E_{PU}^j = 0$, for both *j*. If *A* is taken to be exactly compensated, this assumption is needed only for country B.

$$T = \frac{T_M + T_X}{1 + T_M} \ , \qquad (A1.12)$$

where the T^i are the 'pre-normalization' tax rates. For a small tax, and using the implication of balanced trade that $P_X^A M^A = P_M^A X^A$, (A1.10) thus becomes

$$d\alpha = [(P_M^A M^A)\tau_M^A + (P_X^A X^A)\tau_X^A]\left(\frac{\eta_X^B}{E_M^A + \eta_X^B}\right). \qquad (A1.13)$$

as in (A1.11) where the τ denote transport taxes as a proportion of the corresponding elements of P^A. It follows from (A1.13) that:

- For a small tax, the compensation required is the total revenue (on both imports and exports) scaled by the ratio of the elasticity of export supply from the rest of the world to the sum of that elasticity and the elasticity of import demand in the compensated country.

- In the special case in which these two elasticities are the same, and the tax has the same impact on both exports and imports, the compensation needed for a small tax is exactly equal to the revenue that would have been collected on imports (or exports) alone.

Appendix 2. Optimal Aviation Ticket and Fuel Tax Rates

Keen and Strand (2007) show that when the marginal cost of public funds (δ) exceeds unity, there may be a case for either a general ad valorem ticket tax (at rate τ/Q), or an excise ticket tax t. The constrained optimal rates given that only one of the taxes is applied, are

$$\frac{\tau}{Q}=\left(\frac{\delta-1}{\delta}\right)\frac{1}{\varepsilon}+\frac{MCS.c'}{\delta Q}$$

for the ticket tax, and

$$\frac{t}{p+t}=\left(\frac{\delta-1}{\delta}\right)\frac{1}{(1-\alpha)\sigma+\alpha\varepsilon}+\frac{E'}{\delta(p+t)}$$

for the fuel tax, *where MSC* denotes the marginal social cost of emissions, $\sigma\equiv(p+t)c.c''/c'.(c-c'(p+t))$ the elasticity of substitution in production between fuel and a composite other input, c the (indirect) producer cost function, ε the absolute value of the elasticity of demand for aviation services, and α the share of fuel in total costs.

Magnitude of climate externality from aviation (MSC)	MCF	Ticket tax rate, percent	Fuel tax rate, US$ per liter, σ = 1	Fuel tax rate, US$ per liter, σ = 0.5	Ticket tax revenue (US$ bn)	Fuel tax revenue (US$ bn) σ = 1	Fuel tax revenue (US$ bn) σ = 0.5
$15/tCO2	δ = 1	2	0.03	0.03	8	8	8
	δ = 1.1		0.04	0.05	45	11	18
	δ = 1.25	16	0.06	0.11	90	19	37
$25/tCO2	δ = 1	3	0.04	0.04	14	13	13
	δ = 1.1	10	0.05	0.06	50	17	21
	δ = 1.25	18	0.06	0.12	98	22	40
$40 /tCO2	δ = 1	5	0.08	0.08	20	19	19
	δ = 1.1	11	0.10	0.13	58	25	35
	δ = 1.25	20	0.11	0.19	102	32	62

Appendix 3. The Price Impact of a Selective Fuel Tax

The framework is one in which competitive refiners produce two fuels, A and B, in amounts X^A and X^B, using crude oil of $F(X^A, X^B)$, where F is convex, strictly increasing in each argument and homogenous of degree one. Denoting the producer prices of the fuels by P^i and the price of crude oil by Q, their maximand is thus.

$$P^A X^A + P^B X^B - QF(X^A, X^B) \qquad (A3.1)$$

Final demand for the two fuels are independent, and given, denoting by T a 'tax' charged only on fuel A, by $D^A(P^A + T)$ and $D^B(P^B)$. Substituting these into the refiners' necessary conditions defines $P^i(T, Q)$, and it can be shown that

$$\left.\frac{dP^A}{dT}\right|_{Q,T=0} = \frac{-(1-\alpha)E^A}{\sigma + (1-\alpha)E^A + \alpha E^B} \qquad (A3.2)$$

$$\left.\frac{dP^B}{dT}\right|_{Q,T=0} = \left(\frac{P^B}{P^A}\right)\left(\frac{\alpha}{1-\alpha}\right)\left.\frac{dP^A}{dT}\right|_{Q,T=0} \qquad (A3.3)$$

$$\left.\frac{dP^i}{dQ}\right|_{T} = \left(\frac{P^i}{Q}\right)\left(\frac{\sigma + E^i}{\sigma + (1-\alpha)E^A + \alpha E^B}\right), \qquad i = A, B \qquad (A3.4)$$

where $\alpha \equiv P^A X^A / QF$, $E^i > 0$ denotes the elasticity of demand for fuel i and

$$\sigma \equiv -\frac{F_A F_B}{F F_{AB}} > 0 \qquad (A3.5)$$

denotes the elasticity of substitution, subscripts indicating differentiation. Substituting he $P^i(T, Q)$ into the market-clearing condition for crude oil defines $Q(T)$ by

$$S\big(Q(T)\big) = F[D^A\big(P^A(Q(T) + T), D^B\big(P^B(T, Q)\big)\big] \qquad (A3.6)$$

from which

$$\left(\frac{P^A}{Q}\right)\left.\frac{dQ}{dT}\right|_{T=0} = \frac{-\alpha(E^A + E^B)}{\eta[\sigma + (1-\alpha)E^A + \alpha E^B] + \alpha E^A(\sigma + E^B) + (1-\alpha)E^B(\sigma + E^A)} \qquad (A3.7)$$

The impact on the oil price reported in Table 1 are calculated from (A3.7), and those on final fuel prices from

$$\frac{dP^i}{dT} = \left.\frac{dP^i}{dQ}\right|_{Q,T=0} \left.\frac{dQ}{dT}\right|_{T=0} + \left.\frac{dP^A}{dT}\right|_{Q,T=0}, i = A, B. \qquad (A3.8)$$

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